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ANNUAL REPORT

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भारतीय कृषि अनुसंधान परिषद्
उत्तर पूर्वी पर्वतीय कृषि अनुसंधान परिसर
उमियम-७९३ १०३, मेघालय

Indian Council of Agricultural Research
ICAR Research Complex for N.E.H. Region
Umiam-793103, Meghalaya

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PREFACE

ICAR Research Complex for NEH Region, is an Institute of eminence under the aegis of Indian Council of Agricultural Research. Institute has a large network of six regional centers and 20 KVKs in the entire North Eastern Region. Institute is not only carrying out high throughput research the field of agriculture and allied sectors but also has made concerted efforts in technology transfer in order to cater the specific needs of hill ecosystem in the region. Institute has made significant progress through its divisions and regional centers with an overall aim to realize higher productivity in the agricultural and allied sectors.

Institute has made significant contribution in crop improvements, a total of 16 crop varieties developed by Tripura center have been Gazette notified and five varieties have been released by Sate Government of Meghalaya. Institute has also signed memorandum of understanding (MoU) with M/s Divine Enterprise, Imphal, for popularization and commercialization of 'Bay Leaf Tea' technology. The beverage with indigenous raw materials would be beneficial for consumers across the country.

Technologies developed by the Institute have been successfully implemented in farmer's field. The research work carried out by the Institute has been recognized by various awards and important one includes a prestigious Fakhruddin Ali Ahmed Award conferred for team research by ICAR.

Institute is also catering to the extension needs of farmers through its strong network of regional centers and KVKs and over one lakhs tribal farmers from seven north eastern states were benefitted during 2018-19 by various livelihood programmes, trainings and demonstration.

All these outcomes were possible due to the constant support and inspirational guidance received from Dr T. Mohapatra, Secretary DARE and Director General, ICAR, Govt. of India and Deputy Director General (NRM), Dr K. Alagusundaram, in addition to the support received from all my colleagues at the HQs and Regional Centres.

I complement the editorial board for their efforts in compilation of the annual report and sincerely believe that the document will be of immense value to the agriculture fraternity of the country as a whole and the region in particular.

(N. Prakash)
Director

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कार्यकारी सारांश

उमियम में वर्ष 2018 में कुल वार्षिक वर्षा 2277.9 मि. मी. हुई और मॉनसून वर्षा (जून से सितंबर के बीच) 1473.3 मि. मी. (कुल वार्षिक वर्षा का 65%) थी। इस वर्ष सामान्य वर्षा की तुलना में, कुल वर्षा लगभग 5% कम हुई, और मॉनसून की वर्षा भी 4% कम हुई। प्रतिवेदित अवधि के दौरान दिनांक 26 दिसंबर, 2018 को राजपत्र अधिसूचना सं. 5077 अधिसूचित की गई जिसमें त्रिपुरा केंद्र द्वारा हाल ही के वर्षों में विकसित एवं विमोचित 16 फसल किस्में अधिसूचित की गईं। इन 16 किस्मों में 11 किस्में धान की तथा हरी मटर (फील्ड पी), मूँग, उड़द, तिल और तोरिया प्रत्येक की एक-एक किस्म शामिल थी। उपज और अन्य गुणों के लिए धान के अनेक जननद्रव्यों का परीक्षण किया गया जिनमें से वीआईसी सीवीआरसी द्वारा वर्ष 2018 में TRC 2014-8 (IR 83928-B-B-9-1) / IET 24197 को विमोचित करने के लिए चिन्हित किया गया। धान की इस वंशावली में अच्छी गुणवत्ता वाले कारक पाए गए, जैसे की 68.45% की मिलिंग, 60.85% की हेड राइस रिकवरी, लंबा पतला दाना इत्यादि। विलंबित मॉनसून की स्थिति में पछेती बुवाई के तहत त्रिपुरा खारा धान-1 को अगेती अवधि की किस्म के रूप में चिन्हित किया गया। अमरूद की चार किस्मों, अर्थात मेघा सुप्रीम, मेघा मजेंटा, मेघा वंडर एवं मेघा सीडलेस तथा सोयाबीन की एक किस्म (उमियम सोयाबीन-1) को मेघालय कृषि और बागवानी फसल उप-समिति द्वारा विमोचित करने के लिए संस्तुत किया गया।

धान में, स्वर्णा और भालुम-4 के क्रास से विकसित आशाजनक समजातीय BC_2F_4 समष्टि का प्रदर्शन अपने पैतृकों की तुलना में बेहतर पाया गया। धान जननद्रव्य की आणविक जांच की गई जिसमें 50 SSR मार्करों के एक सेट का प्रयोग किया गया। उमियम में आणविक जांच में ≥80% की पैतृक प्रायिकता के साथ मेघालय में 122 जननद्रव्य परिशुद्ध पाए गए, जबकि < 80% की पैतृक प्रायिकता के साथ 28 जीनप्रारूपों की पहचान अधिमिश्रण (एड्मिक्सचर) के रूप में की गई जिनमें मिश्रित पैतृकता पाई गई। उपज और उससे संबद्ध गुणों के लिए गुणानुवर्णन किए गए 10 काले धान जीनप्रारूपों में से, Latara और उसके बाद PnahSder एवं KbaHeh को उमियम में उत्कृष्ट पाया गया। मणिपुर से धान की किस्म RCM-36 एवं RCM-37 को खरीफ 2018 के प्रारंभिक किस्मगत परीक्षण, IVT M (H) में शामिल करने के लिए नामित किया गया। डीयूएस गुणानुवर्णन में यह पाया गया कि मणिपुर में किसानों की धान किस्में, अर्थात लेंगफोउ चाहाओ, दारुम, राजेन/मार्जेन, कथई एवं सानायांबी फोउ विशिष्ट (अलग) पाई गई। अतः इन किस्मों का पुनः वैधीकरण एवं किसानों के लाभार्थ पंजीकृत करने की आवश्कता है। सिक्किम की मध्य पहाड़ियों में धान रोपण की पारंपरिक विधि की तुलना में, धान सघनीकरण प्रणाली (एसआरआई) के तहत 5.79 प्रतिशत की उच्च धान उत्पादकता प्राप्त की गई। मणिपुर में किसानों की भागीदारी से बीजोत्पादन किया गया जिसमें 41.25 हैक्टे. क्षेत्रफल में तथा 58 धान उत्पादक किसानों ने अनेक धान किस्मों, जैसे कि RC Maniphou-7, RC Maniphou-10, RC Maniphou-12 और RC Maniphou-13 का प्रयोग किया गया है। इस भागीदारी से 573.78 क्विंटल धान के बीज का उत्पादन किया गया और प्री खरीफ में 45.0 क्विंटल प्रति हैक्टे. औसत बीज उपज प्राप्त की गई। मिजोरम के निचले क्षेत्रों में धान की किस्म गोमती का प्रदर्शन अच्छा पाया गया, जबकि ऊपरी भूमि वाले क्षेत्रों में किस्म IURON 514 से काफी अधिक दाना और भूसी उपज प्राप्त की गई। कुल मिलाकर केवल त्रिपुरा केंद्र द्वारा वर्ष 2018 में विमोचित किस्मों के 393.9 क्विंटल प्रजनक बीज; 4093 क्विंटल विश्वसनीय लेबलयुक्त बीज और 1055 क्विंटल दलहन बीजों का उत्पादन किया गया।

उमियम में, जैविक खेती के तहत मक्का की किस्म DA 61A और RCM-75 का प्रदर्शन अन्य किस्मों की तुलना में बेहतर पाया गया। कंपेरिजन प्लॉट विश्लेषण के आधार पर, मेघालय में मक्का की अनेक किस्मों अर्थात् RCMGP 126, RCMGP 114, RCMGP 85, RCMGP 118, RCMGP 120, RCMGP 128 एवं RCMGP 127 में उच्च उपज देने वाली किस्में के रूप में पहचान की गई। स्थानीय मक्का जननद्रव्य के बीज उत्पादन संरक्षण के लिए अरूणाचल प्रदेश में मक्का की किस्म टापो पोली एवं

सागो लोकल की खेती की गई। भाकृअनुप मणिपुर केंद्र, इम्फाल ने 47 किसानों के खेतों में 23 हैक्टेयर क्षेत्रफल में फसल प्रणाली प्रक्रिया के तहत उन्नत मक्का उत्पादन प्रौद्योगिकी का प्रदर्शन किया। नागालैंड में जैविक पोषकतत्व प्रबंधन विधियों के तहत मक्का किस्म VMH- 53 (6.40 टन प्रति हैक्टे.) में तथा उसके बाद VMH-45 (6.10 टन प्रति हैक्टे.) में सबसे अधिक उपज दर्ज की गई। इसी प्रकार धान की किस्म, भालुम-3 (3.25 टन प्रति हैक्टे.) में तथा उसके बाद SARS-8 (2.30 टन प्रति हैक्टे.) में सर्वाधिक उपज दर्ज की गई।

रागी (फिंगर मिलेट) की विभिन्न किस्मों में से, मेडिना 352 में उमियम में सबसे अधिक उपज (1.30 टन प्रति हैक्टे.) दर्ज की गई। परीक्षण की गई दलहन किस्मों में, मसूर किस्म (DPL-61) और काबूली चना किस्म (D-21) में अधिक जड़ निस्रवण की क्षमता के साथ उच्च फास्फोरस दक्षता पाई गई। नागालैंड में तिल किस्म TRC TIL 1-8 में 1.3 टन प्रति हैक्टे. के साथ सबसे अधिक उपज दर्ज की गई और उसके बाद सावित्री में 1.1 टन प्रति हैक्टे. की उपज पाई गई। सूरजमुखी किस्म KBHS (1430 कि. ग्रा. प्रति हैक्टे) में और LSFH-171 (1347 कि. ग्रा. प्रति हैक्टे.) में अत्यधिक उपज प्राप्त की गई। मणिपुर में, जांच किए गए 29 पेरीला जीनप्ररूपों में से, RC Thoiding 8 (IC-0615369) (56.5 ग्रा. प्रति पादप) में सबसे अधिक प्रति पादप उत्पादकता दर्ज की गई। मेघालय से लगभग 40 पेरीला जीनप्रारूपों के फील्ड एवं अनुमानित डाटा के आधार पर, अनुवर्ती शेल्फ लाइफ अध्ययनों के लिए कुछ जीनप्रारूपों का चयन किया गया।

खासी मंडेरिन पर किए गए प्रकंद मूल्यांकन अध्ययनों सें, सी. जामभिरी में अधिकतम कलमें (ग्राफ्ट) दर्ज की गईं। कचाई लेमन की कृत्रिम परिवेश में उगाई गए पौधों से प्राप्त नोडल सेगमेंट एवं शूट टिप्स का प्रयोग मणिपुर में बहु प्ररोह पुनरुत्पादन अध्ययनों के लिए कर्तोतकों के रूप में सफलतापूर्वक किया गया। इलायची लेमन के इन विट्रो बहुगुणन के लिए, 0.5 मि. ग्रा. प्रति ली. BAP से संपूरित एमएस मीडिया से अधिकतम संख्या में प्रति पादप प्ररोह प्राप्त किए गए। मेघालय में आड़ू में Y आकार के ट्रेलिस को सबसे अधिक उत्कृष्ट ट्रेनिंग सिस्टम के रूप में पाया गया। मिजोरम के कोलासिब एवं मामित जिले के 20 स्थानीय आम के जननद्रव्य से अधिकतम फल वजन, फल लंबाई, फल चौड़ाई और फल टीएसएस तत्व दर्ज किया गया। कुल 216 केला मेट्स/जीनप्रारूप संग्रहित किए गए जिन्हें पूर्वोत्तर भारत के 'केला जीन बैंक' में अनुरक्षित किया गया है।

किसानों के खेतों में प्रकाश-असंवेदनशील बुश टाइप डोलिकोस बीन 'सेलेक्शन 1' जीनप्रारूप में सबसे अधिक उपज पाई गई। बागवानी विशेषकों/गुणों और उपज के बीच लक्षणप्रारूपी सहसंबंधों का अध्ययन करने हेतु किंग चिली के विभिन्न जीनप्रारूपों का मूल्यांकन किया गया। फ्रेंचबीन के बीजों को As से एक्सपोज किए जाने से उसकी जड़ों की लंबाई काफी कम हो गई (30-40%)। जड़ों की लंबाई में गिरावट की दर में तब और भी तेजी देखी गई जब एक्सपोजर अवधि को 24 घंटों से बढ़ाकर 124 घंटे किया गया। अरूणाचल प्रदेश में फ्रेंच बीन के लिए एक पोषकतत्व प्रबंधन विधि का मानकीकरण किया गया। नागालैंड में नागा किंग चिली के गैर मौसमी उत्पादन के लिए कृषि विधियों के एक पैकेज का मानकीकरण किया गया। भंडारण अध्ययनों में यह पाया गया कि प्याज में बल्ब सड़न तथा वजन हानि के आधार पर, KH M-1 (3.6%) तथा उसके बाद NHRDF Red-2 (7.6%) में प्रतिशत नुकसान भंडारण के 2 माह की अवधि के बाद न्यूनतम पाया गया। टमाटर में, टीएसएस, एसकौरबिक एसिड, अपचयित शर्करा और लाइकोपेन जैसे गुणवत्ता कारक 100% जैविक प्रबंधन के तहत सर्वाधिक पाए गए। कुल मिलाकर, 33 आर्किड प्रजातियों को संग्रहित किया गया और वानस्पतिक एवं पुष्पण गुणों का पता लगाने के लिए उनका गुणानुवर्णन किया जा रहा है। जरबेरा जीनप्ररूप RCGH-22 में सबसे अधिक पुष्प प्रति पादप दर्ज किए गए, जबकि जीनप्ररूप 'RCGH-117' में सबसे अधिक वेस लाइफ (जीवित्ता) दर्ज की गई।

फलों के रस में फल मक्खी को नियंत्रित करने हेतु, जैव कीटनाशक एवं फल मक्खी कीट जालों सहित एक मॉड्यूल अभिज्ञात किया गया। मेघालय में आक्रमणकारी सोलेनम फल मक्खी बैक्ट्रोसेरा लेटिफ्रॉन्स को पहली बार पाया गया जो बैंगन के फलों को नुकसान पहुंचा रही थी। प्रमुख क्रूसिफेरस निष्पत्रकों के विरूद्ध विटेक्स नेगुन्डो के N हेक्सेन फ्रेक्शन और ओसिमम बेसिलिकम एवं

पाइपर नाइग्रम के ऐसेनशियल तेलों को प्रभावकारी पाया गया। टमाटर में, नोवेलुरॉन एवं क्लोरेंट्रानिलिप्रोल के क्षय का अध्ययन किया गया। अमरूद किस्म RCGH-7 में फल मक्खी के प्राकृतिक नोवेलुरॉन क्षेत्र परजीवों को अधिक मात्रा में पाया गया। जोखिम आकलन अध्ययन में अजाडिराकटिन, अनोनिन, बी. बेसियाना एवं *Bt* var. *k* को चारा तलाश करने वाली (फोरेजिंग) मक्खियों अर्थात एपिस सेरेना के प्रति मामूली से लेकर मध्यम विषाक्त पाया गया, जबकि स्पिनोसैड और इमिडाक्लोप्रिड को मक्खियों के प्रति घातक पाया गया। सॉफ्ट स्केल जो प्लेटिलेसेनियुम वंश से संबंधित था, को भारत में पहली बार पाया गया। महत्वपूर्ण तेजी से फैलने वाले हानिकारक कीटों का अन्वेषण किया गया और किसानों तथा राज्य सरकार के कार्यालयों को आवश्यक एडवाइजरियां जारी की गईं। लौकी में रोग उत्पन्न करने वाले चार रोगजनकों की पहचान की गई। कीट रोगजनक, पेंडोरा फोर्मिकाई को भारत में पहली बार पाया गया। मेघालय क्षेत्र में चावल प्रध्वंस रोगजनक (पाइरिकुलेरिया ओरिजी) के भिन्न उग्रता पैटर्न प्रेक्षित किए गए। भंडारण के दौरान चावल में कीटों के प्रबंधन के लिए मणिपुर से चार देसी पादपों अर्थात प्लेक्ट्रान्थुस टेरनिफोलियुस, गोनियोथालामुस सेसक्विपेडालिस एवं जेंथोजाइलुम ऑकेन्थोपोडियुम को प्रभावकारी पाया गया। मणिपुर में सोलेनेसियस परपोषी पर लार्ज कॉर्डमम चिरके वायरस (LCCV) संक्रमणों की पहली बार खोज की गई। सिक्किम मंडेरिन में फल झड़न रोग का प्रमुख कारण फल मक्खी एवं फ्युसेरियम प्रजा. का संक्रमण था। भिन्न अंगमारी रोग लक्षणों और मीडिया पर संवर्धों में अंतर से यह पता चला कि सिक्किम में बड़ी इलायची के अंगमारी रोग की प्रकृति काफी विषम व जटिल है। मेघालय के लिए चार उच्च उपज वाली मशरूम प्रजातियों, अर्थात PL-16-04, PL-17-07, PL-16-01 एवं Pl-17-03 की पहचान की गई। पोषाहार की दृष्टि से, प्ल्यूरोटस फ्लेबेलाटुस एवं प्ल्यूरोटस सेजोरकाजू को छः अन्य खुम्ब प्रजातियों (जिनका मूल्यांकन उनकी निकटतम संरचना और मणिपुर में पोषक तत्व का पता लगाने के लिए किया गया था) की तुलना में बेहतर पाया गया। मौसम के दौरान प्राकृतिक रूप से उगने वाले लगभग 33 खुम्बों को नागालैंड से संग्रहित किया गया और उनका प्रलेखीकरण किया गया। इनमें से छः खुम्ब खाने योग्य थे। ओयस्टर मशरूम की विभिन्न प्रजातियों में से, प्रजाति सं. PL1703 से सिक्किम में 56.1 कि. ग्रा./100 कि. ग्रा. शुष्क सबस्ट्रेट की उच्च उपज प्राप्त की गई।

मेघालय में मध्यम ऊंचाई वाले क्षेत्रों में लो.फ्लाईंग ड्रोन की मल्टी.स्पेक्ट्रल और हाइपर-स्पेक्ट्रल का प्रयोग करते हुए, खेतों में खड़ी मक्का फसल में पाले से हुए नुकसान को दर्ज किया गया । पाले से नुकसान के कारण दृश्य एवं अवरक्त (इन्फ्रा.रेड) क्षेत्रों में पादपों के स्पेक्ट्रल रेफलेंक्टेंस में वृद्धि पाई गई और अवरक्त की लघु तरंग पर विशिष्ट रेफलेंक्टेंस शीर्षता पाई गई। मेघालय में अन्य फलीदार अंतर फसलों की तुलना में, फ्रेंच बीन के साथ मक्का की अंतर फसल उगाए जाने से अधिकतम मक्का उपज प्राप्त की गई। उमियम में एकल मक्का फसल प्रणाली की तुलना में, मक्का-फ्रेंच बीन फसल प्रणाली के तहत C-stocks में 14% की वृद्धि पाई गई। मेघालय में चावल आधारित प्रणाली में 9 से अधिक वर्षों तक निरंतर शून्य जुताई किए जाने से एसओसी (SOC) में मामूली वृद्धि पाई गई, जो 1.45% से बढ़कर 1.62% था। संस्तुत नाइट्रोजन, फास्फोरस और पोटेशियम (NPK) का प्रयोग करते हुए निचली परती चावल भूमि में शून्य जुताई के तहत MZFB 48 में अधिकतम मटर समतुल्य उपज (4.24 टन प्रति हैक्टे.) दर्ज की गई, जबकि कोलासिब में पूसा सरसों में अधिकतम बीज उपज (1.31 टन प्रति हैक्टे.) दर्ज की गई। पारंपरिक जुताई (0.94 टन प्रति हैक्टे.) और शून्य जुताई (0.86 टन प्रति हैक्टे.) की तुलना में अपचयित जुताई (1.30 टन प्रति हैक्टे.) में राजमा फसल के तहत उच्च दाना उपज दर्ज की गई, जबकि अन्य जुताई विधियों की तुलना में शून्य जुताई (0.94 टन प्रति हैक्टे.) में उड़द में उच्च दाना उपज प्राप्त की गई। सिक्किम की स्थिति के तहत पारंपरिक जुताई (10.15 टन प्रति हैक्टे.) की तुलना में शून्य जुताई में 11.33 टन प्रति हैक्टे. की सर्वाधिक मक्का समतुल्य उपज दर्ज की गई।

मक्का (RCM 76) की उपज और विकास पर कोई खास अंतर नहीं पाए गए, जबकि मिजोरम में मिश्रित पोषक तत्वों तथा लाइम की पूर्ण खुराक के साथ उच्च उपज प्राप्त की गई। मिजोरम में सुपारी की खेती के बाद रबड़ की खेती के लिए उपयोग की गई भूमियों में मृदा जैविक कार्बन (एसओसी) में गिरावट पाई गई। सागौन की खेती में

यह गिरावट सबसे कम (1.12 %) थी। भूमि उपयोगों के बावजूद, अप्रैल और अक्तूबर में एसओसी काफी अधिक था। नागालैंड में, 50% RDF (80-60-40 N, $P_2 0_5$ एवं K_2O कि. ग्रा. प्रति हैक्टे.) के साथ 5 टन प्रति हैक्टे. (एफवाईएम) का प्रयोग किए जाने से मक्का की फसल आर्थिक रूप से लाभप्रद पाई गई और उच्च उपज (4.6 टन प्रति हैक्टे.) दर्ज की गई। जैविक खाद के विभिन्न स्रोतों में से, कुक्कुट खाद (2.5 टन प्रति हैक्टे.) को काफी प्रभावकारी पाया गया और नागालैंड में मूंगफली की सर्वाधिक उपज (2750 कि. ग्रा. प्रति हैक्टे.) दर्ज की गई। कुक्कुट खाद @ 2.5 टन प्रति हैक्टे. + RDF (25%) और FYM @ 10 टन प्रति हैक्टे. + RDF (50%) से उपचारित और पॉलीहाउस के तहत उगाए गए पादपों ने मेदजीफेमा में काफी उच्च फसल विकास प्रदर्शित किया जिसके फलस्वरूप पादपों से उच्च उपज प्राप्त की गई। नागालैंड में अध्ययनगत क्षेत्र के तहत अन्य पोषक प्रबंधन विधियों का प्रयोग किए जाने के बावजूद, सोयाबीन (45%), मूंगफली (18.5%), मक्का (30.5%) और चावल (40%) की उपज पर उन्नत झूम प्रबंधन विधियों का सकारात्मक प्रभाव देखा गया। टॉप ड्रेसिंग नहीं किए जाने की तुलना में, यूरिया के माध्यम से नाइट्रोजन की 15 से 90 कि. ग्रा. प्रति हैक्टे. तक टॉप ड्रेसिंग किए जाने से त्रिपुरा में राजमा बीज एवं बायोमास की उपज अधिक प्राप्त की गई। त्रिपुरा में 50 प्रतिशत पुष्पण स्तर पर पर्णिल छिड़काव के रूप में 2% यूरिया + 2% KCl के एकीकृत प्रयोग से कंट्रोल की तुलना में, सरसों और मसूर की बीज उपज में सुधार पाया गया। पेंडिमेथालिन @ 1000 g a.i./ha + 30 DAS पर एक हाथ से खरपतवार निकालने से समतुल्य दाना उपज (4.67 टन प्रति हैक्टे.) प्राप्त की गई जैसा कि खरपतवार रहित उपचार (4.8 टन प्रति हैक्टे.) के तहत दर्ज की गई। त्रिपुरा में लीची के लिए 60 कि. ग्रा. एफवाईएम, 2.0 कि. ग्रा. यूरिया, 1.8 कि. ग्रा. एसएसपी और 600 ग्रा. एमओपी प्रति वृक्ष के प्रयोग और फाल-विंटर (अगेती शीत ऋतु) मौसम के दौरान 15 दिनों के अंतराल पर तथा पुष्पण से लेकर फल परिपक्वता के दौरान 7 दिनों के अंतराल पर सिंचाई का मानकीकरण किया गया। त्रिपुरा में NPKS (100%) + 10 टन प्रति हैक्टे. FYM + VAM + PSB + लाइम का प्रयोग किए जाने से प्याज में सर्वाधिक कुल बल्ब उपज (35.5 टन प्रति हैक्टे.) तथा विपणन योग्य उपज (34.2 टन प्रति हैक्टे.) दर्ज की गई। मिजोरम में, ड्रेगन फल पर जब NPK @ 25:75:75 ग्राम प्रति पादप + FYM @ 2 कि. ग्रा. प्रति पादप + वर्मीकंपोस्ट @ 1 कि. ग्रा. प्रति पादप का उपचार किया गया तब पादपों में सर्वाधिक संख्या में शाखाओं का विकास देखा गया और उच्च संख्या में फल (7 सं.) प्राप्त किए गए।

हल्दी में, अन्य मल्चिंग और जैविक खाद उपचारों की तुलना में, FYM + स्ट्रा मल्च @ 5 टन प्रति हैक्टे. का प्रयोग किए जाने से काफी अधिक राइजोम उपज (10148 कि. ग्रा. प्रति हैक्टे.) दर्ज की गई। तोरिया और मक्का दोनों के लिए मक्का डंठल आवरण + कुक्कुट खाद + 5 टन प्रति हैक्टे. की दर से एमब्रोसिया के प्रयोग को सर्वश्रेष्ठ अवशिष्ट प्रबंधन विकल्प के रूप में पाया गया (जिसके कारण संबंधित कंट्रोल्स की तुलना में 81% और 34% की उपज वृद्धि प्राप्त की गई)। एकीकृत जैविक कृषि प्रणाली (IOFS) मॉडल अपनाए जाने से 0.43 हैक्टे. क्षेत्रफल से रु. 73,903/- प्रति वर्ष का शुद्ध लाभ दर्ज किया गया। मेघालय में इस मॉडल को अपनाए जाने से फसल प्रणाली के अंतर्गत मृदा में नाइट्रोजन की 94.3%, कुल फास्फोरस की 81.2% और कुल पोटेशियम की 98.2% की आवश्यकता की पूर्ति भी हुई। ढलान वाली भूमियों पर विकसित किए गए आठ कृषि प्रणाली मॉडलों में से, एग्रो-पास्टोरल प्रणाली (0.64 हैक्टे.) के तहत क्रमशः रु. 2,51,108/- और रु. 1,11,646/- का क्रमशः सकल एवं शुद्ध लाभ प्राप्त किया गया जिसका इनपुट-आउटपुट अनुपात 1.22 है। मेघालय में कृषि/सब्जी, बागवानी फसल प्रणाली, तालाब में मछली, पशुपालन आदि पर आधारित प्रणाली के साथ 1.0 हैक्टे. के ढलान वाले क्षेत्रफल में अपनाए गए एकीकृत कृषि प्रणाली मॉडल से रु. 1,69,794/- प्रति वर्ष का शुद्ध लाभ प्राप्त किया गया। सिक्किम में, चावल आधारित फसल प्रणाली में फलीदार फसलों (चावल-मेथी) का समावेशन किए जाने से जैविक प्रबंधन के तहत चावल की उपज (4.6 टन प्रति हैक्टे.) में काफी वृद्धि हुई। सिक्किम की पारिस्थितिकी के तहत मक्का + लोबिया-सब्जी मटर फसल चक्र में उच्च मक्का समतुल्य उपज (12.42 टन प्रति हैक्टे.) प्राप्त की गई। मणिपुर में सब्जी लोबिया-मक्का + लोबिया फसल प्रणाली अपनाए जाने से अधिकतम प्रणाली उत्पादकता (10.33 टन प्रति हैक्टे.) दर्ज की गई। मणिपुर की पारिस्थितिकी के तहत 2 टन प्रति हैक्टे. की दर से वर्मीकंपोस्ट का प्रयोग

किए जाने से उच्च मक्का समतुल्य उपज (6.91 टन प्रति हैक्टे.) प्राप्त की गई। भिंडी फसल में कृषि लाइम और रॉक फास्फेट के साथ वर्मीकंपोस्ट जैसे जैविक खादों का एकीकृत प्रयोग किए जाने से उपज में काफी वृद्धि हुई। सिक्किम और पूर्वोत्तर भारत के अन्य भागों की अम्लीय मृदाओं के प्रबंधन के लिए मैन्यूर बायोचर को-कंपोस्ट का प्रभावकारी रूप से प्रयोग किया जा सकता है। सिक्किम में 50% एग्रो-शेड नेट के साथ आंशिक संरक्षण के तहत 'A' ग्रेड किवी फसल उत्पादन के उच्चतम सीमा तक ले जाने के लिए जैविक कृषि विधियों के पैकेज का मानकीकरण किया गया।

पॉपुलस गैम्ब्लाई, जो तेजी से बढ़ते पॉप्लर की एक देशज प्रजाति है, का व्यापक रूप से सर्वेक्षण किया गया और उसकी आनुवंशिक विविधता का आकलन करने हेतु पत्ती नमूने संग्रहित किए गए। पाइनस केशिया में पादप की वक्ष स्थल की ऊंचाई (जीबीएच) पर उसकी परिधि की सहायता से भूमि आधारित बायोमास के वायुमंडलीय एवं भूमिगत बायोमास से प्रति वृक्ष उत्सर्जित कुल कार्बन और वायुमंडलीय कुल बायोमास के पूर्वानुमान के लिए कुछ सर्वश्रेष्ठ एवं उपयुक्त मॉडल विकसित किए गए। हिमालय के समस्त क्षेत्रों से वेलेरियेना की अठाईस समष्टियां संग्रहित की गईं जिनमें प्रत्येक के 20-30 प्रतिदर्श पादप थे। मार्कर कम्पाउंड के आधार पर, वेलेरियेना जटामानी की 11 वन्य समष्टियों का मूल्यांकन किया गया और इन समष्टियों में से तीन समष्टियों, अर्थात Ziro (AP), दिरांग (AP) और Pfutsero Phek को उत्कृष्ट पाया गया। भौतिक विकास मापदण्डों के आधार पर, बसर की पारिस्थितिकी में बहुआयामी वृक्षों, पाइनस केसिया, इलियोकार्पस स्फेरिकस, अकेसिया मैनजियम एवं मेंगलियेशिया इनसिग्निस को आशाजनक/लाभप्रद पाया गया। टर्मिनेलिया माइरियोकार्पा + गुनिया घास दोनों का एक साथ प्रयोग किए जाने से बसर में सर्वाधिक घास उपज दर्ज की गई। पाइनस केसिया से राल को आवधिक रूप से संग्रहित कर राल उत्पादन किया गया। ओलियो-रोसिन से टरपेन्टाइन और रोसिन को अलग करने हेतु ओलियोरेसिन को स्टीम डिस्टिलेशन प्रक्रिया के द्वारा आसुत (डिस्टिल) किया गया। कृषि वानकी प्रणालियों में से, शीशम-अनानास और सागवान-अनानास प्रणाली के तहत उच्च एसओसी (SOC) संग्रह, कार्बन पृथक्करण प्राप्त किया गया जो त्रिपुरा में सतही मृदा परत में कृषि योग्य भूमि से संबद्ध है। हाइब्रिड नेपियर, कॉन्गोसिग्नल और कोम्बो नेपियर घासों की तुलना में, प्राकृतिक घासों के तहत मृदाओं में उच्च टीओसी (TOC) संग्रह पाया गया।

विभिन्न घासों के हाइड्रोलॉजीकल संव्यवहार का अध्ययन किया गया। इन घासों में से हाइब्रिड नेपियर घास में न्यूनतम अनुप्रवाह (%) पाया गया। ऐतिहासिक मौसम कारकों और मौसम पूर्वानुमान विश्लेषण में पूरे क्षेत्र (विशेष रूप से उन क्षेत्रों में जो उग्र वर्षा सूचकांकों की तुलना में उग्र तापमान सूचकांकों से संबंधित थे) में मौसम की उग्रताओं में काफी बदलाव देखा गया। ग्रेविटी ड्रिप सिंचाई प्रणाली के लिए माइक्रोकंट्रोल आधारित स्वचालित नियंत्रण प्रणाली अभिकल्पित की गई। पूर्वोत्तर भारत के सघन वर्षा वाले क्षेत्रों के लिए माइक्रोकंट्रोलर आधारित सोलर टनल ड्रायर का मानकीकरण उपयुक्त रूप से किया जा रहा है। वर्ष 2018 के दौरान, 1122 AAS बुलेटिन और 95,829 एसएमएस तैयार कर किसानों को भेजे गए। संस्थान ने एक पावर पैडी थ्रेसर एवं क्लीनर विकसित किया और उसके प्रसार के लिए नौ गांवों में हस्त चालित विनोवर का प्रर्दशन किया गया।

उत्तर पूर्व के राज्यों के लिए फसल-जलवायु संबध का मात्रीकीकरण किया गया जिसमें सीमिंग्ली अनरिलेटेड रिग्रेशन मॉडल का प्रयोग किया गया। अरूणाचल प्रदेश को छोड़कर, उत्तर पूर्व के अन्य सभी राज्यों के संबंध में न्यूनतम तापमान के लिए गुणांक पोजिटिव तथा महत्वपूर्ण पाए गए। केंद्र सरकार के संगठनों के लिए विस्तार सेवा की प्रभावकारिता हेतु जो प्रावधान किए गए थे, उनमें भाकृअनुप (16.7%) और उसके बाद कृषि विज्ञान केंद्र (2%) के लिए प्रावधान सबसे अधिक थे। राज्य सरकार के संगठनों में से, राज्य कृषि विभाग द्वारा सबसे अधिक (2.7%) भूमिका निभाई गई थी। किसानों के लिए विस्तार सेवाओं की आवश्यकता के बारे में प्राप्त जानकारी से यह पता चला कि उन्हें सब्जी फसल उगाने के लिए सामग्रियों (87.4%), सूचना एवं एडवाइजरी (69.8%) और क्षमता निर्माण (57.1%) की आवश्यकता थी। किसानों से एकत्रित किए गए डाटा से यह पता चला कि किसानों को भिन्न कृषि विधियों के बारे में सूचना एव संचार प्रोद्योगिकी (ICT) साधनों के माध्यम से दृश्य विवरण के रूप में सहायता की आवश्यकता है।

पूर्ण जीनोम अनुक्रमण (डब्ल्यूजीएस), असेम्बली और फीनोटाइपिक विश्लेषण में यह पाया गया कि बीफ, चिकन और मानव से संबंधित वियुक्त (आइसोलेट्स) एंटीबायोटिक के प्रति ज्यादा प्रतिरोधी थे। माइकोबैक्टीरियोडस चेलोनेई M77 वियुक्त का पूर्ण जीनोम अनुक्रमण कार्य पूरा किया गया। प्रोटोटाइप RK-13 सेल लाइन के विकास से VSFV लाइव एटेनुवेटेड वैक्सीन को अनुकूलित किया गया। पशु रोगों की सीरो-निगरानी में पोरसाइन सिर्को वायरस (77.78%), की उच्चतम व्यापकता और उसके बाद क्रमशः क्लासिकल स्वाइन फीवर (69.5%), ब्ल्यूटंग (60.20%) और ब्रूसेलोसिस (38.02%) जैसे रोगों की व्यापकता का पता चला। मिजोरम में, सूअरों के कुल 89 सीरम नमूनों को PRRSV के लिए, 89 नमूनों को CSFV के लिए, 164 नमूनों को PCV2 के लिए तथा 75 नमूनों को PPV के लिए पोजेटिव पाया गया। ई. कॉली के *stx2* (4), *hly* (1), *eaeA* (1), *astA* (12), *papC* (1) विरुलेंस जीन्स के लिए पोजिटिव PCR ऐस्से (आमापन) को रिकॉर्ड किया गया और मिजोरम के सूअरों से औचक रूप से संग्रहित विष्ठा नमूनों से 20 वियुक्तों को *blaCMY* के लिए पोजेटिव पाया गया। सियार के मस्तिक से केनाइन डिस्टेम्पर वायरस (CDV) और MDCK एवं ESK-4 सेल लाइन में CSF वायरस (CSFV) का वियोजन किया गया। सूअरों में क्रिप्टोस्पोरिडायोसिस और बेलेटिडायोसिस के आणविक वर्णन का कार्य पूरा किया गया। बी. माइक्रोप्ल्स टिक्स की लार ग्रंथि एंटीजन के SDS-PAGE विश्लेषण में 150 kDa, 92 kDa, 74 kDa, 64 kDa, 37 kDa, 24 kDa और 16 kDa पॉलीपेप्टाइड की मौजूदगी का पता चला। BHK-21 सेल लाइन में खुरपका और मुंहपका रोग विषाण J (FMDV) को अलग किया गया। मेघालय की ग्रामीण बत्तख समष्टि में क्लोस्ट्रिडियुम परफ्रिंजेन्स (34%) रिकॉर्ड किया गया।

मिजोरम, मणिपुर, नागालैंड और मेघालय के बर्मीस ब्लैक पिग का गुणानुवर्णन पूरा किया गया। बर्मीस ब्लैक पिग का शारीरिक वजन भारत के देसी सूअरों से अधिक था। सूअर उत्पादन की लगभग 70% लागत मेघालय में उनके चारे पर खर्च होती है। सूअर पालक, सूअर पालन मास (80%) तथा प्रजनन 20% के लिए करते हैं। लगभग 90% सूअर उत्पाद थोक व्यापारियों को बेचे जाते हैं और 10% उत्पाद खुदरा व्यापारियों को बेचे जाते हैं। कुल मिलाकर, लगभग 70% उत्पाद उपभोक्ता को बेचे जाते हैं। देसी सूअर प्रजातियों से ऐथनिक पोर्क खाद्य उत्पाद तैयार कर प्रसारित किए गए और उत्पादों को रिटॉर्ट प्रसंस्करण प्रौद्योगिकी का प्रयोग कर उपभोग के लिए उपलब्ध कराया गया। रिटॉर्ट किए गए उत्पादों को सामान्य तापमान पर भंडारित किया जा सकता है, जो लंबी दूरी के वितरण एवं विपणन में सहायता करता है। मेघालय में टर्की पक्षियों के ताजे वीर्य की विशिष्टताओं का मूल्यांकन किया गया। त्रिपुरा में, कलर्ड ब्रायलर का विकास निष्पादन, अन्य कुक्कुट जननद्रव्य की तुलना में, उत्कृष्ट पाया गया। कलर्ड ब्रायलर (वाणिज्यिक) में सर्वाधिक प्रतिशत उर्वरता 85.53% थी। नर सूअरों, जिन्हें ओमेगा-3 वसा अम्ल का अनुपूरण दिया गया था, उनके वीर्य गुणवत्ता प्राचल में काफी सुधार ($p<0.05$) पाया गया। सिक्किम में, संघेरी बकरियों का प्रजनन पूरे वर्ष किया जा सकता है और बकरियों में कामोन्माद उत्पन्न करने के लिए प्रजनन योग्य बकरियों का बकरे से समागम कराया जा सकता है।

वनराजा मुर्गी में चार माह की आयु की मुर्गियों के लिए खुराक में 1 कि. ग्रा. प्रति टन स्तर पर प्रोबायोटिक (प्रोपियोनिबैक्टीरियम फ्रेयूडेनरीची), नीम (अजाडिराचटा इंडिका), एमओएस और टॉक्सिन बाइंडर सहित वाणिज्यिक खाद्य योगज का आहारीय अनुपूरण दिए जाने से प्रति दिन अंडा उत्पादन में ($P<0.05$) वृद्धि हुई। थारपरकर क्रास गोपशु में दूध गुणवत्ता मापदण्डों पर परिरक्षित चारा (साइलेज) के प्रभाव से यह पता चला कि जब पशुओं को 4 कि. ग्रा. प्रति दिन की दर से परिरक्षित चारा खिलाया गया, तब पशुओं को दिए गए सांद्रण की मात्रा घटाकर आधी हो गई। अरूणाचल प्रदेश में मिथुन (बोस फ्रॉनटेलिस) द्वारा उपभोग की गई कुल 21 गैर.पारंपरिक चारा प्रजातियों की पहचान की गई।

मेघालय में अक्वेरियम टैंकों में तीन भिन्न तापमानों अर्थात 20, 25 और 30°C के तहत 28 दिनों तक अमुर (सी. कार्पियो अमुर) स्पान के विकास एवं जीवित्ता का मूल्यांकन किया गया। मेघालय में उमट्रयू नदी की मछली विविधता और लिम्नोलॉजी का अध्ययन किया गया और 23 देसी मछली प्रजातियों को संग्रहित कर उनकी पहचान की गई। मेघालय से विलुप्त हो रही चॉकलेट महशीर

(नियोसोकीलियस हेक्सागोनोलेपिस) मछली प्रजाति के अतिरिक्त, विभिन्न ऊपरी जल मछली प्रजातियों, यथा स्किस्टूरा, ग्लाइप्टोथोरेक्स, बेडिस प्रजातियों को संग्रहित किया गया। सिंघी, मृगल की खाल और नीम (पत्तियां एवं छिलके) के छिलकों के अर्कों को एक एंटीबैक्टीरियल एजेंट के रूप में माना जा सकता है। मणिपुर में बीज उत्पादन प्रोटोकॉल के विकास के लिए ओमपाक बिमाकुलेटस का प्रजनन स्थैतिक स्थिति में सफलतापूर्वक किया गया जिसमें 0.7 मि. ली. प्रति कि. ग्रा. की दर से ओवेसिस का प्रयोग किया गया। मिजोरम की तीन प्रमुख नदियों में मछली विविधता के आकलन में यह पाया गया कि मछली प्रजातियों के 14, 9 और 12 परिवार क्रमशः छिमटुईपुई, टुट और टीरेई नदियों से संबंधित थे। नागालैंड में चाथे नदी की समरूपी मछली विविधता का प्रलेखीकरण किया गया और अब तक 12 प्रजातियों का प्रलेखीकरण किया गया है जो 9 वशों से संबंधित हैं, अर्थात बेडिस (2), स्किसटुरा (2), गारा (1), बारलियुस (2), लेपिडो सेफालिचिथिस (2),रसबोरा (1),पेथिया (2) और डेनियो (1)। त्रिपुरा में, छोटे कद के फिंगरलिंग, बहु भंडारण, बहु मछली पकड़ और वायु संचारण यंत्रों का प्रयोग किए जाने से प्रति हैक्टेयर मछली उत्पादन में वृद्धि हुई। रुद्रसागर झील से संग्रहित की गई कुल 46 मछली प्रजातियों में से, सात प्रजातियां ऐसी थीं जो भविष्य में विलुप्त (नियर थ्रेटन्ड) हो सकती हैं; एक प्रजाति को संवेदनशील तथा एक प्रजाति को विलुप्त होने के कगार पर अधिसूचित किया गया। विभिन्न पोषकतत्वों, अर्थात नाइट्राइट, नाइट्रेट और फास्फेट के औसत प्रेक्षित मान क्रमशः 0.005 ppm, 0.397 ppm और 0.582 ppm थे।

निक्रा (NICRA) परियोजनाओं के तहत समस्त उत्तर पूर्व क्षेत्र के लिए वार्षिक वर्षा का अध्ययन 30 वर्षों की अवधि तक किया गया। अध्ययन में यह पाया गया कि विभिन्न कालावधियों में औसत वर्षा में कोई खास अंतर नहीं था। लेकिन, वर्षा का दायरा काफी बढ़ चुका है, जो 1255-2855 मि. मी. (1901-30) से बढ़कर 1226-5162 मि. मी. (1991-2015) था। इस अध्ययन से यह पता चलता है कि वर्षा के बढ़े हुए दायरे से काफी अनिश्चिताएं पैदा हो गई हैं जिसके कारण बारबार सूखा और बाढ़ जैसी स्थितियां उत्पन्न होती हैं। वर्ष 2018 में किए गए वायुजीवी (ऐरोबिक) परीक्षणों में चावल वंशावली, TRC 2015-12 / IET 25662 (नवीन x कटकतारा) VIC CVRC प्रस्ताव के लिए प्रोन्नत हुई। बढ़ते तापमान क्षेत्रों में मक्का जीनप्ररूप, RCGMP 73 का प्रदर्शन बहुत अच्छा पाया गया। ढलान प्रवणताओं एवं खाली छोड़ी गई भूमि की अवधियों के साथ झूम खेतों से पोषक तत्व और जैविक कार्बन हानियों को भी रिकॉर्ड किया गया। 60% ढलान प्रवणता वाले खेतों एवं नये झूम खेतों से N, P, K और जैविक कार्बन की हानियां अधिकतम थीं।

मणिपुर में, कृषि विज्ञान केंद्रों, गैर सरकारी संगठनों, स्वयं सहायता समूहों और किसान क्लबों को शामिल करते हुए बीज ग्राम के लिए गुणवत्ता बीजोत्पादन विधियों का भागीदारी विकास कार्यक्रम काफी सफल रहा। मणिपुर केंद्र से विकसित 'बे लीफ बीवरेज' प्रौद्योगिकी के प्रसार एवं वाणिज्यकरण के लिए मैसर्स डिवाइन इंटरप्राइज, इम्फाल, मणिपुर, के साथ समझौता ज्ञापन (MOU) पर हस्ताक्षर किए गए। मणिपुर के सेनापति जिले में पुरुल अकुटपा गांव में जैविक कीवी फल के लिए सेनापति उत्पादक संगठन (SPOOK) का शुभारंभ किया गया। मणिपुर केंद्र में स्थापित एग्री.बिजनेस इनक्यूबेशन सेंटर ने 40 से अधिक नवोदित उदीयमान कृषि उद्यमियों को इनक्यूबेशन सहायता प्रदान की। इनमें से 17 उद्यमी/इनक्यूबेटी ने इनक्यूबेशन में सफलतापूर्वक प्रशिक्षण प्राप्त कर अपने स्वयं के व्यवसाय उद्यम स्थापित किए हैं।

इस क्षेत्र में संस्थान के बीस कृषि विज्ञान केंद्रों का नेटवर्क स्थापित है। वर्ष 2018 में 1137 क्षमता निर्माण प्रशिक्षण कार्यक्रमों का आयोजन किया गया जिनसे कुल 37,043 किसान लाभान्वित हुए। इसके अलावा, कृषि विज्ञान केंद्रों द्वारा पूरे क्षेत्र में 2013 प्रदर्शनों, 941 फार्म परीक्षणों और 163 विस्तार कार्यक्रमों का आयोजन भी किया जिनमें कुल 82,617 किसानों ने सहभागिता की। जनजातीय उपयोजना (TSP) के तहत आयोजित किए गए विभिन्न आजीविका कार्यक्रमों से वर्ष 2018 के दौरान उत्तर पूर्व के सात राज्यों से कुल 22169 से अधिक जनजातीय किसान लाभान्वित हुए। उत्तर पूर्व के पर्वतीय राज्यों के विभिन्न जनजातीय गांवों में अनेक प्रकार की कुल 407 भौतिक परिसंपत्तियां सृजित/वितरित की गईं, जिनमें कुक्कुट शेड, सूअर पर्यावास, प्रसंस्करण यूनिट, जलकुंड, बीहाइव ब्रीकेट मेकिंग यूनिट, वर्मीकंपोस्टिंग यूनिट, छायादार गृह, कम लागत की सूअर प्रजनन यूनिट, पॉली हाउस जैसी परिसंपत्तियां शामिल हैं।

EXECUTIVE SUMMARY

The total annual rainfall of Umiam for the year 2018 was 2277.9 mm with monsoon rainfall (June to September) of 1473.3 mm (65% of the total annual rainfall). The total rainfall was about 5% lower than normal in the year, and monsoon rain was also less by 4%. Gazette Notification No. 5077, dated: 26 December, 2018, has notified 16 crop varieties developed and released by the Tripura Centre in recent years including 11 varieties of rice; 1 variety each of field pea, green gram, black gram, sesame and toria. Out of several germplasms of rice tested for yield and other attributes, TRC 2014-8 (IR 83928-B-B-9-1) / IET 24197 was identified for release by VIC CVRC in 2018. The entry also has good quality parameters like 68.45% milling, 60.85% head rice recovery, long slender grains etc. Tripura Khara Dhan-1 was identified as early duration variety under late sown condition for delayed monsoon. Four varieties of guava namely Megha Supreme, Megha Magenta, Megha Wonder and Megha Seedless and one variety of Soybean (Umiam Soybean-1) have been recommended for release by the Meghalaya Seed Sub-Committee for Agricultural and Horticultural Crops.

In rice, promising homozygous BC_2F_4 population developed from the cross of Swarna and Bhalum-4 was observed to perform better than the parents. Molecular screening of rice germplasm was done using a set of 50 SSR markers and 122 genotypes with affiliation probability of ≥80% were found to be pure whereas 28 genotypes with affiliation probability of <80% were identified as admixture having mixed ancestry at Umiam. Among the 10 black rice genotypes characterized for yield and its contributing trait, Latara followed by PnahSder and KbaHeh were found to be superior at Umiam. Rive variety RCM-36 and RCM-37 have been nominated for inclusion in initial varietal trial, IVT M(H) of *Kharif* 2018 from Manipur. DUS characterization revealed that Farmers' rice varieties namely *Langphou chahao, Darum, Rajen/ marjen, kathei* and *Sanayambi phou* were found to be distinct in Manipur, thus these varieties need to be further revalidated and registered for the benefit of farmers. System of rice intensification (SRI) recorded 5.79 per cent higher grain yield over conventional method of planting of rice in mid hills of Sikkim. Participatory Seed Production of rice covered 41.25 ha with 58 farmers growing rice varieties RC Maniphou-7, RC Maniphou-10, RC Maniphou-12 and RC Maniphou-13 with a production of 573.78 quintals and average seed yield of 45.0q/ha in pre-*kharif* in Manipur. Rice variety Gomati performed well in the low lying areas of Mizoram while significantly higher grain and straw yield was observed in IURON 514 in upland areas. In total 393.9q breeder seed of released varieties; 4093q truthful labeled seed and 1055 q pulses seed were produced by the Tripura center alone in 2018.

Maize variety DA 61A and RCM-75 performed better over other varieties under organic farming condition at Umiam. Based on comparison plot analysis, RCMGP 126, RCMGP 114, RCMGP 85, RCMGP 118, RCMGP 120, RCMGP 128 and RCMGP 127 of Maize were identified as having high performance for yield in Meghalaya. Maize variety Tapo Poli and Sago Local were cultivated for seed production and conservation of local maize germplasm in Arunachal Pradesh. ICAR Manipur Centre, Imphal demonstrated improved maize production technology in cropping system mode in 23 ha area on 47 farmer's field. Maize variety VMH- 53 (6.40 t/ha) recorded highest yield followed by VMH-45 (6.10 t/ha) under organic nutrient management practices in Nagaland and similarly Paddy variety, Bhalum-3 (3.25t/ha) recorded the highest yield followed by SARS-8 (2.30 t/ha).

Among the different varieties of Finger millet, Madina 352 recorded the highest grain yield (1.30 t/ha) at Umiam. Among all the pulses tested, Lentil (DPL-61) and chickpea (D-21) had more phosphorus efficiency with more root exudation potential. Sesame variety TRC TIL 1-8 recorded the highest yield with 1.3t/ha followed by Savitri (1.1t/ha) in Nagaland. Sunflower variety KBHS (1430 kg/ha) recorded highest yield followed by sunflower variety,

LSFH-171 (1347 kg /ha) in Nagaland. Among 29 perilla genotypes, RC Thoiding 8 (IC-0615369) (56.5 g/plant) recorded the highest seed yield per plant in Manipur. Based on field and proximate data of around 40 perilla genotypes from Meghalaya, few genotypes are selected for subsequent shelf life studies.

In rootstock evaluation studies on Khasi mandarin, maximum graft success was recorded with *C. jambhiri*. Nodal segments and shoot tips obtained from in vitro grown seedlings of *Kachai lemon* were successfully used as explants for multiple shoot regeneration studies at Manipur. For in-vitro mass multiplication of Elaichi lemon, maximum number of shoots/explants was observed from the MS media supplemented with 0.5 mg/L BAP. Y shape trellis was found significantly superior training systems for peaches in Meghalaya. Maximum fruit weight, fruit length, fruit width and fruit TSS content were recorded from 20 local mango germplasm of Kolasib and Mamit district of Mizoram. A total of 216 banana mats/genotypes were collected and maintained as 'field gene bank of banana of NE India.

Photo-insensitive bush type Dolichos bean 'Selection 1' was found high yielding genotype in farmer's field. Different genotypes of King Chilli were evaluated to study the phenotypic correlations between horticultural traits and yield. Exposure of seeds to Arsenic (As) caused a significant reduction (30-40%) in root lengths of French beans and the rate of decrease was more with increase in duration of exposure from 24h to 124 h. A nutrient management practice was standardized for French bean in Arunachal Pradesh. Package of practice for off season production of Naga King Chilli has been standardized at Nagaland. Storage studies revealed that percentage of loss in terms of bulb rotting in onion and weight loss were minimum after 2 months of storage in KH M-1 (3.6%) followed by NHRDF Red-2 (7.6%). Quality parameters namely TSS, ascorbic acid, reducing sugar and lycopene in tomato were found to be highest under 100% organic management. A total of 33 orchid species were collected and being characterized for vegetative and flowering characters. Gerbera genotype RCGH-22 recorded maximum number of flowers/ Plant, while 'RCGH-117' recorded longest vase life.

Module consisting of biopesticides and fruit fly traps has been identified for the control of fruit flies in squash. Invasive solanum fruit fly, *Bactrocera latifrons* reported for the first time damaging brinjal fruits in Meghalaya. N-hexane fraction of *Vitex negundo* and essential oils of *Ocimum basilicum* and *Piper nigrum* were found effective against major cruciferous defoliators. Dissipation pattern of novaluron and chlorantraniliprole was studied in tomato. Natural field parasitism of fruit flies was found higher in guava variety RCGH-7. In risk assessment study, the Azadirachtin, Anonnin, *B. bassiana* and *Bt* var. *k* were found slightly to moderately toxic to the foraging bees, *Apis cerana*; whereas Spinosad and Imidacloprid were found dangerous to the bees. Soft scale belonging to genus *Platylecanium* has been reported for the first time in India. Important invasive pest species were detected and necessary advisories were issued to the farmers and state government offices. Four pathogens involved in disease complex of bottle gourd were identified. Entomopathogen, *Pandora formicae* has been reported for the first time from India. Differential virulence pattern of rice blast pathogen (*Pyricularia oryzae)* was observed in Manipur region. Indigenous plants from Manipur *viz*., *Plectranthus ternifolius, Goniothalamus sesquipedalis* and *Zanthoxylum acanthopodium* were found to be effective in management of rice store grain pest. Large Cardamom Chirke Virus (LCCV) infections have been detected for the first time on Solanaceous host in Manipur. The major cause of fruit drop in Sikkim mandarin was mainly due to the infestation of fruit flies and *Fusarium* spp. The different blight symptoms and difference in cultures on media indicated the complex nature of the blight of large cardamom in Sikkim. Four high yielding mushroom strains *viz*., PL-16-04, PL-17-07, PL-16-01 and Pl-17-03 were identified for Meghalaya. *Pleurotus flabellatus* and *Pleurotus sajorcaju* was found to be nutritionally superior over six other mushroom species evaluated for their proximate composition and nutrient content in Manipur. Around 33 naturally growing seasonal mushrooms were collected and documented from Nagaland, of which 16 were edible. Among different strains of oyster mushroom, strain No PL17-03 produced higher yield of 56.1 kg/100 kg dry substrate at Sikkim.

Using hyper-spectral and multi-spectral imaging by low-flying Drone at mid-altitude Meghalaya, the frost damage of in-field maize crop was detected. Frost injury led an increase in spectral reflectance of plants in the visible and infra-red regions with a distinct reflectance peak at short wave infra-red. Intercropping of maize with French bean produced the maximum maize yield compared to other leguminous intercrops in Meghalaya. The C-stocks was increased by 14% under maize-French bean system as compared to sole maize at Umiam. Over 9 years of continuous practice of zero tillage in rice based system, the SOC increased marginally from 1.45% to 1.62% in Meghalaya. Under **zero tillage in lowland rice fallow using recommended dose of NPK,** MZFB 48 recorded maximum pea equivalent yield (4.24 t/ha) whereas Pusa Mustard recorded maximum seed yield (1.31 t/ha) at Kolasib. Rajmash recorded higher grain yield in reduced tillage (1.30 t/ha) over conventional tillage (0.94 t/ha) and zero tillage (0.86 t/ha) while black gram produced higher grain yield in zero tillage (0.94 t/ha) compared to other tillage practices. Zero tillage recorded significantly higher maize equivalent yield of 11.33 t/ha over conventional tillage (10.15 t/ha) under Sikkim condition.

No significant differences were observed on growth and yield of maize (RCM 76) whereas full dose of mix nutrients and lime exerted higher yields in Mizoram. Soil organic carbon (SOC) found to be decreased from Arecanut to Rubber land uses and lowest at Teak (1.12 %) in Mizoram. SOC was significantly higher during April and October irrespectively of the land uses. Application of 5t/ha (FYM) along with 50% of RDF (80-60-40 N, P_20_5 and K_2O kg/ha) was found to be economically viable and recorded the higher yield of maize (4.6t/ha) in Nagaland. Among different sources of organic manure, the crop receiving poultry manure (2.5t/ha) recorded the highest yield of groundnut (2750 kg/ha) at Nagaland. The plants grown under polyhouse treated with Poultry manure @2.5 t/ ha+ RDF (25%) and FYM @ 10t/ha+ RDF (50%) showed significantly higher growth and yield at Medziphema. The effect of Improved *Jhum* management practices was found to be influenced positively on the yield of soybean (45%), groundnut (18.5%), maize (30.5%) and rice (40%) irrespective of other nutrient management practices under the study in Nagaland. Top dressing of nitrogen from 15 to 90 kg/ha through urea increased the Rajmash seed and biomass yield significantly over without top dressing in Tripura. Combined application of 2% urea + 2% KCl as foliar spray at 50% flowering stage improved the seed yield of mustard and lentil over control in Tripura. Application of pendimethalin @ 1000 g a.i./ha + ONE hand weeding at 30 DAS recorded statistically at par grain yield (4.67 t/ha) as recorded in the weed free treatment (4.8 t/ha). Application of 60 kg FYM, 2.0 kg urea, 1.8 kg SSP and 600g MOP per tree and irrigation at 15 days intervals during fall-winter season and at 7 days intervals during flowering to fruit maturity is standardized for Litchi in Tripura. Application of NPKS (100%) + 10 t/ha FYM + VAM + PSB + Lime gave the highest total bulb yield (35.5 t/ha) as well as marketable yield (34.2 t/ha) of onion in Tripura. Significantly higher growth, number of branches and higher number of fruits (7 no.) were observed in Dragon fruit when treated with NPK @ 25:75:75 g/plant + FYM @ 2 kg/plant + Vermicompost @ 1 kg/plant in Mizoram.

FYM + Straw mulch @ 5 t/ha each recorded significantly higher rhizome yield (10148 kg/ha) in Turmeric as compared to other mulching and organic manure treatments. Maize stalk cover + Poultry Manure + Ambrosia @ 5 t/ha was found as the best residue management option for both toria and maize (81% & 34% yield increase over respective controls). Integrated organic farming system (IOFS) model recorded net return of Rs. 73,903/- per year from an area of 0.43 ha. The model met 94.3 % of its N, 81.2 % of the total P and 98.2% of total K requirement within the system. Among the eight Farming System models developed on sloppy land, the Agro –pastoral system (0.64 ha) recorded gross and net income of Rs. 2,51,108/- and Rs. 1,11,646/-, respectively giving an input–output ratio 1.22 in Meghalaya. Integrated Farming System model on sloppy land on 1.0 ha area involving agri/vegetable based cropping system, horticulture, pond, livestock etc. gives Rs. 1,69,794/- of net return/annum in Meghalaya. Inclusion of legumes (Rice -fenugreek) in the rice based cropping

system significantly increased the yield of rice (4.6t/ha) under organic management at Sikkim. Maize + Cowpea-Vegetable Pea cropping sequence recorded the higher maize equivalent yield (12.42 t/ha) under Sikkim condition. Maximum system productivity was recorded under Vegetable cowpea-Maize + Cowpea (10.33 t/ha) cropping system in Manipur. Application of 2 t/ha vermicompost gave higher maize equivalent yield (6.91 t/ha) under Manipur conditions. Fruit yield of okra increased significantly with combined application of organic manures like vermicompost with agriculture lime and rock phosphate**.** Manure biochar co-composts can be effectively used for management of acid soils of Sikkim and other parts of Northeast India. Organic package of practices were standardized for maximization of 'A' grade kiwifruit production under partial protection with 50% agro-shade net in Sikkim.

Natural distribution zone of *Populus gamblei*, an indigenous species of fast growing poplar was extensively surveyed and leaf samples were collected to assess genetic diversity. Some of the best fit models developed for prediction of total above ground biomass and total carbon per tree accrued both from above and below ground biomass with the help of Girth at Breast Height (GBH). Twenty eight populations of *Valeriana* spp (medicinal plant) each containing 20-30 sample plants were collected from across the Himalayan ranges. On the basis of marker compound, 11 wild populations of *Valeriana jatamani* were evaluated and out of these populations three populations Ziro (AP), Dirang (AP) and Fputsero Phek were found to be superior. The multipurpose trees viz. *Pinus kesia, Eleocarpus spharicus, Acacia mangium* and *Manglietia insignis* were found promising in Basar condition in terms of the physical growth parameters. The combination of *Terminalia myriocarpa* + Guinea grass recorded the highest grass yield at Basar. Resin production from *Pinus kesiya* was being done by tapping periodically. Oleoresin was distilled through steam distillation process to separate turpentine and rosin from the oleo-rosin. Among the agroforestry systems, sisso-pineapple and teak-pineapple had higher SOC pool, carbon sequestration relative to cultivated land in the surface layer in Tripura. Soils under natural grasses had higher TOC pool than hybrid napier, congosignal and combo napier.

Hydrological behavior of different grasses was studied, among which minimum runoff (%) was found in Hybrid Napier grass. Analysis of historical weather variables and weather forecasting revealed a significant change in extremes over the whole region especially those related to extreme temperature indices as compared to the extreme rainfall indices. The microcontroller based automatic control system for gravity drip irrigation system has been designed. Microcontroller based solar tunnel drier is being standardized suitable for heavy rainfall region of northeast India. During 2018 year, 1,122 numbers of AAS bulletins and 95,829 numbers of SMS were prepared and disseminated to the farmers. Institute made Power paddy thresher cum cleaner and hand operated winnower were demonstrated in nine villages for popularization.

The crop climate relationship was quantified using Seemingly Unrelated Regression Model for NE states. The coefficients for minimum temperature were all positive and significant except Arunachal Pradesh. The extent of effectiveness of extension service provisioning among Central Govt. Organizations was highest for ICAR (16.7%) followed by Krishi Vigyan Kendra (2%). Among the State Govt. Organizations, the greatest role is played by State Agriculture Dept. (2.7%). The extent of need of extension services of farmers revealed the need for inputs (87.4%), Information & Advisory (69.8%) and Capacity Building (57.1%) for growing vegetables. Data collected from the farmers' field revealed that farmers need assistance in form of visual description about the different agricultural practices through ICT means.

Whole genome sequencing (WGS), assembly and phenotypic analysis indicated that isolates of beef, chicken and human origin were considerably more resistant to antibiotics. Whole genome sequencing of Mycobacteriodes chelonae M77 isolate has been completed. Development of prototype RK-13 Cell line adapted CSFV live attenuated vaccine. Sero-surveillance of livestock diseases revealed highest prevalence of Porcine circo virus (89.70%) followed by Porcine parvo virus (77.78%), Classical swine

fever (69.5%), Blutongue (60.20%) and Brucellosis (38.02%). A total of 89 serum samples of pigs were positive for PRRSV, 89 samples for CSFV, 164 samples for PCV2 and 75 samples for PPV in Mizoram. Positive PCR assays were recorded for, stx2 (4), hly (1), eaeA (1), astA (12), papC (1) virulence genes of E. coli and 20 isolates were positive for blaCMY from fecal samples collected randomly from pigs of Mizoram. Isolation of Canine Distemper virus (CDV) from Jackal brain and CSF virus (CSFV) in MDCK and ESK-4 cell line was done, respectively. Molecular diagnosis of Cryptosporidiosis and Balantidiosis in pigs completed. SDS-PAGE analysis of salivary glands antigen of B. microplus ticks revealed presence of 150 kDa, 92 kDa, 74 kDa,, 64 kDa, 37 kDa, 24 kDa and 16 kDa polypeptides. Isolated Foot and Mouth Disease Virus (FMDV) in BHK-21 cell line. *Clostridium perfringens* (34%) recorded in rural duck population of Meghalaya.

Characterization of Burmese Black Pig of Mizoram, Manipur, Nagaland and Meghalaya has been completed. The body weight of Burmese black pig was higher than the indigenous pigs of India. Around 70% of pig production cost goes to feed in Meghalaya. Majority of producer (80%) reared pig goes for fattening purpose and remaining 20% goes for breeding. Around 90% products go to aggregator and remaining 10% goes to retailer and then 70% of product goes to consumer. Ethnic pork delicacies prepared from indigenous recipes could be popularized and made accessible for consumption using retort processing technology. Retorted products can be stored at room temperature which aids in long distance distribution and marketing. Fresh semen characteristics of Turkey birds in Meghalaya were evaluated. In Tripura, growth performance of coloured broiler was found to be superior over other germplasm of poultry. The highest percent fertility was found in Coloured broiler (Commercial) 85.53%. Semen quality parameters of boars that received supplementation of omega-3 fatty acid showed significant ($p<0.05$) improvement. Singharey goats in Sikkim can be bred round the year and buck exposure to breedable females can be used effectively to synchronize estrous in goats.

Dietary supplementation of commercial feed additive containing probiotics (*Propionibacterium freudenreichii*), neem (*Azadirachta indica)*, MOS and toxin binder at the level of 1 kg/ton of feed for 4 months significantly ($P<0.05$) increased the hen day egg production (%) in Vanaraja . Effect of silage feeding on the milk quality parameters in the Tharparkar cross cattle revealed that when silage was fed to the animals @ 4kg per day, the amount of the concentrate given to animals was reduced to half. A total of 21 non-conventional fodder species consumed by Mithun (*Bos frontalis*) were identified at Arunachal Pradesh.

The growth and survival of Amur (*C. carpio amur*) spawn under three different temperatures of 20°C, 25°C and 30°C in aquarium tanks for 28 days was evaluated in Meghalaya. Fish diversity and limnology of Umtrew River in Meghalaya was studied and 23 indigenous fish species have been collected and identified. In addition to the endangered chocolate mahseer (*Neosocheilus hexagonolepis)*, various other upstream fish species of *Schistura, Glyptothorax, Badis species* etc were also collected from Meghalaya. Integumentary secretions of singhi, mrigal and neem (leaves and bark) extracts can be considered as a viable antibacterial agent. Breeding of *Ompok bimaculatus* was done successfully in captivity using ovasis @0.7ml/kg for the development of seed production protocols at Manipur. The fish diversity assessment in three major rivers of Mizoram revealed presence of fish species belonging to 14 families, 9 families and 12 families from Chhimtuipui, Tut and Teirei river, respectively. Documentation of the ichthyo-diversity of River Chathe in Nagaland was undertaken and so far 12 species belonging 9 genera *viz. Badis* (2), *Schistura* (2), *Garra* (1), *Barilius* (2), *Lepido cephalichthys* (2), *Rasbora* (1), *Pethia* (1) and *Danio* (1) has been documented. Introduction of stunted fingerlings, multiple stocking, multiple harvesting and use of aerators increased the per hectare production of fish in Tripura. Out of the total 46 species collected from Rudrasagar lake, seven species as near threatened, one listed as vulnerable and one species listed as endangered. The mean observed value of nutrients viz., nitrite, nitrate and phosphate were 0.005 ppm, 0.397 ppm and 0.582 ppm, respectively.

Under NICRA projects, the annual rainfall at a temporal interval of 30 years was studied for entire NE region. The mean rainfall does not vary much among different time periods. But the range increased distinctly, from 1255-2855 mm (1901-30) to 1226-5162 mm (1991-2015). It is indicating more and more uncertainty associated with rainfall leading to frequent occurrence of drought and floods. Rice entry, TRC 2015-12 / IET 25662 (Naveen x Kataktara) has qualified for CVRC VIC proposal in Aerobic trials in 2018. Maize genotype, RCGMP 73 have performed well under elevated temperature regimes. Nutrients and organic carbon losses were also recorded from jhum fields with various slope gradients and fallow periods. Losses of N, P, K and organic carbon were maximum from 60% slope gradient and fresh jhum fields.

Participatory development of quality seed production practices for seed village involving KVKs, NGOs, Self-help Groups and Farmers Clubs was very successful in Manipur. MoU with M/S Divine Enterprise, Imphal, Manipur was signed for popularization and commercialization of 'Bay leaf Beverage' technology developed at Manipur Centre. Senapati Producers' Organization of Organic Kiwifruit (SPOOOK) at Purul Akutpa Village, Senapati district of Manipur has been launched. The Agri-business Incubation Centre at Manipur Centre has provided incubation support to more than 40 budding agripreneurs. Of these, 17 incubates have graduated successfully and started their own business venture.

The Institute has the network of twenty KVKs in the region. In year 2018, 1,137 nos. of capacity building training programmes were organized wherein 37,043 farmers were benefitted. A total of 82,617 farmers participated in 2,013 numbers of demonstrations, 941 numbers of on Farms Trials and 163 extension programmes that were organized by KVKs across the region. More than 22,169 tribal farmers from seven North Eastern states were benefitted during 2018 by various livelihood programmes conducted under Tribal Sub Plan (TSP). Different physical assets (407 nos.) *viz*., poultry shed, pigsty, processing unit, Jalkund, beehive briquette making unit, vermicomposting unit, shade net house, low cost pig breeding unit, poly-house were created/ distributed in different tribal villages of the hill states of North East.

1. INTRODUCTION

ICAR Research complex for NEH Region is the premier Institute dedicated to research in agricultural sciences in the North Eastern Hill Region of India since its establishment in 1975. The Institute has been developing location specific technologies through its ten divisions in the headquarters at Umiam, Meghalaya and its six regional centers at the six hill states of the NE region. The Institute has been delivering these technologies to a large number of farmers in the remote areas through these 20 KVKs spread across different states. The Institute has also been involved in imparting sustainable livelihood options in agriculture and allied fields through trainings, demonstrations and awareness programmes. The Institute has been also involved in teaching and research guidance through its scientific staff to the students of different universities in and outside the region.

The Institute has four Flagship projects *viz.*, a) Improvement for sustainable livelihood; b) Trans-boundary diseases surveillance and control measures; c) Research Network on Medicinal and Aromatic plants for development of nutraceuticals healthcare drugs, etc. and d) Temperate horticulture development in North East Hills. A multi institutional and multi-disciplinary project on medicinal plants has been under way to tap the rich medicinal resources of the NE region. Some competitive projects such as DBT, DST, NICRA, NHB and NMSHE, TSP, KIRAN, Agri-Consortia on Water etc. are operating in the region. The Institute has been disseminating modern technologies for livelihood and nutritional security in the region that include truthfully labeled seeds, quality planting materials, improved animal breeds, poultry and fish seeds including proto-type implements and tools suitable for hill agriculture, soil health testing kits, diagnostic kits for animal parasites, diseases and critical inputs. Several in-house projects, mostly of interdisciplinary nature are being pursued. The strategic and frontier research on climate change adaptation and mitigation under NICRA is a major research thrust area of the Institute. The Institute has strong linkage with other ICAR Institutes and Universities, International organizations like IRRI, ICRISAT, ILRI, and IWMI. The Institute also collaborates with government sponsored agencies like NERCOMP, MRDS, NABARD and IFAD; several NGOs and farmers bodies and co-operative societies for technology dissemination.

THRUST AREAS

- To evolve sustainable integrated farming systems for *jhum* improvement and restoration of degraded lands
- To increase the overall productivity of different crops through research in cereals, pulses, oilseeds, horticultural crops including temperate horticulture, agroforestry, fisheries and other economical crops.
- Development of feed and fodder resources from locally available fodder for livestock.
- Improvement of citrus plantation to reinvigorate the citrus industry
- Animal health coverage and improvement of livestock production system including trans-boundary diseases.

MANDATE

1. To develop and improve sustainable farming systems for different agro-climatic and socio-economic conditions of NEH region, including organic agriculture.
2. To improve crops, horticulture, livestock and fishery and to impart training for development of local competence for efficient management of resources.
3. To collaborate with state Departments for testing and promotion of improved farming technologies.

LABORATORIES

The headquarters of Institute at Umiam is well equipped with laboratory facilities in all the divisions. Besides, a centre of Biotechnology and central laboratory at headquarter with the state of art instrumentation facilities has also catering the research needs in different agricultural and horticultural crops. A post-harvest processing unit and well-equipped

workshop of Division of Agricultural Engineering is in place for value addition of the produce, research and development, fabrication and repair of agricultural implements and tools. A State of art facilities such as FATE, CTGC, Biochar, TOC, DNA sequencers, Flow cytometer, HPLC, GC, AAS, bio-safety cabinet for isolation works under containment condition, seven environmental control chambers, rainout shelters, transgenic facilities have also been developed at headquarter. The laboratories in all the six centers of the Institute are also being strengthened with basic and advanced instrumentation facilities.

HUMAN RESOURCES

Category	Sanctioned post	Filled post	Vacant post
Institute			
Scientific	181	138	43
Technical	250	127	123
Administrative	106	75	31
Skilled Support	115	80	35
Total	652	420	232
Krishi Vigyan Kendra			
Scientific	20	08	12
Subject Matter Specialist	120	81	39
Prog. Assist/ Farm Manager	60	35	25
Assistant/ Stenographer	40	13	27
Driver cum Mechanic	40	24	16
Skilled Support	40	25	15
Total	320	186	134

LIBRARY

Nature of publication	No. of copies available
Books & Reports	30769
Back volumes of journals	12656
Foreign journals	Nil
Indian journals	45
News papers	15
Hindi books	4478
Magazines	07

BUDGET

Actual expenditure for 2018-2019 (in lakh)

Head	Plan	
	RE	Expenditure
A. Recurring		
Establishment charges	5678.60	5677.56
Wages	1325.00	1324.82
Travelling allowances	103.00	102.98
Recurring contingencies	1862.96	1868.35
Total A	**8969.56**	**8973.71**
B. Non - recurring		
Works	645.66	645.64
Equipments	177.34	176.94
Information Technology	62.73	62.73
Furniture & Fixture	35.02	35.02
Books	21.88	21.87
Live stocks	7.27	7.26
Other items (HRD)	15.15	15.14
Repair & maintenance	64.07	64.07
Pension	2200.00	2198.35
Loans & Advances	70.00	64.04
Total B	**3299.12**	**3291.06**
C. TSP	770.90	770.87
Total C	**770.90**	**770.87**
D. SCSP	147.65	147.65
Total D	**147.65**	**147.65**
Grand total A+B+C+D	**13187.23**	**13183.29**

IT FACILITIES

The institute has computer lab and perpetual license for SAS, SPSS and STATISTICA. ARC GIS software with workstation is also in place to carry out data analysis and processing on GIS and remote sensing. Online ARS-NET examination facilities developed at Umiam are functional since 2012. KIRAN, a dedicated website managed by the Institute has started providing much needed service and knowledge sharing including integrated agro-advisory services through SMS. The Institute has internet connectivity through NKN and more than 200 computers are provided with internet connectivity.

IMPORTANT MEETINGS

Research Advisory Committee (RAC) Meeting

The RAC meeting was held on 16th April, 2018 at the Committee room, ICAR Research Complex for NEH Region, Umiam. The committee comprised Dr SP Ghosh as a Chairman with members; Dr Chandan Rajkhowa, Dr Mathura Rai, Dr S.K. Dhyani, Dr A.K. Gogoi, Dr B.N. Sadangi, Dr N. Prakash and Dr K.P. Mohapatra as member secretary. The committee after attentive perusal of the presentations from different regional stations and divisions of the headquarters provided recommendations for the institute. The committee recommended upscaling and outscaling of technologies developed by the institute and its impact evaluation, field trials of technologies generated, replication of jhum improvement programmes in more locations, prioritization of commercially important medicinal plants for research and establishment of value chain for commercially viable technologies.

Fig 1. Meeting of the Research Advisory Committee, ICAR RC for NEH Region, Umiam

Institute Research Committee (IRC) Meeting

The IRC meeting was held during 2-3 June, 2018 under the chairmanship of Dr N. Prakash, Director, ICAR RC for NEH Region, Umiam at the DNB Conference Hall of the institute. The chairman evaluated over 31 new project proposals from the regional stations and different divisions of the headquarter and among them, 16 projects were advised for modifications. The chairman expressed the need to minimize the number of institute projects and encouraged to undertake collaborative projects. It was also suggested to operationalize local PME Cell at each regional station. The chairman also recommended validation of technologies developed by the institute at farmers' field.

Review meeting on advanced animal diseases diagnosis and management consortium, Umiam

The Third Annual Review meet on the Advanced Animal Diseases Diagnosis and Management Consortium (ADMaC) was held at ICAR Research Complex for NEH Region, Umiam on 13th June 2018. The event was attended by Dr A. Chakraborty, Project Co-ordinator; Dr S.N. Das, Senior Consultant; Dr Lal Krishna, Senior Consultant; Dr Md. Aslam, Advisor DBT, Dr K.M. Bujarbaruah, VC AAU and Dr N Prakash, Director, ICAR Research Complex for NEH Region, Umiam. The ADMaC Mobile application, an in-house indirect ELISA for detection of CSFV antibodies in serum and plasma from pigs (IPR being applied) and other manuals *viz.*, Biennial Progress report, 2016-18, Standard Diagnostic Protocol, Booklet on Sampling plan for surveillance of Livestock diseases in North East Region and a

Fig 2. Book release during review meeting on Advanced Animal Diseases Diagnosis and Management Consortium

CD entitled "Database of Indian Classical Swine Fever Virus Sequences" were launched during the programme.

NAAS Regional Chapter Meet, Umiam

A one day meeting was convened by the National Academy of Agricultural Sciences (NAAS), Regional Chapter, Patna for the region of Assam, West Bengal and North East India in collaboration with ICAR Research Complex for NEH Region, Umiam on 12th July 2018. Dr A.K. Singh, Secretary, NAAS was the

Chief Guest for the event. The event was attended by Dr Ashok Kumar, ADG, Animal Sciences; Dr B.P. Bhatt, Director, ICAR Research Complex for Eastern Region, Patna; Dr A. Pattanayak, Director, VPKAS, Almora and Dr N. Prakash, Director, ICAR Research Complex for NEH Region, Umiam. The academy strongly suggested to develop a BSL-III laboratory facility for the region at ICAR RC for NEH, Umiam would be of contextual importance in order to intensify efforts to contain threat of trans-boundary diseases and can save huge monetary losses. More than 100 participants from CPGS, ATARI and ICAR RC for NEH Region, Umiam attended the NAAS chapter meet.

Fig 3. Expert group during the NAAS Regional Chapter Meet, Umiam

Annual Review Meeting of AICRP on Poultry Breeding, Umiam

Two days Annual Review Meeting of All India Coordinated Research Project (AICRP) on Poultry Breeding and Poultry Seed Project (PSP) was organized at ICAR Research Complex for NEH Region, Umiam, Meghalaya during 23rd and 24th August, 2018. Dr J.K. Jena, Deputy Director General (Animal Sciences), ICAR, New Delhi, graced the occasion as Chief Guest. Other dignitaries present during the occasion were Dr R.S. Gandhi, ADG (AP&B), ICAR, New Delhi, Dr A. Sharma, Director, ICAR-National Bureau of Animal Genetics Resources, Karnal and Dr S. Rajkhowa, Director, ICAR-NRC on Pig, Guwahati. Dr Jena emphasized the role and need of poultry production in the region and the country as a whole. Centre in-charges of 24 AICRP and PSP centres covering different states of the country participated in the review meeting.

Fig 4. Review Meeting of AICRP on Poultry Breeding

Interface meeting between ICAR Research Complex for NEH Region -Mizoram Centre and State level stakeholders

ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib organized an interface meeting with the state level stakeholders on 24th September, 2018, at Aizawl Club, Aizawl, Mizoram. Pu Lalsawta (Cabinet Minister, Finance and Planning, Govt of Mizoram) graced the programme as Chief Guest and Pu P.C. Lalthanliana (Cabinet Minister, Horticulture, Govt. of Mizoram) was the Guest of Honour. Dr N. Prakash, Director, ICAR Research Complex for NEH Region, Umiam; Dr B.C. Deka, Director ATARI-Umiam; Dr S. Desai, Principal Scientist, ICAR-CRIDA; Dr I. Shakuntala, Joint Director, ICAR Research Complex for Mizoram Center co-ordinated the interface meeting.

Fig 5. Interface meeting between ICAR RC for NEH Region and Mizoram Govt. State Officials, Kolasib

DISTINGUISHED VISITORS

Shri Radha Mohan Singh, Hon'ble Union Minister for Agriculture and Farmers' Welfare visited ICAR RC for NEH Region, Umiam

Shri Radha Mohan Singh, Hon'ble Union Minister for Agriculture and Farmers' Welfare, Govt. of India visited ICAR Research Complex for NEH Region, Umiam on 28th July, 2018 and interacted with the farmers of Ri-Bhoi District and Scientists of the Institute. The Hon'ble Minister suggested that the research should be focused on "income centric plans", marketing and value addition of agricultural produce. He also stressed upon organic farming and diversification of agriculture with allied activities viz., horticulture, dairying, bee keeping, mushroom cultivation etc. Integrated farming system models having B:C (benefit cost ratio) more than 2, should be demonstrated and popularized amongst farmers. He also emphasized upon popularization of micro-irrigation for efficient use of water in hills.

Fig 6. Shri Radha Mohan Singh, Hon'ble Union Minister for Agriculture and Farmers' Welfare interacting with farmers and scientists, Umiam

Hon'ble Chief Minister of Mizoram Shri Lal Thanhawla visited ICAR Mizoram Centre

Hon'ble Chief Minister of Mizoram, Shri Lal Thanwala inaugurated the ICAR buildings and one Day Awareness Programme on "Climate Change: Agriculture Adaptation and Mitigation Strategies in Mizoram" during his visit at ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib on 22nd January, 2018. He was accompanied by Shri P.C. Zoram Sangliana, Chairman of Mizoram Food and Allied Industries Corporation Ltd. (MIFCO) and MLA from Kolasib Constituency, Shri Hmingdailova Khiangte, MLA fromTuirial Constituency, Shri Zarzosanga, Deputy Commissioner of Kolasib District, Mizoram and Shri Zion Lalremruata, General Secretary, All Mizoram Farmers Union (AMFU), Aizawl, Mizoram. A Book entitled "Technological Options for Agricultural Production in Mizoram" was released and Fruit fly traps developed by ICAR RC for NEH Region, Mizoram Centre, Kolasib were demonstrated.

Fig 7. Hon'ble Chief Minister of Mizoram Shri Lal Thanhawla at ICAR, Mizoram Centre.

Hon'ble Chief Minister, Sikkim, Shri Pawan Chamling visited ICAR Stall during Sikkim Organic Day Program

Hon'ble Chief Minister of Sikkim, Shri Pawan Chamling along with Acharya Balkrishna, CEO Patanjali; Shri Somnath Poudyal, Hon'ble State

Agriculture Minister, Government of Sikkim and other dignitaries visited ICAR stall during the Sikkim Organic Day Programme held for two days (January 17-18, 2018). The programme was organized at Saramsa Garden, Ranipool. The Hon'ble Chief Minister along with other dignitaries showed immense interest in the research and development activities being carried out by the Institute. Joint Director, Dr. R.K. Avasthe briefed about the research and extension activities being carried out by the Institute on agriculture and allied activities for improving the livelihood of the farmers.

Fig 8. Joint Director, Sikkim Centre detailing ICAR technologies to the Hon'ble Chief Minister, Sikkim

Tripura Chief Minister Shri Biplab Kumar Deb visited ICAR RC for NEH Region, Tripura Centre

The Hon'ble Chief Minister of Tripura Shri Biplab Kumar Deb inaugurated "Rice Day & Innovative Rice Farmers Meet 2018" at ICAR Research Complex for NEH Region, Tripura centre on 22nd October, 2018. Shri Deb along with Shri Pranjit Singha Roy, Minister of Agriculture & Farmers Welfare, Govt. of Tripura visited different rice experimental and germplasm blocks maintained at Farmers Field Experiment Station at Mirza Math and addressed a large gathering of farmers, extension workers, administrators and scientists.

Fig 9. Hon'ble Chief Minister of Tripura, Shri Biplab Kumar Deb felicitating innovative rice farmers on the occasion

Shri PB Acharya, Hon'ble Governor of Nagaland visits during 'Sensitization programme for enhancing farm income and livelihood security in Nagaland'

ICAR Research Complex for NEH Region, Nagaland Centre organized a 'Sensitization programme for enhancing farm income and livelihood security in Nagaland' on 24th November, 2018. The Hon'ble Governor of Nagaland Shri PB Acharya, graced the occasion as Chief Guest and inaugurated the exhibition unit cum sale counter, mushroom spawn production unit and ornamental fish breeding and rearing unit. A farmers-scientist interaction programme was organized wherein resource persons from ICAR Nagaland centre and KVKs addressed the problems raised by the farmers. Simultaneously, a technical session on Agri-entrepreneurship development in Nagaland was also held. About 110 farmers along with other stakeholders participated in the programme.

Fig 10. Shri PB Acharya, Governor of Nagaland at ICAR Nagaland Centre

Other distinguished visitors at Sikkim Centre

Fig 11. His Excellency Governor of Sikkim, Shri Ganga Prasad has visited ICAR-Research Farm on September 21, 2018

Fig 12. Hon'ble Minister for Agriculture, Dr. Prem Kumar, Govt. of Bihar visited ICAR Research Farm along with Joint Director on June 15, 2018

IMPORTANT EVENTS

North Eastern Zone Regional Agri-Fair, Umiam

Regional Agri-Fair with the theme "Drive to doubling income of Tribal Farmers in the North East India", a four day programme (6th – 9th Jan, 2018), was inaugurated by Shri Radha Mohan Singh Hon'ble Union Minister for Agriculture and Farmers' Welfare, Govt. of India at ICAR Research Complex for NEH Region, Umiam. The event witnessed various activities and funfair with traditional food and cuisine being the highlight. The farmers-scientist interaction was a key feature of the event which created an opportunity at regional level to exchange ideas, knowledge and experiences for effective transfer of technology. Brainstorming sessions on "doubling farmers' income" and successful implementations of the schemes of Govt. of India for the farmers were another highlight of the event. The Zonal Technology Management Unit (ZTMU) of the institute facilitated the signing of three MoU's. The Agri Fair souvenir and the CD on successful technological intervention for doubling farmer's income in NE India were launched during the event.

Institute Foundation Day, Umiam

The 43rd foundation day of ICAR Research complex for NEH Region was celebrated on 9th January 2018 During the event, selected staffs from various categories (scientific, technical, administrative and supporting) were felicitated for their outstanding contribution in the growth of the Institute. Dr C. Rajkhowa, Former Director, ICAR-NRC on Mithun, Medziphema, Nagaland graced the occasion as chief guest and opined the importance of combining technology with the traditional farming practices in the conservation of natural resources. Shri B.K. Sohliya, OSD, Meghalaya Institute of Entrepreneurship, Shillong, Dr S.V. Ngachan, former director of the institute also graced the occasion.

One-day Workshop cum Brainstorming Session on "Rice Residue Burning in Manipur: Issues and Strategies for Sustainable Management"

A one-day workshop cum brainstorming session on "Rice Residue Burning in Manipur: Issues and Strategies for Sustainable Management" was organized by Indian Association of Hill Farming in collaboration with ICAR Research Complex for NEH Region, Meghalaya on 31st January, 2018 at Imphal, Manipur. The inaugural function was graced by Shri V. Hangkhanlian, Hon'ble Minister of Agriculture, Veterinary and Animal Husbandry,

Fig 13. Inauguration of North East Regional Agri-fair by Shri Radha Mohan, Hon'ble Union Minister for Agriculture and Farmers' Welfare

Fig 14. Workshop cum brainstorming session on Rice Residue Burning in Manipur

Govt. of Manipur. The occasion was also attended by Prof Adya Prasad Pandey, Vice-Chancellor, Manipur University; Dr Suhel Aktar, Additional Chief Secretary, Manipur; Shri PN Praveen Kumar, General Manager, NABARD, Imphal; Shri Ph Rajendra Singh, Director, Department of Agriculture, Manipur; Dr Y. Nabachandra Singh, Director, Directorate of Environment, Manipur and Dr N. Prakash, Director, ICAR Research Complex for NEH Region, Meghalaya. More than 100 delegates including ICAR scientists, line department officials, NGO members, extension workers, students and farmers of Manipur participated in the said event.

Regional Workshop on Maize for North East: Emerging Trends and Technology at ICAR Manipur Centre, Imphal

A One day Regional Workshop on "Maize for North East: Emerging Trends and Technology" on 28 Feb, 2018 was organized jointly by ICAR Research Complex for NEH Region, Manipur Centre, Imphal and ICAR-Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab at Imphal (Lampelpat). The function was graced by Dr N. Prakash, Director, ICAR Research Complex for NEH Region, Umiam; Dr C.A. Srinivasamurthy, Director Research, CAU, Imphal, Dr I. Meghachandra Singh, Joint Director and Dr M.A. Ansari, Scientist, ICAR Manipur Centre as Chief Guest, Guest of Honour, President and organizing secretary, respectively. Around 135 scientists, extension personal, officers from state government, and representatives from NGOs, Farmers club, SHGs attended the workshop.

Fig. 15. Regional Workshop on Maize for North East, Manipur

International Congress on Cotton and other Fibre Crops, Umiam

The International Congress on Cotton and other Fibre Crops was organized during 20th-23rd Feb, 2018 by ICAR Research Complex for NEH Region, Umiam in collaboration with Cotton Research and Development Association (CRDA), Hisar and Indian Association of Hill Farming (IAHF). The Hon'ble Governor of Meghalaya, Shri Ganga Prasad had inaugurated the event and appreciated ICAR for organizing such an innovative programme for the benefits of the farmers of the region. Dr S.S. Siwach, Vice President, CRDA Hisar; Shri Ram Muivah Secretary, NEC; Dr S.V. Ngachan, former Director, ICAR, RC NEH and Dr N. Prakash, Director, ICAR Research complex for NEH region Umiam also graced the inaugural session of the event. About 250 scientists, academicians, researchers and students from various parts of the country exchanged views on various issues related to sustainable development of fibre crops in India.

Fig 16. Dignitaries with Governor of Meghalaya, Shri Ganga Prasad during international congress on cotton and other fibres

Workshop on Indian Livestock Farming and use of Biotechnology, Umiam

One day workshop on "Indian Livestock farming and use of biotechnology" was jointly organized by Livestock Production Division of ICAR RC for NEH Region, Umiam and National Institute of Animal Biotechnology (NIAB), Hyderabad on 4th July 2018. A total of 80 livestock farmers and 17 veterinarians from North Eastern states including Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura participated in the program. The workshop was aimed to understand the recent burning and pending problems of farmers and veterinarians in the grass root level and finding solutions from the gambit of modern biotechnology. The Chief Guest, Dr A.K.K. Rawat, Director, Department of Biotechnology (DBT), suggested region specific solution to address the problems with focus on farmers. The programme was also attended by Dr Subeer S. Majumdar, Director, NIAB as Guest of Honour and Dr B. Mawthoh, Director, Department of Animal Husbandry & Veterinary, Meghalaya.

Fig. 17. Workshop on Indian Livestock farming and use of biotechnology

National Workshop cum Brainstorming Session on "Unleashing the Hidden Potential of Maize Technology in NEH Region: Status, Options and Strategies", Manipur

In order to explore the potentialities of maize cultivation in the North Eastern Hill (NEH) region and chalk out future road maps for its popularization, a two days National Workshop cum Brainstorming Session on "Unleashing the Hidden Potential of Maize Technology in NEH Region: Status, Options and Strategies" was organized by ICAR Research Complex for NEH Region, Umiam in collaboration with ICAR-Indian Institute of Maize Research, Ludhiana at ICAR Manipur Centre. Shri Y. Joykumar Singh, Hon'ble Deputy Chief Minister of Manipur was the Chief Guest. The occasion was also graced by Dr N. Prakash, Director, ICAR RC NEH, Umiam; Dr S.L. Jat, Coordinator, ICAR-IIMR, NEH Maize Programme; along with Joint Directors and Scientists from Arunachal Pradesh, Meghalaya, Mizoram, Sikkim, Tripura and Nagaland Regional Centres of ICAR RC NEH. Around 150 farmers from all the districts of Manipur and 76 delegates across India participated in the workshop.

Fig 18. "Unleashing the Hidden Potential of Maize Technology in NEH Region" at ICAR RC for NEH Region, Manipur Centre.

State Level Sensitization Workshop on "Agripreneurship Development for Increasing Farm Income and Promotion of Agri-business in Manipur" held under Agri-business Incubation Centre, Manipur

A state level sensitization workshop on "Agripreneurship Development for Increasing Farm Income and Promotion of Agri-business in Manipur" was organized by ICAR Manipur Centre on 21 August, 2018 with the aim to create awareness

among the aspiring agripreneurs about the role of Agri-Business Incubators, different options for entrepreneurship development, government schemes for entrepreneurship development and marketing strategies for fresh and processed farm produces. The inaugural function was graced by Prof M. Premjit Singh, Hon'ble Vice Chancellor, CAU, Imphal as Chief Guest; Shri P.N. Praveen Kumar, General Manager, NABARD, Manipur as Guest of Honour; Dr N. Prakash, Director, ICAR RC for NEH Region, Meghalaya as President and Dr G. Kadirvel, Principal Investigator (ABI), ICAR RC for NEH Region, Umiam, Meghalaya as special guest. Experts from NGI Skill India, MSME Technology Centre, MSFAC, NERAMAC and ICAR deliberated on various avenues of agri-business ventures in Manipur. More than 100 agripreneurs including budding start-ups and extension functionaries from different districts of Manipur attended the workshop.

Fig 19. State Level Sensitization Workshop on Agripreneurship Development for Increasing Farm Income and Promotion of Agri-business in Manipur" under ABI

National Symposium on Role of Plant Pathology in Empowering and Doubling Farmers' Income, Umiam

ICAR Research Complex for NEH Region, Umiam, Meghalaya in collaboration with Indian Society of Plant Pathologists (INSOPP) PAU, Ludhiana organised a three day national symposium during 25th-27th October 2018. The symposium was inaugurated by the Hon'ble Governor of Meghalaya, Shri Tathagata Roy in the presence of Dr N. Prakash, Director, ICAR Research Complex for NEH Region, Umiam, Dr Narinder Singhm Secretary INSOPP; Dr Dinesh Singh, Secretary, Indian Phytopathological Society and Dr Pankaj Baiswar, Senior Scientist, ICAR Complex, Umiam as the organizing secretary. Scientists, academicians and students from all over India participated in the symposium and presented their work on various themes. More than 100 delegates from across India attended the programme.

Fig 20. National symposium on Role of Plant Pathology in Empowering and Doubling Farmers' Income

Vigilance Awareness Week, Umiam

ICAR Research Complex for NEH Region, Umiam celebrated "Vigilance Awareness Week" with the theme "Eradicate Corruption-Build a new India" from 29th October to 3rd November, 2018. Smt. Kala Rama Chandra, IPS & Director, North Eastern Police Academy (NEPA), Umiam, Meghalaya was the Chief Guest and emphasized the roles and responsibilities of every citizen to keep a strict vigil for good governance. The week long awareness programme organized various competitions under the said theme such as: poster making, slogan writing, essay

Fig 21. Vigilance Awareness Week at ICAR RC for NEH Region, Umiam

competition, extempore and quiz. The awareness week was concluded with a valedictory function graced by Shri Spill Thamar, SP, Ri-Bhoi, Nongpoh as the Chief Guest and Dr S.K. Das, Principal Scientist & Vigilance Officer of the Institute. Shri Spill Thamar spoke about the inculcation of ethics and the moral upbringing of the younger generation to eradicate corruption from the society.

National Conference cum Krishi Unnati Mela, Arunachal Pradesh

A two days (17-18 November, 2018) National Conference cum Krishi Unnati Mela with a focal theme "Approaches for doubling the farmers income - the road ahead for farmers prosperity" was organized jointly by ICAR RC for NEH Region, AP Centre, Basar and Krishi Vigyan Kendra, Namsai with the financial support from the National Bank of Agriculture and Rural Development (NABARD), Itanagar and Arunachal University of Studies, Namsai. Chow Tewa Mein, Hon'ble MLA from Chowkham was the Chief Guest and Chow Zignu Namchoom, Hon'ble MLA of Namsai was the Guest of Honour of the inaugural session. The KVK administrative building and staff quarters of ICAR-KVK, Namsai was inaugurated during the event. Dr N Prakash, Director, ICAR RC for NEH Region, Umiam, Dr B.C. Deka, Director, ICAR-ATARI, Umiam, Dr Tapasya Raghav, IAS, Deputy Commissioner, Namsai, Prof V.K. Kawatra, Vice Chancellor, Arunachal University and other dignitaries from ICAR, CAU, AAU, NEIST, SLRD, Line Departments, NGOs, FPCs and SHGs attended the event.

Fig 22. National Conference cum Krishi Unnati Mela at ICAR RC for NEH Region, Arunachal Pradesh Centre

First Manipur Kiwifruit Festival at Purul Akutpa Village, Senapati District, Manipur

Under the patronage of ICAR Research Complex for NEH Region, Manipur Centre and financial support from MIDH and Tribal Sub-Plan, the First Manipur Kiwifruit Festival 2018 with the theme "Kiwifruit for Rural prosperity and Healthy Living" was successfully organized during 24-25 November, 2018 at Purul Akutpa Village, Senapati District, Manipur by Senapati Producers Organization of Organic Kiwifruit (SPOOK). The festival was inaugurated by Hon'ble Minister of Horticulture and Soil Conservation, Govt. of Manipur, Shri Th Shyamkumar Singh. Representatives from ICAR, NEC, NABARD, MSFAC and Line departments also attended. More than 100 kiwifruit growers and other farmers participated in the said event.

Fig 23. First Manipur Kiwifruit Festival 2018

National Seminar on Challenges and Opportunities for Farmers' Prosperity in Hill Agriculture, Umiam

ICAR Research complex for NEH Region, Umiam, Meghalaya, National Academy of Agricultural Science (NAAS), International Maize and Wheat Improvement Centre (CIMMYT) and the Indian Association of Hill Farming (IAHF), Umiam collaboratively organised a two days National Seminar on "Challenges and Opportunities for Farmers' Prosperity in Hill Agriculture" during 29th -30th November 2018. Chief Guest of the function was Shri Wailadmiki Shylla, Member of Legislative Assembly, Jowai. Dr N Prakesh, Director, ICAR RC for NEH Region, Umiam, pointed out that bridging the gap between hill and plain agriculture have the potential to achieve double income of the farmers.

The Guest of Honour for the occasion Shri Allentry F Dkhar, Advisor and Secretary to the Chief Minister, Govt of Meghalaya opined "Mission Organic" should be one of the focal points in the seminar.

Fig 24. Inauguration of National Seminar on Challenges and Opportunities for Farmers' Prosperity in Hill Agriculture

Conference on Startups and MSMEs in Food Processing, Umiam

A one day conference on "Startups and MSMEs in Food Processing" was organized by the Associated Chambers of Commerce and Industries of India (ASSOCHAM) in collaboration with Ministry of Food & Processing Industries (MoFPI), Government of India and ICAR Research Complex for NEH Region, Umiam, Meghalaya and SIDBI. The purpose was to provide a platform to aspiring food entrepreneurs, existing SMEs in food, agriculture professionals, students, progressive farmers, Self Help Groups, etc. for sharing their views and learn about latest initiatives, schemes and opportunities available in the field of Agro Food Industries. More than 100 participants from the state attended the conference.

The chief guest for the occasion was Shri Tathagata Roy, Hon'ble Governor of Meghalaya. Dr N Prakash, Director, ICAR RC for NEH Region; Shri M L Suiam, OSD, Directorate of Food Processing, Government of Meghalaya; Shri Chetan Vij, Assistant Director, ASSOCHAM; Dr G Kadirvel, Principal Scientist & PI, ABI, ICAR RC for NEH Region, Umiam; Shri Girinda Brahma, Assistant General Manager, SIDBI; Shri Sajjan Kumar Tharad, Secretary, Frontier Chamber of Commerce and Industry, Meghalaya, Smt Sunita Rai, Assistant General Manager from APEDA, Shri SK Das, Assistant Director from MSMR-DI were other speakers in the conference.

Fig 25. Conference on Startups and MSMEs in Food Processing

2. RESEARCH ACHIEVEMENTS

MEGHALAYA

WEATHER REPORT- 2018

Weather at Umiam (Barapani), Meghalaya for the period of January to December, 2018 was represented by daily rainfall, maximum and minimum temperature, relative humidity (morning and evening), wind speed and direction and evaporation data recorded at the agro-meteorological observatory of the Institute. The total annual (2018) rainfall received was 2277.9 mm, with 65% contribution from monsoon months (June to September) alone. The rainfall (monsoon and annual) was 4-5% less than normal year. A total of 121 annual rainy days were recorded, of which 69 days was recorded within monsoon months. The remaining rainy days were recorded during pre- and -post monsoon months. The monthly and annual rainfall pattern was similar to normal year till October (Fig 1) but in November, it was 88% less than normal year. Maximum one day rainfall was 86.7 mm received on August 13th, 2018. The total annual pan evaporation loss was 836.0 mm. The rainfall amount was more than the pan evaporation from April to October and but the reverse was observed for rest of the months.

The mean monthly maximum (Mean T_{max}) and minimum (Mean T_{min}) temperatures showed similar pattern of change throughout the year (Fig 2 a). The mean T_{max} varied between 26.7 to 29° C for all the months except for October to March where it varied from 20.7 to 26.5° C. It was observed that T_{max} was either similar or more than its long period average (LPA) value for almost all the months. The phenomenon of higher than normal T_{max} was also observed during last few years, indicating a slow but persistent increase in T_{max} over the place. The highest mean monthly T_{max} of 29.0° C was observed in the month of August. The mean monthly T_{min} was highest (21.0° C) in the month of July and lowest (6.8° C) in January. It can be seen that the mean monthly minimum temperature increased after January to reach the maximum on July and thereafter, decreased to the minimum at January again. For most of the months, the mean monthly T_{min} values were either similar or lower than its LPA value, indicating towards the decrease in T_{min} over the years in the place.

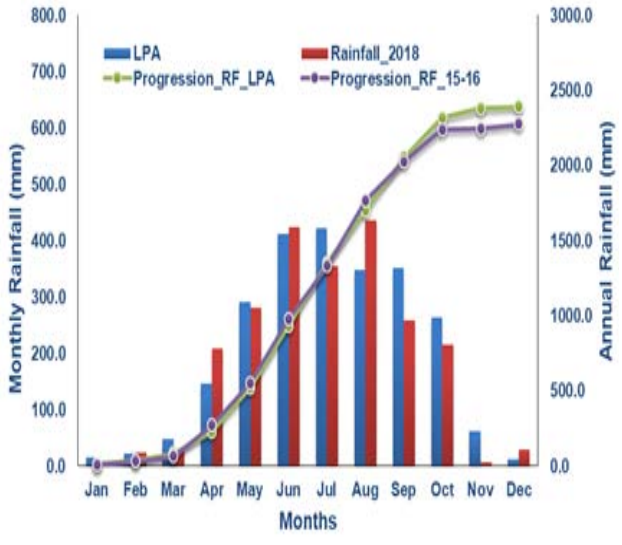


Fig 1. Monthly & annual rainfall pattern at Umiam, Meghalaya

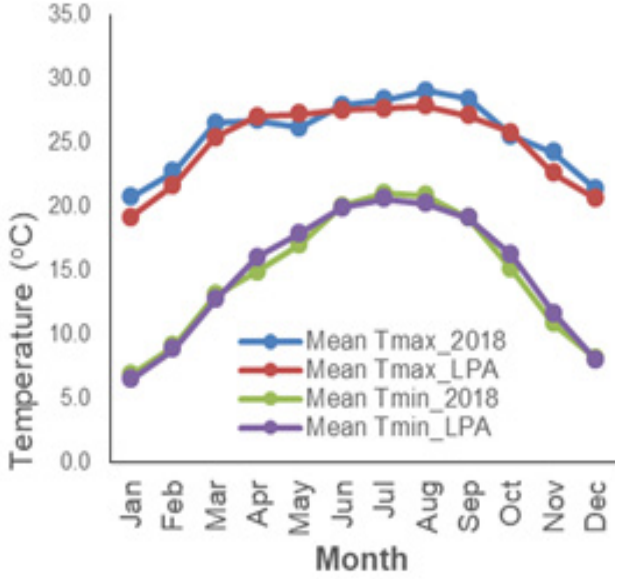


Fig 2. Monthly values of mean maximum & minimum temperature during 2018

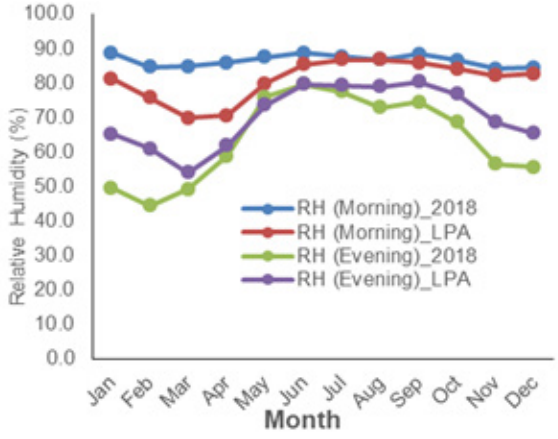


Fig 3. Monthly values of mean relative humidity during 2018

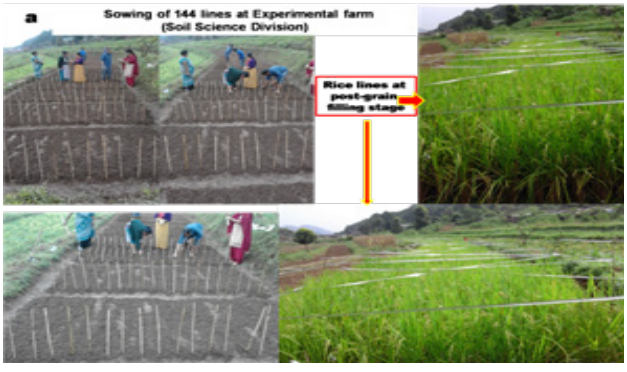
Variation in morning relative humidity (RH-morning) lesser compared to the evening relative humidity (RH-evening) (Fig 2 b). The RH (evening) showed larger variation as it varied between 44.3% and 79.5% in February and June, respectively. The RH-evening was much lower than its LPA value in many months of the years which is mainly due to increase in T_{max} at Umiam. The average wind speed was highest at 2.8 km/hr in the month of March but average monthly wind speed was lower than normal (23 to 57%) years. The average wind speed has decreased persistently over the years.

CROP SCIENCES

Rice

Development of phosphorus efficient rice by marker assisted back cross breeding

Few promising homozygous BC_2F_4 population developed from the cross of rice line (Swarna and Bhalum 4) were screened in the field of Soil Science and they showed better performance over the parents (Fig 4a & b).



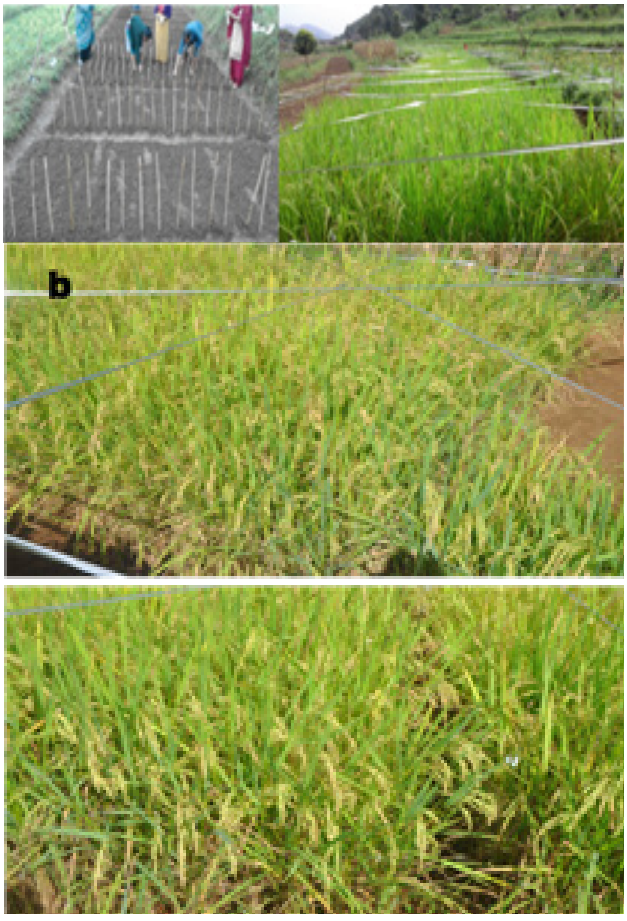


Fig 4 a. Experimental Plot (b)Crossed materials developed from (Swarna X Bhalum 4) at maturity

Screening of rice genotypes for the presence of the rice QTL phosphorus uptake 1

One hundred and sixty genotypes of lowland rice and seventy genotypes of upland rice were screened for the presence of the rice QTL Phosphorus uptake 1(Pup1) using a set of 7 SSRs markers viz., K1, K5, K20 1,K20 2,K29 1,K29 2 and K29 3. Kasalath was taken as a reference. The difference in the amplicon size between the reference and the samples was too less and could not be differentiated in the agarose gel for markers namely, K 1 (125/122), K 5 (272/280), K 20 1 (240/243), K 20 2 (282/285), K 29 1 (212/216), K 29 2 (219/212) and K 29 3 (236/238), thus new SSRs viz., K 41(382), K 42(918), K 43(912), K 45(276), K 46(523), K 46 2(227), K 48(847), K 52(505) and K 59(550) which shows presence of the amplicon in the reference (Kasalth) and absence in the non Kasalth will be used for further study.

Screening rice germplasm for Blast resistance

One hundred and sixty genotypes of lowland rice and seventy genotypes of upland rice were screened for resistance to blast using a set of 8 SSRs markers viz., AP4007, C1454, Pibdom, RM208, AP5659 5, NBS2 Pi9, YL155/ YL87 and YL153/ YL154 conferring resistance to the genes *Pi2*, *Pib*, *Pi9* and *Pita*, respectively (Fig 9). The marker AP4007 could identify 160 genotypes showing the presence of gene *Pi2*, Pibdom could identify 106 genotypes showing the presence of the gene *Pib*, RM208 could identify 80 genotypes showing the presence of the gene *Pi2*, AP5659 5 could identify 44 genotypes showing the presence of the gene *Pi9*, YL155/ YL87 could identify 57 genotypes showing the presence of the gene *Pita* and YL153/ YL154 could identify 81 genotypes showing the presence of the gene *Pita*.

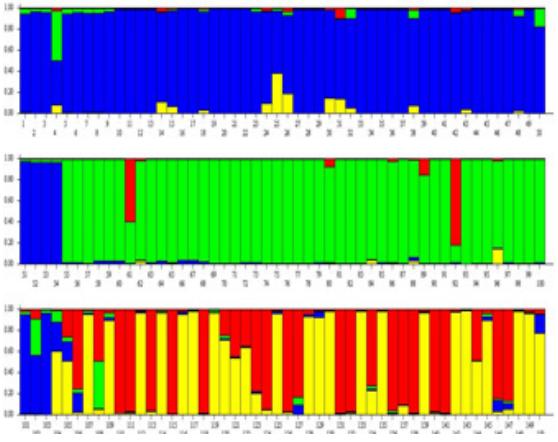


Fig 5. Model based clustering of rice germplasm

Assessment of genetic diversity among rice germplasm

Molecular screening of rice germplasm was performed using a set of 50 SSR markers identified under generation challenge programme of IRRI, Philippines. Neighborhood clustering based on Roger's genetic distance had differentiated the genotypes into three major clusters. Model based clustering with a burn-in period of 50000 and Montecarlo Markov chain replication of 50000 based on maximum likelihood had also differentiated the genotypes into 3 groups. Around 122 genotypes with affiliation probability of ≥80% were found to be pure whereas 28 genotypes with affiliation probability of <80% were identified as admixture having mixed ancestry. The distant lines with high performance were subjected to hybridization programme.

Marker assisted screening for presence of fertility restorer genes

Both gene based and gene linked molecular markers were used to identify the potential fertility restorers. Restoration of fertility of the WA CMS was governed by two major loci namely, *Rf3* located on chromosome 1 and *Rf4* on chromosome 10 (Table 1). For *Rf3*, 119 genotypes were found to be homozygous for restorer alleles with both linked as well as gene based markers. With respect to *Rf4* gene, 125 genotypes were homozygous for restorer allele of *Rf4* with both gene linked marker. Thus,*Rf4* was the most predominant allele as compared to *Rf3*.

Table 1. Screening for fertility restorer genes in rice germplasm

Markers	*Rf3Rf3*	*Rf3rf3*	*rf3rf3*	Missing	Total	Markers	*Rf4Rf4*	*Rf4rf4*	*rf4rf4*	Missing	Total
DRRM-RF3-5	89	59	2	0	150	RMS-SF21-5	127	5	16	2	150
DRRM-RF3-10	128	17	3	2	150	RM6100	22	25	103	0	150
RMS-PRR9-1	119	24	4	3	150	DRCG-RF4-14	125	7	15	3	150

Identification of promising rice genotypes

In RCRT (upland) RCPL1 413 (3.6 t/ha), RCPL1 129 (3.2 t/ha) and RCPL1 131 (3.2 t/ha) again confirmed their superiority for yield. As far as RCRT (lowland) is concerned, RCPL 300 (3.t q/ha) and RCPL1 145 (3.6 t/ha) were the high performer for grain yield.

Characterization of black rice genotypes

A set of 10 black rice genotypes were characterized for yield and its contributing traits. Latara (33.89 g) followed by PnahSder (26.16 g) and KbaHeh (22.17 g) were found superior (Fig 6). Utilization of these lines in developing black rice varieties, short in stature with higher yield can be a remarkable breakthrough in enhancing farmers' income and livelihood.

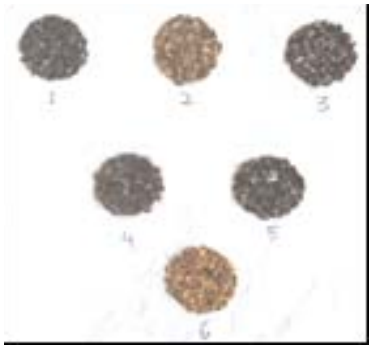


Fig 6. Black rice germplasms

Fig 7. Low light experimental area

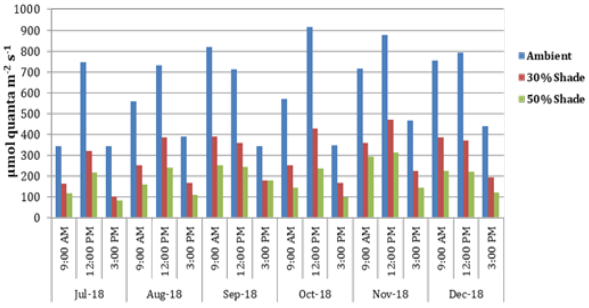


Fig 8. Light Intensity during crop growth kharif 2018

Study of rice yield under low light intensity using genomic approaches

Field trial of fifty screened genotypes was undertaken under control and two shade-net conditions (30% and 50% shading), respectively, during kharif 2018 (Fig 7) with the following checks *viz.*, Swarna Prabha (SP, Tolerant) and IR-8 (Susceptible). Light intensity was recorded daily during the crop period (Fig 8).

Table 2. Effect of low light on physiological traits at anthesis

Unit	Transpiration rate (E)			Stomatal Conductance (GH_2O)			Photosynthetic Rate (A)			Intracellular CO_2 Concentration (ci)		
	mmol m^{-2} s^{-1}			mmol m^{-2} s^{-1}			µmol m^{-2} s^{-1}			ppm		
Genotypes	Control	30% shade	Decrease %	Control	30% shade	Decrease %	Control	30% shade	Decrease %	Control	30% shade	Increase %
IR-8	8.9	6.6	25.5	413.6	358.0	13.5	22.9	18.0	21.5	302.3	333.7	10.4
Swarna Prabha	9.6	6.6	31.0	505.5	412.8	18.4	23.6	17.7	24.9	308.6	320.9	4.0
Purandu	10.0	9.5	4.1	450.6	427.3	5.2	22.0	20.9	5.2	305.9	326.2	6.6
Subhadra	12.0	10.5	12.7	735.2	668.0	9.1	29.8	26.2	12.3	328.0	329.9	0.6
BVD111	12.3	7.4	40.4	810.8	558.7	31.1	31.1	22.0	29.4	333.4	337.6	1.3
Danteswari	9.0	8.8	2.4	643.3	629.3	2.2	24.1	22.6	6.3	337.3	348.0	3.2
Bhalum-4	10.5	6.5	38.4	775.5	547.4	29.4	23.6	17.7	24.9	355.9	361.2	1.5
Palghar-2	12.5	6.1	51.6	871.0	518.7	40.5	27.7	20.3	26.8	352.3	363.3	3.1
Katkabhog	9.2	6.5	29.5	624.6	565.7	9.4	24.6	17.1	30.7	324.0	343.3	6.0

Photosynthetic rate, transpiration rate and stomatal conductance are sensitive/responsive to low light. A lesser reduction in stomatal conductance, transpiration rate and photosynthetic rate was observed in genotypes Purandu, Subhadra and Danteswari; this indicates more open stomata in tolerant genotypes allowing greater conductance, and thereby, better photosynthesis and transpiration rates as indicated by the results (Table 2). More of starch accumulation was observed under shading than normal light, indicating an active sink activity in grains under low light in relatively tolerant genotypes. A higher sucrose synthase activity in grains under shading identifies with the observations (Fig 9). Grain yield per plant, spikelet fertility, biological yield, number of effective panicles etc. were observed as key traits in response to low light intensity.

Low light intensity tolerant genotypes identified were namely Subhadra, Khira, Jyati, Narendra-1, T. Basumati, Purandu, BVD 111, Danteswari, Bardogi dhan, and Kunti. Susceptible genotypes included ASD-18, Palghar 2, Satika, Murgibalam, Rimynkon and Kba rim.

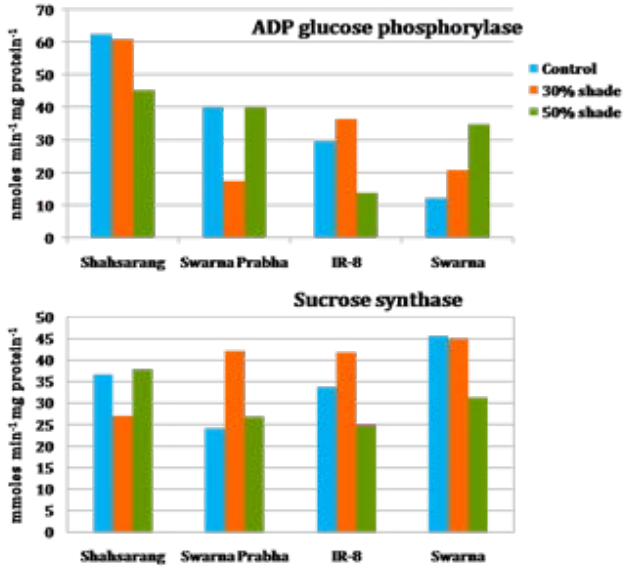


Fig 9. AGPase and Sucrose synthase activity in grains at 30DAA

Evaluation of Maize germplasm

The composite lines developed by the Institute *viz.*, RCM 1 1, RCM 1 2 (popcorn), RCM 1 61, RCM 75 and RCM 76 were evaluated for mean performance and stability. These lines were maintained and their yield potential were evaluated (Table 3). Also a set of maize germplasm maintained by Plant Breeding section was evaluated for yield performance and stability using GGE Biplot (Fig 10). Based on comparison plot analysis, RCMGP 126, RCMGP 114, RCMGP 85, RCMGP 118, RCMGP 120, RCMGP 128 and RCMGP 127 gave higher yield and these lines were also stable throughout different years.

Table 3. Performance of maize composite developed by the Institute

Genotypes	Yield (t/ha)
RCM 1-1	3.7
RCM 1-2 (pop corn)	2.5
RCM 1-3	3.8
RCM 1-61	4.3
RCM 1-75	4.1
RCM 1-76	4.4

Rapeseed and Mustard

Based on the evaluation of 25 yellow sarson germplasm for agro-morphological traits, the genotypes were grouped into three major groups (Fig 11). Cluster I had 9 genotypes whereas cluster II and III had 6 and 10 genotypes, respectively. As far Indian mustard genotypes are concerned, 37 genotypes were grouped into two major clusters. There were 18 genotypes in Cluster I whereas Cluster II had 19 genotypes.

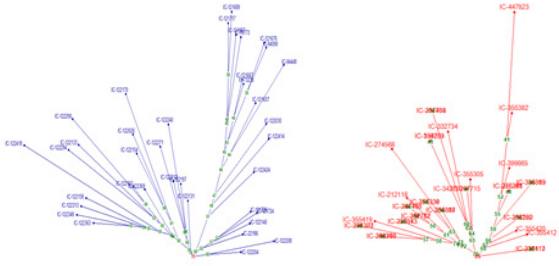


Fig 11. Clustering of yellow sarson (red) and Indian mustard (blue) genotypes

Soybean

Soybean 1 (US1) is a pure selection from a cross PK 1137 x Bragg and was released by the State seed Sub Committee Meeting held at Raj, Bhawan, Shillong on 6th August, 2018 (Figs 12-13). It has a

flowering duration of 68-72 days and yield potential of 2.6-2.9 t/ha. It is an erect type genotype with plant height of 65-75 cm. One genotype RCS 110, a semi-spreading genotype was found to be promising with a yield potential of 2.7-3.1 t/ha. The IVT and AVT1 of AICRP on Soybean were conducted. In IVT, code 14, code 16 and code 28 were found to be promising. The PS 1613 was most performing genotype in AVT1.

Fig 12. Umiam soybean 1

Fig 13. Inspection of AICRP Soybean

Evaluation of shelf life of Perilla (*Perilla frutescens* L.) for viability and medicinal bneenefits

First field trial of forty Perilla genotypes under augmented design was undertaken for the study to select the genotypes for shelf life studies (Fig. 14).

Fig 14. Perilla experimental area

Table 4. Descriptive Statistics of field performance of Perilla genotypes

Parameters	No. Of Obser.	Min	Max	Mean	SD (n)	Var (n)	Kurtosis (Pearson)	Skewness (Pearson)
Height	39	114.4	257.6	199.1	38.37	1472.4	-0.36	-0.76
No of Internodes	39	12.6	22	17.52	2.25	5.06	-0.24	-0.02
No of Branches	39	15.6	28.6	22.38	3.14	9.87	-0.38	-0.07
Length of largest Inflorescence	39	4.8	18.6	8.89	3.16	9.96	0.92	1.05
No. of Inflorescence plt^{-1}	39	52.8	270.8	140.0	64.1	4108.3	-0.74	0.65
No of florets in largest inflorescence	39	36.8	88.8	60.88	14.07	197.9	-0.77	0.40
Yield plt^{-1}	39	1.534	24.22	10.11	5.62	31.60	0.14	0.71
1000 SW	39	0.902	2.34	1.66	0.34	0.11	-0.36	-0.12
Fibre %	36	13.5	35.25	22.85	4.30	18.47	1.61	-0.01
Fat %	37	30.29	53.5	41.08	5.00	24.97	0.18	0.40

Based on the field and proximate data, the perilla genotypes highlighted for shelf life studies include PR-MN-6, PR-MN-7, PR-MN-11, PR-SK-12, PR-AR-1, PR-AR-2, and PR-NL-5

HORTICULTURE

Guava

Four guava varieties *viz.*, Megha Supreme; Megha Magenta; Megha Wonder and Megha Seedless (Fig. 15-18) developed by Division of Horticulture, ICAR Research Complex for NEH Region, Umiam, Meghalaya have been recommended for release by the Meghalaya Seed Sub-Committee for Agricultural and Horticultural Crops on 1st October, 2018 in Raj Bhawan, Shillong.

Fig 15. Megha Supreme

Fig 16. Megha Magenta

Fig 17. Megha Wonder

Fig 18. Megha Seedless

Citrus

DUS guidelines for lemon *(Citrus limon* (*L*) Burm)

Lemon varieties *viz.*, Assam lemon, Jaintia lemon, Kachai lemon and Elichai lemon were selected from the north eastern region for developing Distinctive Uniformity and Stability (DUS) guidelines. The pomological traits were assessed, in which Jaintia lemon showed upright growth habit while Assam lemon has drooping growth habit. The leaf anthocyanin content was absent in Jaintia lemon while present in Assam lemon, Kachai lemon and Elichai lemon. The shape of leaf apex was obtuse in Jaintia lemon while acuminate in others. The leaf length varied from 9.0 to 14.20 cm and leaf width varied from 5.0 to 7.2 cm. The no. of spines (30 cm shoot length) varied from 6 to 13.2 nos. Fruit shape varied from spheroid to ellipsoid. The fruit weight ranged from 78.50 to 170 g; fruit length and fruit diameter ranged from 5.80 to 10.2 cm and 5.0 to 6.2 cm, respectively. No. of seeds ranged from 0.00 to 38 nos. The juice content varied from 24.10 % to 40.1%; TSS ranged from 6.0^0 B to 7.5^0 B and titratable acidity ranged from 4.30% to 6.10%.

Evaluation of different rootstocks of Khasi Mandarin in different altitudes

Seedlings of different rootstocks viz., Rangpur Lime, Karna Khatta, Trifoliate orange, Rough Lemon, *C. latipes*, *C. taiwanica* and *C. volcameriana* were raised, wedged grafted with scion of Khasi mandarin. Maximum graft success (94.5%) was recorded with *C. jambhiri.*

Influence of altitude on leaf nutrients content of declined Khasi Mandarin orchards

A regression study on altitude and leaf nutrient contents of declined Khasi Mandarin orchards showed a decrease in nutrient content in higher altitude; while it was contradictory for Fe, Mn and Cu content which was increased with elevation of declined orchards (Fig. 19).

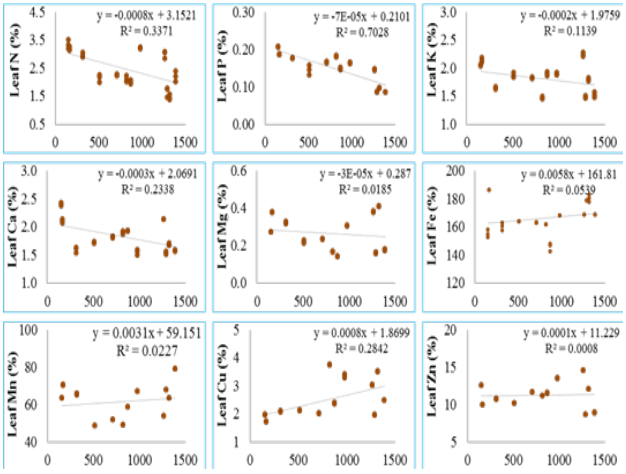


Fig 19. Regression study on altitude and leaf nutrient contents of declined Khasi Mandarin orchards

Jackfruit

DUS guidelines of jackfruit

For DUS guidelines of jackfruit (*Artocarpus heterophyllus*), qualitative and quantitative characters were studied. Variations were observed in tree crown shape (pyramidal, broadly pyramidal, spherical, oblong, semicircular, elliptical to irregular), branching pattern (erect, opposite, verticillate, horizontal to irregular), leaf posture (flattened, upper surface cup shaped, revolute to conduplicate), fruit shape (obloid, spheroid, ellipsoid, clavate, oblong, cordate to irregular), stalk attachment to fruit (depressed, flattened to inflated), fruit surface (smooth, moderate, spiny to very spiny), spine density (sparse, medium to dense), latex exudation (low, medium to high), flake texture (soft, firm, coarse, fibrous to melting), seed shape (spheroid, ellipsoid, elongate, oblong, reniform to irregular) and seed surface pattern (uniform, regular striations to patchy). The leaf length ranged from 7.30 to 38.93 cm, leaf blade ratio from 0.81 to 2.50 and petiole length varied from 1.05 to 6.08 cm. Weight of the fruit and spine density (5x5 sq.cm area) ranged from 0.29 to 39.49 kg and 21 to 660 nos. respectively. Flake length varied from 2.90 to 8.10 cm, TSS of the flakes from 6.6 to 32.9°Brix and total number of flakes per kilogram of fruit ranged from 1.37 to 45.74.

Fig 20. Fruit shape and flake variability in jackfruit

Fig 21. Variability in shape of jackfruit leaf apex

Peach

Two low chilling peach cv. Partap and Flordaprince were evaluated at different training system and densities *viz.*, espalier system: 3.0 m x 2.0 m; tatura trellis system (Y-Shape): 2.0 m x 5.0 m; central leader system (4 scaffold branches): 3.0 m x 3.0 m and open centre system: 3.5m x 3.5m (Fig. 22). At 3rd year cv. Partap recorded higher plant height (1.52 m), canopy volume (1.15m^3), Trunk Cross Section Area (2.71 cm^2), scion girth (1.80 cm) and rootstock girth (1.92 cm) than Flordaprince. In training systems, peaches trained on Y shape trellis recorded the highest plant height (1.80 m), canopy volume (2.30 m^3), Trunk Cross Section Area (4.93 cm^2), scion girth (2.46 cm) and rootstock girth (2.58cm) and found significantly superior over espalier, open centre and central leader systems. Interaction effect (V x T) was found non-significant for the growth attributes at Umiam, Meghalaya.

A. Espalier system

B. Tatura trellis

C. Central leader

D. Open centre

Fig 22. Evaluation of low chilling peach under different training systems

Dolichos bean

Among 135 accessions collected from different states of North Eastern states of India. Wider variability was observed for all the traits; leaf length ranged from 9.30 to 21.30 cm, pod weight (4.80-21.36 g), no of seeds per pod (3.0-8.0), yield per hill (257.0-2685 g), protein content (15.57-36.75 mg/100g), vitamin-C (20.16-51.84 mg/100g), and anthocyanin content (0.12-1.24 mg/100g).

Genotypic coefficient of variation contributed significantly towards phenotypic characters. High heritability and genetic advance as percent of mean was observed for the traits like pod length (92.5 and 56.12), pod weight (85.84 and 67.51), yield per hill (86.63 and 86.97), protein (94.00 and 40.57) and anthocyanin contents (76.0 and 47.07), respectively. The results of principal component analysis (PCA) revealed that the first seven PCA contributes over 70% of total variance with Eigen value over 1. Important characters with greater weights in PCA-I were yield per hill, pod weight, pod width and pod length while the variation in PCA-II was contributed by chlorophyll a, b and pod length.

Among the accessions, high yielding genotypes were ASDBC-16 (2.68 kg/hill) and TRDBC-11(2.02 kg/hill). Some unique genotypes were identified as TRDBC-9 (21.30 cm) for high pod length and MZDBC-22 for higher anthocyanin content (1.23 mg/100g); while Selection-1 was high yielding, photo-insensitive bush type. These high yielding and unique lines can be used for the commercial production and further breeding programme to increase yield as well as nutritional security of the population.

Evaluation of local teasel gourd

Total 49 female accessions of teasel gourd (*Momordica subangulata* ssp. *renigera*) were evaluated for yield and quality attributes. Wide variability was observed for yield and quality attributes. The peduncle length ranged from 5.8 to 25.0 cm, average fruit weight from 37.5-128.6 g and yield from 0.15- 1.99 kg/plant. The high yielding accessions were RCSG-32 (1.9 kg /plant) followed by RCSG-40 (1.6 kg/plant). Harvesting between 12 - 16 days after fruit set was found to be optimum. Phenol and antioxidant ranged from 62.7-190.6 mg/100g GAE and 61.7-64.8 mg AEAC/100g, respectively.

Further, molecular characterization was also carried out using 43 SSR markers. Among the markers, maximum number of alleles (4) were observed in markers A-4 (325-355bp), C-30 (225-255bp) and McSSR-5 (240-265bp), respectively. However, three markers (McSSR-14, McSSR-18 and Sed-11) were found to be monomorphic.

Evaluation of chow-chow germplasm

Out of 52 accessions, the highest fruit weight was observed in dark green fruit genotype from Mizoram Collection-2 (750 g) followed by RCSC-44 (660 g). However, the maximum yield per plant was recorded from RCSC-44 (19.0 kg) followed by RCSC-16 (17.2 kg) and Mizoram Collection-2 (17.0 kg). Ideal stage of fruit harvesting ranged from 18 to 22 days after fruit set. Dark genotype was superior with maximum antioxidant (85 mg AEAC/100 g) content while pale yellow had maximum total phenolic (6.14 mg GAE/100 g) and flavonoid (32.26 mg CE/100 gm) contents.

Fig 23. Variability in fruit colour of chow chow

Garden pea

Garden pea (*Pisum sativum* var. *hortense* L.) varieties *viz.,* Vivek Matar-11 and Vivek Matar-12 were evaluated during *rabi* season. The tallest plant (99.74 cm) Vivek Matar-12 produced early flowers (in 89.8 days), early flowering (89.83 days), maximum number of pods per plant (16.67), number of seeds per pod (7.33) and pod yield (9.63 t/ha). The same treatment combination also recorded second highest B: C ratio in both the evaluated varieties.

AICRP on Vegetable Crops

French bean germplasm evaluation: Out of 75 pole type accessions, the maximum pod length was recorded in MZFB-45 (20.0 cm) followed by MZFB-52, MZFB-43 (16.0 cm each), respectively. However, maximum yield per plant was observed in MZFB-47 (317 g) followed by RCFB-19 (305 g), MNFB-7 (267 g) and RCMFB-1A (260 g) , respectively. Similarly, among the pole type accessions, the highest yield per plant was observed in RCBFBC-3 (114 g).

Varietal/Hybrid trials: Under advance varietal trial of tomato (AVT-II), highest yield was recorded in 2015/TOINDVAR-6 (347.0 q/ha) closely followed by 2015/TOINDVAR-5 (345 q/ha). In cherry tomato, the highest yield was recorded in 2015/TOCVAR-5 (422 q/ha) followed by 2015/TOCVAR-3 (406.9 q/ha). In brinjal round segment, the highest yield was observed in 2015/BRRVAR-2 (284.5 q/ha) followed by 2015/BRRVAR-4 (271.0 q/ha) while in brinjal long the highest yield accession was 2015/BRLVAR-3 (263.2 q/ha). Further, in cabbage hybrid, the highest yield was observed in 2015/CABHYB-1 (565 q/ha) followed by 2015/CABHYB-5 (467 q/ha).

Resistant trials: A field experiment of brinjal against bacterial wilt was conducted during 2018 under natural condition. The per cent wilting ranged from 8.77%-33.45%. Among the accessions the highest yield (426 q/ha) and lowest wilting (8.77%) was recorded in 2016/BRBWRES-2 while, accession 2016/BRBWRES-3 was susceptible to bacterial wilt.

Fig 24. Performance French bean at farmers field

AICRP on Tuber Crops

Sweet potato : Six sweet potato entries supplied by ICAR-CTCRI, Thiruvananthapuram, were evaluated for yield and other parameters. The variety TSp12-12 recorded the highest marketable yield (10.03 t/ha) as well as the highest total yield (15.53 t/ha). Dry matter content was found highest in TSp12-10 (30.47 %) whereas starch and sugar were

found highest in Sree Bhadra and Tsp12-9 (19.52% and 3.95%), respectively. Evaluation of another 32 collections of sweet potato for yield and yield attributing parameters revealed that collection-3 had the highest total yield (24.47 t/ha) and tuber diameter (6.37 cm) whereas, Mizo Collection 2, recorded the maximum tuber length (16.18 cm). Average tuber weight was found highest in Selection -1 (183.44 g).

Colocasia : Six entries were evaluated for their yield parameters *viz.* number of cormels per plant, weight of corm and cormels per plant, cormel yield (t/ha), total yield (t/ha), as well as corm and cormel shape. Quality parameters such as calcium oxalate, tolerance to leaf blight, keeping and cooking quality were also recorded. Muktakeshi recorded the maximum number of cormels (21.33) and weight of cormels per plant (933.33g). Cormel yield (11.65 t/ha) and total yield (15.11 t/ha) were also found highest in Muktakeshi. After analysis, lowest calcium oxalate (0.15%) was observed in Megha Taro-1.

Similarly, 6 nos. entries of Bunda type were evaluated, TBd17-7 recorded the highest corm weight /plant (616.67g) and total yield (13.55 t/ha) whereas TBd 17-8 recorded lowest calcium oxalate (0.19%) with good acceptability for corm as well as petiole consumption.

Sohphlang: Survey was conducted in different parts of Meghalaya to find the variability in shape of Sohphlang (*Flemingia vestita*) tubers like cylindrical, fusiform, napiform, round and oval. Size of tubers ranged from 2.5-8.6 cm in length, 1.5-3.0 cm in width and 5 - 40 g in weight.

Fig 25. *Flemingia vestita* tubers sold in market

Spices

Character Association and path analysis in King Chilli

A total of 15 genotypes of King Chilli (*Capsicum chinense* Jacq.) were evaluated to study the phenotypic correlations between ten major horticultural traits and its consequences in direct and indirect effects on yield by path analysis. The results indicated that the correlation of fruit yield per plant with number of fruits per plant (0.69), days to 50% flowering (0.51) and plant height (0.47) were positive and significant. The number of fruits per plant (0.74) and days to 50% flowering (0.56) also exhibited direct effect on fruit yield per plant.

AICRP on Spices

Organic production of Turmeric: Three (3) genotypes of turmeric viz. Megha Turmeric-1, Rajendra Sonia and Prathiba were evaluated. Recommended Package (NPK 120:90:90 kg/ha) produced higher yield of 39.40 t/ha and 34.79 t/ha in Megha Turmeric-1 and Prathiba, respectively. While higher yield of 30.72 t/ha was obtained in Rajendra Sonia with the organic package developed by IISR (Seed rhizome treatment with GRB-35 @ 1 capsule/100 litre water + FYM @ 25-30 t/ha + Vermicompost @ 2 t/ha/Ash 0.5 t/ha + IISR micronutrient booster @ 5 g/l water 3-5 kg/ha). The organic package developed by IISR gave the second highest yield in Megha Turmeric-1 (31.60 t/ha) and Pratibha (24.21t/ha). The dry recovery percentage was higher under organic package developed by IISR in all the three varieties.

Organic production of ginger: Three (3) genotypes of ginger viz. Jorhat, Suprabha and Hiching were evaluated under the present study. Maximum yield of 29.92 t/ha (Hiching), 29.54 t/ha (Suprabha) and 23.58 t/ha (Jorhat) were recorded with recommended package (NPK 100:90:90 kg/ha). The second highest yield of 14.09 t/ha, 15.32 t/ha and 14.97 t/ha were obtained with the organic package developed by IISR (Seed rhizome treatment with GRB-35 @ 1 capsule/100 litre water + FYM @ 25-30 t/ha + Vermicompost @ 2 t/ha/Ash 0.5 t/ha + IISR micronutrient booster @ 5 g/l water 3-5 kg/ha) in Johrat, Suprabha and Hiching, respectively. Organic package developed by IISR showed lower fibre content and higher oleoresin content in all the three varieties.

Effect of micronutrients on growth and yield of Ginger: Three (3) genotypes of ginger viz. Hiching, Himgiri and Nadia were evaluated under the present study. Application of recommended package of practice (NPK 100:90:90 kg/ha**)** along with IISR micronutrients @ 5g/l at 60 and 90 days after planting produced higher yield of 36.78 t/ha, 22.68 t/ha and 30.51 t/ha in Hiching, Himgiri and Nadia, respectively. Higher oleoresin content in Hiching (4.04%), Himgiri (4.17%) and Nadia (4.35%) were also recorded under recommended package of practice +IISR micronutrients (5g/lit).

Effect of biocapsule on growth and yield of Ginger: Experiment was conducted with three genotypes viz. Himgiri, Nadia and Hitching. For Himgiri and Nadia, the highest yield was recorded with application of POP + *Trichoderma* capsule + GRB 35 capsule (32.87 t/ha and 30.01 t/ha, respectively). Higher oleoresin content in Himgiri (4.16%), Nadia (4.38%) and Hitching (4.10%) was also recorded with POP + *Trichoderma* capsule + GRB 35 capsule.

Flowers

Collection, characterization, evaluation and maintenance of Orchid germplasm

A total of thirty-three orchid species were collected, evaluated and characterized for vegetative and flowering characters. Twenty two species out of 33 have started flowering. Regarding vegetative characters, plant height ranged from 18.67 cm (in *Paphiopedillum fairrieanum)* to 148.68 cm in *Phaius tankervilleae,* plant spread from 19.48 cm in *Vanda parasii* to 107.83 cm in *Phaius tankervilleae*). Maximum pseudobulb size (length, 27.73 cm in *Dendrobium nobile* and width, 2.57 cm in *Dendrobium densiforum*), leaf size in *Phaius tankervilleae* (length, 112.86 cm and width, 15.42 cm) and number of leaves in *Coelogyne flaccid* (97.73 leaves/plant) were observed. Inflorescence length was maximum in *Cymbidium aloifolium* (43.64 cm) and minimum in *Pleione pracox* (1.75 cm). Number of flowers was highest in *Aerides multiflorum* (94.28/ inflorescence) and minimum in *Paphiopedilum spicearianum* (1.00/ inflorescence). *Cymbidium* hybrids recorded the maximum flower diameter (9.42 cm) and flower length (5.84 cm), while minimum flower diameter (0.63 cm) and length (0.62 cm) were recorded in *Pleione pracox*.

Evaluation of promising gerbera hybrids under open field conditions

Four promising hybrids of gerbera RCGH-12, RCGH-22, RCGH-114 and RCGH-117 (Fig. 26) developed by the Division of Horticulture were evaluated. Result showed that RCGH-114 recorded maximum flower stalk length (53.47 cm), while RCGH-117 recorded the highest flower stalk diameter (5.36 mm), flower diameter (11.08 cm), number of ray floret/ head (170.56). RCGH-22 showed maximum number of flowers/ Plant (23.52/ year) and longest vase life (5.62 days) in RCGH-117.

A. RCGH-12 **B. RCGH-22**

C. RCGH-114 **D. RCGH-117**

Fig 26. Promising hybrids of gerbera

Evaluation of gerbera germplasm

Thirty three gerbera genotypes were evaluated for growth and flowering traits in open cultivation. Regarding vegetative characters, RCGH-23 recorded maximum no. of leave per plant (123.84). RCGH-7 had the longest leaf length (26.48 cm). Plant spread (41.48 cm) was highest in RCGH-33. Highest no. of suckers per plant per year was recorded in RCGH-97 (17.61). Regarding flowering characteristics, maximum days to bud burst was recorded in RCGH-32 (18.28), maximum days to first flower opening in RCGH-172 (27.53), maximum flower stalk length (43.54 cm) and flower stalk diameter (6.19 mm) in RCGH-33. RCGH-3 produced highest number of flowers/plant/year (27.37). Among 33 gerbera genotypes, RCGH-28 was identified as miniature gerbera suitable for growing in pot and indoor plant

with stalk length (26.28 cm); flower diameter (9.02 cm); number of 7.72 nos. flowers per plant per month and vase life (6.24 days). In another experiment, 15 varieties of exotic gerbera were evaluated under low cost polyhouse for growth and flowering traits and Alesmera was found to perform better.

CROP PROTECTION

Entomology

Eco-friendly management of fruit flies in squash

Different bio-intensive modules were evaluated (repeated trial) involving botanical pesticides and entomopathogens during fruiting season in squash. The Module consisting of two sprays at 15 days interval of mixture of bio-pesticides *viz.*, Anonin 1EC and Azadirachtin 0.03EC @ 1ml each /liter of water along with mass trapping by using lure traps @ 15/ ha and and soil incorporation of *M. anisopliae* ($1x10^8$ cfu/gm) @ 4 kg/ha was found reducing 68.33% fruit fly damage in squash.

New fruit fly species records in Brinjal and Cucurbit

Invasive solanum fruit fly, *Bactrocera latifrons* was found damaging brinjal fruits in the experimental farm of ICAR-RC for NEH at Umiam. Similarly, fruit fly, *Bactrocera* (*Parasinodacus*) *cilifera* was recorded for the first time infesting cucurbit crops in Meghalaya. Basic biological attributes of both species were studied on respective host crops and these two newly reported species were characterized at molecular level to facilitate its rapid and reliable identification.

Bioefficacy of indigenous plant extracts and essential oils against important defoliators of cruciferus crops

Extracts from different plants *viz.*, *Vitex negundo*, *Curcuma angustifolia*, *Parkia roxburghii* and *Fleminga vestita* and essential oils *viz.*, *Cymbopogon citratus*, *Piper nigrum*, *Mentha piperita*, *Occimum basilicum* and *Rosmarinus officinalis* were tested for their bioefficacy against three important defoliators of cruciferious crops. In topical application technique, LC_{50} value of *O. basilicum* was observed to be 0.09 % and *V. negundo* 1.99 %, against the caterpillars of *S. litura* at 72 hrs; whereas it was 0.28 % and 1.59 % on *P. xylostella*, respectively. In case of *P. brassicae*, LC_{50} of *Piper nigrum* oil and *V. negundo* extract was observed to be 0.02 % and 0.71 %, respectively. When the caterpillars of *S. litura, P. brassicae* and *P. xylostella* were exposed to sub-lethal doses, the significant variation was observed in larval and pupal weight, their duration, per cent pupation and adult emergence. Overall results revealed that, n-hexane fraction of *Vitex negundo* and essential oils of *Ocimum basilicum* and *Piper nigrum* are most effective against major cruciferous defoliators.

Management of cabbage butterfly (*Pieris brassicae*) in cabbage

Three insecticides *viz.* indoxacarb 14.5SC (75 and 150 g a.i./ha), chlorfenapyr 10SC (100 and 200 g a.i./ha) and chlorpyrifos 20EC (200 and 400 g a.i./ ha) were evaluated against cabbage butterfly, *Pieris brassicae* on cabbage. Two sprays were done at 15 days intervals. All the treatments were found significantly superior over untreated control in reducing the larval population. Among the insecticides, indoxacarb was the best to provide maximum protection (>80% reduction of larval population) with highest yield. Indoxacarb also exhibited less toxicity towards spider and coccinellids beetles.

Method standardization and dissipation pattern of novaluron and chlorantraniliprole in tomato

The methods for determination of dissipation pattern of novaluron and chlorantraniliprole residues in tomato and soil were standardized in high performance liquid chromatography (HPLC) with UV detector. The analytes were extracted from tomato and soil samples with acetonitrile following modified QuEChERS method. Novaluron was detected at 7.10 ± 0.02 min under the following optimum HPLC conditions: combination of acetonitrile:water ratio was 75:25, flow rate: 1 mL/min, wave length: 230 nm whereas chlorantraniliprole was detected at 4.01±0.02 min with HPLC condition of acetonitrile/ water ratio - 80:20, flow rate: 0.8 mL/min, wave length: 260 nm. Recovery of both insecticides was more than 80% with these methods. Most of the residues were dissipated within 7 days of application.

Insect pests of cucurbit crops in Meghalaya

Insect pests damaging cucurbit crops studied in Meghalaya. Red pumpkin beetle, Epilachna beetle, fruit flies, Blister beetles, cucurbit longicorn beetle and few minor pests were found attacking cucurbits

in Meghalaya. Among, red pumpkin beetle and fruit fly damage was relatively higher on both the crops. Red pumpkin beetle attacked at early stage causing severe damage on leaf and indirectly hampered the growth of the crops while fruit flies infestation started with initiation of fruit and damaged more than 30 % marketable fruits on both the crops.

Biological attributes of fruit fly and its field parasitism on different varieties of guava fruits

Biological attributes mainly number of maggots/fruit, weight of puparia (mg) and their natural field parasitism (%) were studied on eight different varieties. Significant differences were found in maggot density ($F=53.86$, $p<0.01$), weight of puparia ($F=2.76$, $p=0.02$) and its field parasitism ($F=16.46$, $p<0.01$). Number of maggots per fruits were significantly higher in guava variety Allahabad Safeda (29.20); while weight of puparia and natural field parasitism were maximum in variety RCGH-7 (12.15g and 18.29%, respectively).

Seasonal incidence of insect pests of Colocassia

The chyrsomelid beetle (*Aplosonyx chalybaeus*), leaf folder, mealybug, aphids and white grub, leaf eating caterpillars were recorded as pests of Colocassia. The incidence of chyrsomelid beetles were observed from last week of May. Damage due to oviposition punctures resulted in secretion of exudates and rotting of the affected portions (stems) near the soil. The grubs on hatching feed on the stem tunneling and burrowing downwards inside the corms resulting in numerous holes and tunnels which ultimately decayed. The adults were found feeding on the leaves of Colocasia resulting in circular holes of about 5-6 cm in diameter. Another major insect of Colocasia was leaf folder. The incidence of leaf folder started from last week of June with 2-3 folded leaves/m^2. Several plants were found to be infested with leaf folder. The caterpillars folded the leaves longitudinally and ate the leaves from inside. Masses of excreta and caterpillar could be seen on unfolding the leaves thus leading to economic loss.

Bio-rational management of major pests of ginger

Different botanical pesticides and entomopathogens were evaluated against major pests of ginger in Meghalaya. Significant reduction in pest damage was observed in ginger crop applied with bio-intensive module consisting of "rhizome treatment of *Lecanicillium lecanii* (10^8 spores/ml) @ 10 ml/litre water for 1 hour before planting OR soil application of *Lecanicillium lecani* (1×10^8 cfu/gm) @ 5 kg/ha during earthing up in the month of June followed by foliar spray of Azadirachtin (neem oil based) 0.03 EC @ 5 ml/litre water during July and August and Soil application of *Metarhizium anisopliae* ($1x10^8$ cfu/gm) @ 5 kg/ha during August".

Assessment of effects of biopesticides on honeybee, *Apis cerana* in mustard

Potential impacts of widely used biopesticides was assessed against foraging bees, *Apis cerana* in Mustard (Fig. 1). In laboratory studies, $LC_{50's}$ of pesticides to the honey bee was in the order of *Beauveria bassiana* 1.5L (4.79%) > *Bacillus thuriengiensis* 8SP (1.67%) > Azadirachtin 0.03 EC (1.64%) > Annonin 1EC (1.22%) > Spinosad 2.5 SC (0.006%) > Imidacloprid 17.8SL (0.005%). Based on three essential risk assessment criteria's, the Azadirachtin, Anonnin, *B. bassiana* and *Bt* var. *k* were found slightly to moderately toxic to the honeybee; whereas Spinosad and Imidacloprid were found dangerous to the bees. Entomopathogenic fungus, *Nomuraea rileyi* was found absolutely harmless to the bees. In field studies, the relative abundance, foraging rate and speed of honey bees were significantly affected in different treatments and the effect was strongly observed in Annonin and Spinosad treatments. Significantly higher yield was obtained in Azadirachtin (1.43 t/ha) and Anonin (1.22 t/ha) treated plots.

Monitoring, detection and management of invasive and potentially dangerous pests in northeast India.

Regular surveys were undertaken in different parts of the NEH region and detected some invasive/potentially destructive pests for the first time in north east India viz., Soft scale, *Platylecanium* spp. in wild date palm; South American pinworm, *Tuta absoluta* on potato; Hypogeic mealybug, *Formicococcus polysperes* on Taro etc. Few potentially dangerous pests observed from periodic survey were charectorized at molecular level such as pine lappet moth, *Dendrolimus houi* (Fig 27), Tomato pinworm, *Tuta absoluta*; Vegetable leaf miner, *Liriomyza sativae*, and Paddy armyworm, *Mythimna separata* (Fig 28) in Meghalaya and necessary advisories were

issued to the farmers and state government offices thorugh institute website and different advisory services. Golden dust weevil, *Hypomeces squamosus* (Fig 29) has sporadically appeared in large numbers in different parts of the Assam, Nagaland and found causing significant damage to the Mango, Citrus, Guava, Assam lemmon and many other important crops in the region.

Fig 27. *Dendrolimus houi*

Fig 28. *Mythimna separata*

Fig 29. *Hypomeces squamosus*

Plant Pathology

Concurrence of complex diseases associated with leaf spot (*S. cucurbitacearum*) wilt (*Fusarium striatum*), twig and shoot blight (*Nigrospora sphaerica*) and powdery mildew (*Podosphaera xanthii*) of Bottle gourd in North-East India

Quadri-concurrence of serious complex diseases of bottle gourd *(Lagenaria siceraria*) like gummy stem blight, (*Stagonosporopsis cucurbitacearum* (syn. *Didymella bryoniae*), wilt (*Fusarium striatum*), twig and shoot blight (*Nigrospora sphaerica*) and powdery mildew, *Podosphaera xanthi* in the North eastern region, India. The severity and incidence of leaf spot, wilt, twig and shoot blight and powdery mildew were recorded, 97.32, 83.45, 45.03 and 35.75%, respectively at Entomology Farm, ICAR RC NEH Region, Meghalaya. Typical symptoms of gummy stem blight (*S. cucurbitacearum* included initially small yellow spot and dark brown to black patches gradually covering entirely the whole leaves and blighted (Fig 30). On stem, observed black small spot later on enlarge and infected stem dried up. On the other hand, the symptom of wilt (*F. striatum*) were water soaked lesion at crown region, stem pitting and exudation of gum from infected stems. Pathogenicity test and aggressiveness of *S. cucurbitacearum* and *F. straitum*. in bottle gourd isolated from the Entomology Experimental Farm was tested. *Stagonosporopsis cucurbitacearum* was the most aggressive had lesions of 7.12 to 9.2 cm2 after 7 days of inoculation and differed significantly from the control. To further confirm the identity, genomic DNA was extracted from the isolates using a DNA Gel Extraction Kit. The internal transcribed spacer (ITS) region of the ribosomal DNA was amplified using universal ITS4 and ITS6 primers followed by the sequencing of the PCR products. The ITS sequences showed 99% homology with that of *S. cucurbitacearum*, *F. striatum*, and *N. sphaerica*. The respective species were re-isolated from the diseased tissues, fulfilling Koch's postulates. Future research will be focused primarily on the management of this disease.

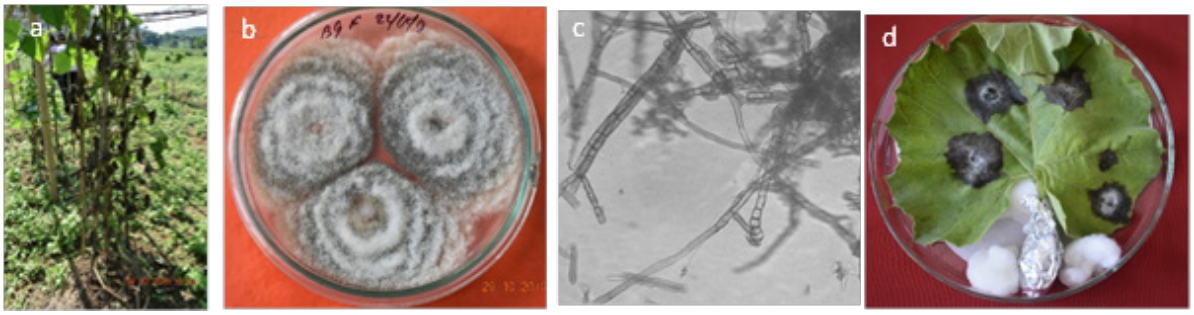


Fig 30. Severely infected bottle gourd plant by leaf spot, *Stagonosporopsis cucurbitacearum*, b) pure culture of *S. cucurbitacearum* , c) typical mycelia characteristics of *S. cucurbitacearum* and d) symptoms of leaf spot (*S. cucurbitacearum)* after 7 days of inoculation

Screening of Maize lines for Turcicum leaf blight

Total 15 lines of AVT-I-II (medium maturity maize hybrids) were evaluated against Turcicum leaf blight at Umiam (Barapani). IMHBG-17K-15 and INDAM 1122 were found to be resistant, DKC7173, LMH 1016, NMH- 4053 were found to be moderately resistant.

Exploration and utilization of hyperparasites (of plant pathogens) and entomopathogens in Meghalaya

Entomopathogen *Pandora formicae* on ant (*Camponotus angusticollis*) has been reported for the first time from India. Pandora type hyphal bodies were present on the cadaver, further microscopic examination revealed it to be *Pandora formicae* (Fig 31 & 32). Survey has been conducted for exploration of hyperparasites and entomopathogens. Entomopathogens of few other aphids have also been identified and are being tested for their efficacy. Few *Ampelomyces* sp. have been detected on powdery mildew pathogens.

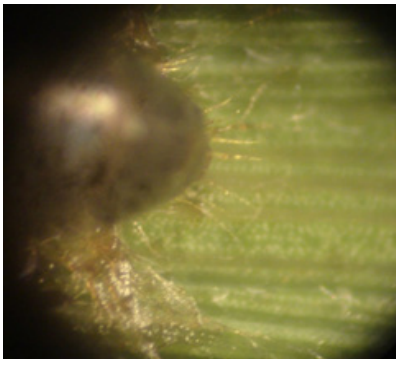


Fig 31. Prominent rhizoids through which the cadaver is attached to leaf

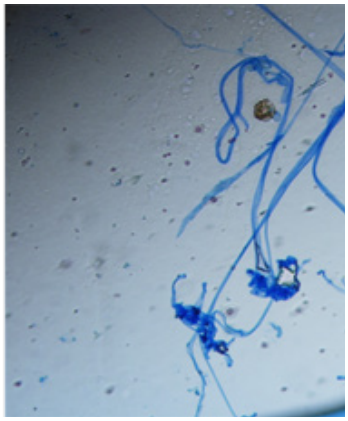


Fig.32. Rhizoids of *Pandora formicae*

AICRP on Mushroom

Many strains were evaluated for disease and pest resistance. Various extension activities in the form of trainings, demonstrations and field days were also conducted for popularization of mushroom cultivation in this region, spawn was also supplied to farmers and entrepreneurs. Total 12 trainings and 7 demonstrations/field days/ lectures were conducted in which total 469 participants were benefited. Twenty two strains of *Pleurotus* sp. were evaluated against competitor moulds, hyperparasites and insect pests in low cost mushroom house at Umiam (Plant Pathology). Spawning was done on 12.07.18 and 14.07.18. Observations revealed that out of 22, eight strains were heavily infested by competitor mould (*Coprinopsis* sp.) and most of the strains were also infested by insect pests. Only few strains PL-16-04 (av. BE 31.8%), PL-17-07 (av. BE 30%), PL-16-01 (av. BE 25.6%) and Pl-17-03 (av. BE 26.8%) were found to be promising since in these cases infestation by competitor moulds and insect pests was very less and yield was good. In few strains like PL-17-12 (av. BE 28.8%) yield was good but infestation by competitor moulds and insect pests was very high.

FARMING SYSTEM RESEARCH

Farming System Research Project

Micro watersheds comprising Dairy based land use (FSW-1), Mixed forestry (FSW-2), Silvi-pastoral land use (FSW-3), Agro-pastoral system (FSW-4), Agri-horti-silvi-pastoral (FSW-5), Silvi-horticultural system (FSW-6), Natural forest block (FSW-7) and Timber-based farming system (FSW-8) were evaluated on long term basis at ICAR Research Complex for NEH Region, Umiam, Meghalaya.

Dairy based farming system (FSW-1)

Dairy based farming system was evaluated on a micro watershed of 1.39 ha area including 0.45 ha of forest land. The area under planned land use was 0.94 ha of which 0.447 ha terrace area was used annual fodder crops and the remaining area was under broom and guinea grass production. Three milch cows along with their calves were maintained in 0.50 ha area. An analysis of fodder production and requirement revealed that total green fodder from forage crops and slopping land was 34.98 t, while the requirement for dairy animals was 32.29 t, resulting in a surplus of 2.69 t annually. The feed concentrate,

paddy straw and medicine were arranged from nearby market with a expanse of Rs. 1 20769/-. The milk yield obtained from the system was 4816 liters amounting to Rs.153216/-. The net annual income from the system was estimated as Rs. 65387/-.

Mixed Forest Block (FSW-2)

Mixed forest block was established in 3.89 ha area, where 3.05 ha area was divided under natural forest and 0.84 ha area under planned land use. The average slope of the micro-watershed was 38%. The area under micro watershed was utilized for plantation of forest tree species viz. *Acacia auriculi formis*, *Michelia oblonga* and *Symingtonia populnea* for timber and fuel purpose. The growth and development attributes of tree species were recorded during 2017-18. The circumference at base and breast height was maximum in *Acacia auriculiformis* (1.23 m and 1 m) followed by *Symingtonia populnea* (1.18 m and 0.81 m) and *Michelia oblonga* (0.84 m and 0.60 m), respectively.

Silvi-pastoral system (FSW-3)

Silvi-pastoral system was established on 2.94 ha area of forest land of which 2.05 ha was under planned land use. The average slope of the area was 32.18%. Forty one goats (6 males, 35 females) were maintained in this system by demarcating 0.5 ha area in the system. The system was not generating profit and hence, poultry (500 no. broilers) chicks were also integrated in three cycles on the dyke of fish pond (500 m^2 area) as a subsidiary source of income. Besides broiler poultry, the system produced 91 kg fish and thus, resulted in a net profit of Rs. 26320. The gross income from this system was Rs. 137820 with input cost of Rs. 111500 on feed, concentrate and procurement for day old chicks. The lower half portion of the watershed was planted with fodder trees species comprising *Symingtonia populnea*, *Bauhinia purpurea*, *Ficus*spp, *Indigofera indica* and wild cherry to provide green leaf fodder to the goats during lean period. Mixed perennial grasses had been planted between the fodder trees to conserve soil and water and to provide supplementary source of fodder for grazing.

Agro –pastoral system (FSW-4)

Agro-pastoral system was established in 0.64 ha area in a sloppy land (32.42 %). The hill slope has forest land of 0.06 ha and a planned land used area of 0.58 ha. About 75 % of the total area was utilized with 200 % cropping intensity (Fig. 33). The system produced 4.83 t of rice equivalent yield (REY) excluding guinea grass. An integrated approach with crops and livestock showed that maximum income was obtained from cow milk (Rs.181906).This system could generate 233 man-days employment amounting to Rs. 70599 adding the cost of other inputs amounting to Rs. 139462. The gross and net income of Rs. 251108 and Rs. 111646 was obtained, respectively giving an input–output ratio 1.22. Production of guinea grass on terrace risers in the lower and middle parts of the watershed and broom on the top portion of the watershed provided green fodder, sufficient enough to support 8 months the dairy unit without any extra input/ management cost.

Fig 33.Vertical cropping of turmeric and bottle gourd in terraces

Agri-horti-silvi-pastoral system (FSW-5)

Agri-horti-silvi-pastoral system was developed in 1.58 ha area as an initiative for jhum improvement programme. Nearly 0.55 ha was under forest while 1.03 ha under planned land use (Fig. 34). The system was standardized in 0.80 ha area. In this system, 0.10 ha of foothills was used for agricultural use, 0.25 ha for horticulture and 0.44 ha for silvi-pastoral crops, respectively. The Agri-horti-silvi-pastoral system produced 6.64 t REY. The highest REY of 3.01 t was estimated with cow milk followed by Capsicum-French bean - Pea (0.62 t REY). Economic analysis indicated gross return of Rs. 82611 from the system while net return of Rs. 41612was obtained from one cow dairy unit. Vegetable component registered a net income of Rs. 7068 amounting to a total net income of Rs. 32113 from the system.

Fig 34. Broccoli cultivation under Agri-Horti-Silvi-Pastoral system

Silvi-horticultural system (FSW-6)

The total area of Silvi-horticultural system was 3.13 ha with a forest land of 2.17 ha and planned land use of 0.96 ha. Around 0.50 ha area from planned landuse evaluated for studying the system. The average slope of the area was 53.18%. Lower terraces covering an area of 490 m^2 was utilized for growing spices (turmeric). The middle portion of the system was utilized for fruit crops such as guava. Upper portion of the system was covered with the forest tree spp. *Alnus nepalensis*. A gross income of Rs.29740 was recorded from this system.

Natural forest block (FSW-7)

A total of 1.03 ha area in natural forest block was divided under forest (0.08 ha) and under planned land uses (0.95 ha). The average slope of the land was 45.87 %. The watershed area was dominated by common weed flora viz. *Fumaria parvifolia, Ciprusirri, Eupatorium adenophorum, Arundinella bengallensis, Solanum khasianum* and *Ageratum* spp. Two tree species (*Pinus* and *Schima)* were commonly grown on the natural forest in the watershed area. The growth and development was more in *Pinus kesiya* (1.6 m) than *Schima wallichii* (1.25 m).

Timber –based farming system (FSW-8)

Total area under timber-based farming system was 0.52 ha, of which 0.02 ha was under forest and 0.50 ha under planned land use. The average slope was 41.35 %. The planned land use system was covered by tree species of *Michelia champaka* and *Michelia oblonga* with a plant height of 1.81 m and 1.14 m and breast of 1.03 m and 1.01, respectively.

Integrated Farming System model on sloppy land for food and nutritional security

One hectare land was optimized for different components of IFS in which 7000 sq m area was allotted to agri/vegetable based cropping system, 2000 sq m under horticulture and 500 sq m under water harvesting pond in which fish was cultured. Livestock sector was utilized under 500 sq m area where vermi-composting unit, threshing floor and miscellaneous uses were accommodated. The economics of various components of IFS was worked out separately. The component wise cost of cultivation and net return achieved was presented in Table 4. Analysis revealed that the maximum net income of Rs. 126557 was obtained only from cropping system followed by Rs. 20481 from livestock component. Horticulture system recorded the maximum B: C ratio with a value of 2.25 followed by cropping component (2.05) (Table 5). The minimum B: C ratio (1.12) was registered from livestock component. As a whole, the IFS gave a net return of Rs. 169794 per ha annually after deducting total cost of production/rearing of Rs. 315557. Total dry matter production amounted to 8.54 t was generated from the system. Out of which, 6.94 t was produced from the field crops and 1.50 t from livestock unit. Horticulture unit having orchard in 2000 m^2 area produced 106.4 kg dry biomass for income. The other dry biomass produced from maize stalk, toria, ginger and turmeric along with livestock excreta and farm waste materials was used to make compost. Overall, 5.73 t dry matter was used for composting and vermi-composting.

Table 5. Cost of production of various components under IFS

Component	Net Area (sq m)	Total Cost (Rs/unit)	Gross return (Rs/unit)	Net return (Rs/unit)	B:C ratio
Crops/ cropping system	7000	1,21,077	2,47,634	1,26,557	2.05
Horticulture	2000	7,084	15,915	8,831	2.25

Livestock	500 no. broiler, 83 no. layer and 3 no. pigs	1,69,221	1,89,702	20,481	1.12
Fisheries	500 +322 pond dyke area	18,175	32,100	13,924	1.85
Total		3,15,557	4,85,351	1,69,794	1.54

ORGANIC FARMING RESEARCH

Evaluation of different varieties of major crops under organic farming

Eleven varieties of Maize and 10 varieties of French bean were screened under organic management practices for identification of suitable lines for mid hills of Meghalaya (Fig 36). Maize was sown under conventional tillage in the month of April 2018 with a spacing of 50 × 25 cm. Well-decomposed Farmyard manure (FYM) was applied on the basis of equivalent nitrogen dose to meet the requirement of 60:60:40 N, P_2O_5 and K_2O kg/ha. The French bean seeds were sown in the furrows between two rows of maize fallow under no till conditions (after harvest of maize) with resultant spacing of 30 × 10 cm. Recommended dose of well decomposed FYM @10 t/ha + Rock phosphate @ 150 kg/ha was applied in small furrows before the sowing of the seeds. Longest cob length was recorded with variety DA 61A (14.7 cm) followed by RCM75 (14.4 cm). Cob weight was maximum in variety DA61A (231.5 g) followed by RCM75 (226.9 g). Maize variety RCM11 exhibited more stem borer infestation and leaf injury while RCM12 was moderately tolerant to stem borer infestation. Among the varieties of French bean, pod length of Naga local (16.20 cm) was highest followed by RCMFB18 (15.9 cm) and RCMFB19 (15.10 cm). Highest yield in terms of green pod was recorded in Naga local (7.31 t/ha) followed by RCMFB18 (6.58 t/ha) and RCMFB19 (5.57 t/ha).

Fig 36. Screening of French bean lines after maize under organic system

Development of Integrated Organic Farming System model

An Integrated organic farming system (IOFS) model was developed for lowland valley ecosystem to utilize all the resources available on- and off the farm effectively and to improve the income. The IOFS model comprising different enterprises such as cereals (rice and maize), pulses (lentil, pea), oilseeds (soybean, rapeseed), vegetable crops (Frenchbean, tomato, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chili, coriander, etc.),

Table 6. On-farm nutrient supply balance sheet under IOFS model (area=0.43 ha)

Components	Nutrient requirement (kg)			On-farm nutrient recycled (kg)			Nutrient Balance (kg)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Cereals (Rice, Maize)	21.0	7.5	17.4	6.6	2.3	12.3	-14.4	-5.2	-5.1
Horticultural crops (Vegetables, Fruits)	33.1	11.8	27.6	15.0	3.1	11.2	-18.1	-8.7	-16.4
Dairy	0.0	0.0	0.0	12.1	4.5	6.1	12.1	4.5	6.1
Others (Oilseeds, Pulses, fodder, Green manuring crop, etc.)	12.1	4.3	10.0	29.9	9.6	25.5	17.8	5.3	15.5
Total	66.2	23.6	55.0	63.6	19.6	55.0	-3.7	-4.4	-1.0

fruits (Assam lemon, papaya, peach), dairy unit (a milch cow + calf), fodder crops, central farm pond, farmyard manure pits and vermicomposting unit. The total cost of cultivation was Rs. 56835/- per year for an area of 0.43 ha while total net return was Rs. 73,903/- per year. For 0.43 ha area, total nutrient requirement for organic crop production was nitrogen (N: 66.1 kg), phosphorus (P_2O_5: 23.6 kg) and potassium (K_2O:55.0 kg). On farm nutrient recycling in IFOS could produce 63.6 kg N, 19.6 kg P_2O_5 and 55.0 kg K_2O. Hence, 94.3 % of the total N, 81.2 % of the total P_2O_5 and 98.2% of total K_2O requirement could be met within the model itself (Table 6) and only meagre amount of N and P_2O_5 was required from the external source to sustain the model.

Comparative efficiency of organic, chemical and integrated management practices in raised and sunken bed land configuration

Four Broccoli based cropping systems namely Broccoli-carrot (CS_1) Broccoli -potato (CS_2), Broccoli -French bean (CS_3), Broccoli –tomato (CS_4) on raised beds and four rice based cropping systems namely Rice (Var. Megha Aromatic 2)- fallow, Rice (Var. Shahsarang 1) - fallow, Rice (Var. Ngoba) - fallow and Rice (Var. Lampnah) - fallow on sunken beds were evaluated under four management practices viz., 100 % organic (NS_1), 100 % inorganic (NS_2), integrated management with 50 % inorganic + 50 % organic (NS_3) and 75 % organic + 10 % vermiwash and 10 % cow urine spray (NS_4). The broccoli based cropping system recorded maximum rice equivalent yield (REY) under 100% organic (39.44 t/ha) followed by integrated (38.62 t/ha) and 75% organic (34.51 t/ha) treatments. Specific gravity (1.28 g/ml), average fruit diameter (53.24 mm), TSS (4.85%), ascorbic acid (30.15 mg/100g), reducing sugar (2.67%), lycopene (17.96 mg/100g) of tomato were recorded highest under 100% organic management. However, acidity (0.75%) and total sugar (5.04%) of tomato was highest under integrated management practice. Broccoli-French bean cropping system effluxes the highest soil CO_2 concentration at 30 DAS whereas, broccoli -carrot cropping system recorded higher soil CO_2 concentration at 45 and 90 DAS. Under raised bed condition, 100% organic treatment recorded maximum SOC with 3.31% at 0-15 cm and 2.80 % at 15-30 cm (Table 7). Maximum available N and SMBC was found under 100% organic (260.3 kg/ha and 178.03 µg/g dry soil, respectively) whereas, maximum P and K were found under integrated management (22.6 and 277.2 kg/ha, respectively).

Organic food production through integrated farming system- cluster approach

Three villages viz., Mynsain, Pynthor and Umden Umbathiang of Ri-Bhoi district of Meghalaya covering 280 farm families and an area of about 110 ha area was adopted for disseminating organic production technology developed in the ICAR Research Complex for NEH Region, Umiam through a model village concept (Fig 38). Several Integrated Organic Farming System (IOFS) models were developed in the adopted villages for improving their income and livelihood security. Integration of crops (rice, maize), vegetables (tomato, French bean,

Table 7. Soil physiochemical and biological properties of soil (0-15 cm soil depth) as influenced by management practices in raised beds

Management practices	WHC (%)	pH	SOC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	SMBC (µg/g dry soil)
75 % Organic	59.4	5.28	3.20	241.9	19.0	267.1	157.7
100% Organic	63.70	5.39	3.31	260.3	19.9	269.6	178.0
Integrated	62.70	5.23	3.22	239.9	22.6	277.2	158.3
Inorganic	52.8	5.13	2.92	235.0	18.0	259.0	141.4
Initial value	49.3	5.14	2.42	220.7	14.4	253.2	148.4
SEm (±)	0.82	0.12	0.07	4.4	0.29	2.15	3.60
CD (p=0.05)	2.82	0.41	0.24	15.2	1.00	7.44	12.2

Fig 38. Vertical cropping over Jalkund in organic village Pynthor, Meghalaya

potato etc.), livestock (dairy/ piggery), and micro water harvesting structure (Jalkund) were carried out. Water from Jalkund used for live saving irrigation in winter months. It increased the crop productivity and diversified their homestead farming to growing remunerative crops and rearing cattle, pigs, poultry, etc. Few farmers obtained a net benefit of Rs. 4000-7000/- from an area of 0.20-0.31 ha. Improved organic rice production technology particularly for Shahsarang-1 were demonstrated in 18 farmer's field and recently a MoU has been signed for rice seed production between farmers of Mynsain Village and ICAR Research Complex for NEH Region, Umiam. Due to adoption of improved organic production technology, the yield of maize, French bean, ginger, tomato, carrot and chilly had been enhanced by 22, 40, 33, 45, 37 and 27 %, respectively over their traditional practices.

Evaluation of different millets and standardization of nutrient management practices

Millets are suitable for hill and tribal agriculture and play a major role in giving nutritional security for the people's lives in hills of NEH Region. An experiment was under taken with different varieties of Finger millet, Foxtail millet, Little millet, Brown top millet and Barnyard millet for judging their suitability under organic production system in North Eastern Hill Region of India. All together 13 varieties (including Finger millet lines from Nagaland and Sikkim) were tested. Among the millets, Proso millet (TNAV145) recorded higher dry matter accumulation. Among the millets, Proso millet (TNAV145) recorded more no. of effective tillers/ m^2 followed by Finger millet (Madina 324). Proso millet (TNAV145) recorded higher grain yield followed by Browntop millet. Among the different varieties of Finger millet, Madina 352 recorded the highest grain yield (1.30 t/ha) followed by Finger millet variety Madina (1.28 t/ha) as compared to germplasm of Nagaland (0.84 t/ha).

Assessing root exudation potential of pulses for improving soil health and acidity tolerance

As phosphorus availability is major constraint for crop production in acidic soils (>80% TGA), enhanced exudation of low molecular weight organic acids (LMWO) by pulse roots is an important adaptive mechanism to solubilize fixed forms of phosphorus. Besides P solubilisation, LMWO's increases quintessential plant microbe interactions with improved soil health and habitat adaptability in degraded acid soils of the north east region. In this backdrop, an attempt was made to screen important nutritive pulses like French bean, lentil, chickpea and pea cultivars for enhanced root exudation through standardized protocols (Fig 39). Among all the pulses tested, Lentil (DPL61) and chickpea (var D21) had more phosphorus efficiency with more root exudation (reflected in terms of more rhizosphere acidification in pH sensitive agar media and increased P solubilisation capacity) which aided the efficient pulse to dissolve abundant fixed forms of phosphorus and release free phosphorus in acid soil and consequently, resulted an increase in pulse yield to the tune of 15-20%.

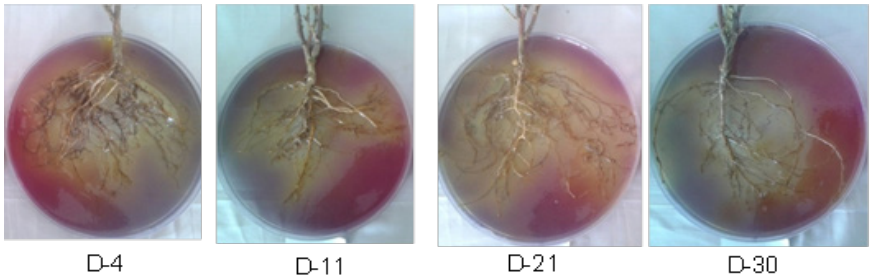


Fig 39. Rhizosphere acidification due to root exudation among different cultivars

Production and quality assessment of vermicompost repaired using various weed biomasses and their impact on soil and crop productivity

Considering huge production of weed biomass of diverse species; a trial was conducted for conversion of such weed biomasses into quality manure through vermicomposting.The prepared vermicompost types were used for growing maize crop to study their effect on yield and yield attributes of maize (RCM 76). The number of cobs per plant across the treatments ranged from 1.0 to 1.2. Maximum cob length (17.21 cm) was recorded in plants treated with vermicompost prepared from Goat weed and minimum (12.39 cm) in Blue snakeweed vermicompost treated plants. Cob weight (without husk) ranged from 86.22 g/cob in Alligator weed vermicompost treated plants to 139.33 g/cob in Fire weed vermicompost treated plants. Kernel yield of maize ranged from 2.6 t/ha in control to 4.2 t/ha in Fire weed vermicompost treated plants (Table 8).

Table 8. Yield and yield attributes of maize as affected by different Vermicompost treatments

Vermicompost	No. of cobs per plant	Cob length (cm)	Cob weight (g/cob)	Kernel yield (t/ha)
Goat weed	1.2	17.2	105.8	2.9
Paddy straw	1.0	15.5	101.5	3.4
Lantana	1.0	14.1	97.5	3.1
Fire weed	1.0	15.2	139.3	4.2
Maize straw	1.0	15.6	131.3	4.0
Mixed grasses	1.1	14.8	117.5	3.5
Crofton	1.0	15.5	116.2	3.6
Blue snakeweed	1.0	12.3	97.7	3.4
Beggar ticks	1.0	15.3	95.1	3.4
Alligator weed	1.0	13.2	86.2	2.9
Fern	1.0	14.2	119.7	3.7
Control	1.0	15.4	102.4	2.6

NATURAL RESOURCE MANAGEMENT

Soil Science

Frost damage detection and assessment of *in-field* maize crop: Use of Hyperspectral and aerial Drone/UAV based Remote Sensing

In the recent years, rainfed upland hill agriculture of Northeast India (NEI) experienced series of untimely hoar frost events at peak crop growth stages, which led partial to complete crop failures. Frosts poses severe threat to the farmers of the NEI since they are mostly unpredictable, sudden in occurrence and the internal injury to the standing plant is lethal, mostly beyond recovery. Recently, (January 2018), one such hoar-frost incidence severely damaged many standing agricultural crops including maize in the hilly landscape of Meghalaya (Fig 1). Inadequacy in technological advancement for prediction of frost occurrence, rapid detection, and damage assessment limits devising post-frost swift healing measures.

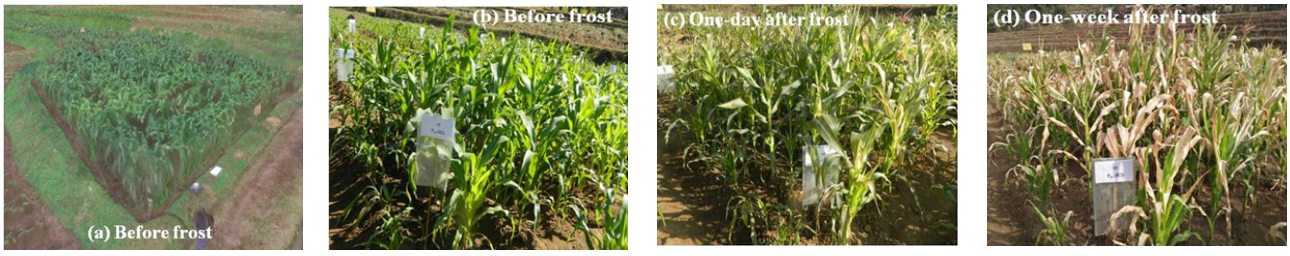


Fig 1. Pictorial view of *in-field* maize crop before frost (a, b), after one-day (c) and one-week (d) of frost occurrences

Remote sensing (RS) technology (such as hyper spectral remote sensing and aerial low-flying unmanned aerial vehicle, UAV/Drone) offers rapid, non-destructive and *in-field* detection of frost damage to crops at different spectral and spatial dimensions. Using hyper-spectral (spectroradiometer: 350-2500 nm) and multi-spectral imaging by low-flying (80 m flying height above ground) Droneat mid-altitude (1000 m msl) Meghalaya, we detected the frost damage of *in-field* maize crop (cultivar RCM176). Following standard protocols, sensitive biochemical constituents (chlorophyll a, b, carotenoid, anthocyanin, tissue-nitrogen, phosphorus etc.) of frosted plants were measured in the laboratory and compared with frost-free plants. Frost injury led an increase in spectral reflectance of plants in the visible (440-480 nm and 580-680 nm) and infra-red (1420-1600 nm & 1890-2500 nm) regions with a distinct reflectance peak at short wave infra-red (SWIR: 2100 nm) (Fig 2). Principal Component Analysis (PCA) revealed three

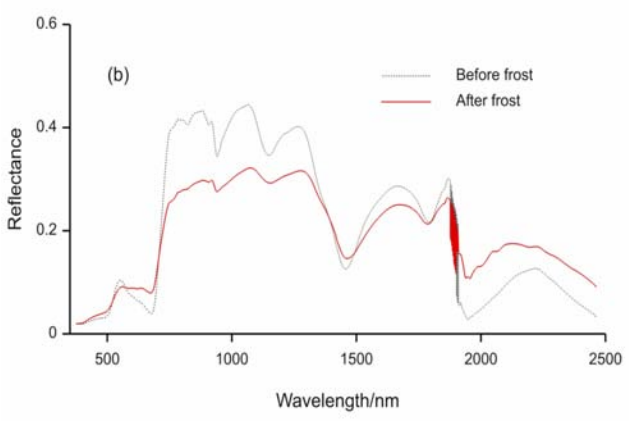


Fig 2. Differences in smooth reflectance spectra (350-2500 nm) of maize crop before (solid line) and aftermath of frost (dash line) occurrence

principal components (PC1-PC3) explained 95% of the spectral data variability with dominant wavelength regions at 2000 nm to 2100 nm (PC1), 740-890 nm (PC2) and 450-650 nm (PC3), respectively (Fig 3). Frost injured plant leaves had significant (p<0.03-0.0001) decline in pigments except anthocyanin: chlorophyll a by 21.5%, chlorophyll b by 38.3%, total chlorophyll by 27% and carotenoid by 35.8% while stress metabolite anthocyanin content increased by 17.4% compared to non-frosted plants. Frost injury led significant changes in the values of estimated hyperspectral vegetation indices, sensitive to plant growth (Red Edge, NDVI- Normalized Difference Vegetation Index) and leaf pigments (Modified Chlorophyll Absorption in Reflectance Index- MCARI, Photochemical reflectance Index -PRI, Carotenoids Reflectance

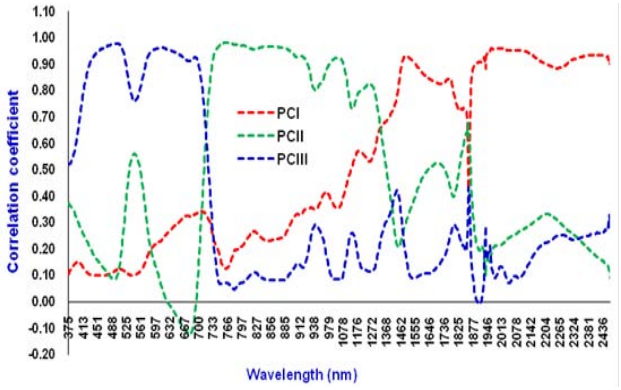


Fig 3. Rotation component matrix of Principal Component Analysis indicating frost sensitive wave length regions

Index-CRI1 &Anthocyanin Reflectance Index -ARI1) than non-frosted plants (Table 1, Fig 4). Imposition of nutrient management regimes (Nitrogen and phosphorus stressed vs. stress-free) in maize plant responded differently to frost damages. Drone born image analysis of maize field before and aftermath of frost occurrence affirmed a reduction in NDVI values from 0.50 in non-frosted plants to 0.31 in frost injured plants (Fig 5). The ground based spectroradiometer also affirmed a drastic reduction in NDVI values from 0.31 to 0.13 and also had a strong correlation coefficient (r^2 = +0.64) with NDVI estimated from drone mounted camera. The study suggests that hyperspectral reflectance measurements and low-flying drone technology should enable farmers to monitor and assess frost damage immediately after it has happened and perhaps to predict the likely losses of yield of standing crops.

Table 1. List of hyperspectral vegetation indices estimated for detection of frost injury in maize plant

Vegetation Indices	Equation	Reference
Normalized Difference Vegetation Index (NDVI)	NDVI=(R800nm – R670nm)/(R800nm + R670nm)	Rouse *et al.* (1974)
Modified Chlorophyll Absorption in Reflectance Index (MCARI)	MCARI=((R700nm - R670nm) - (0.2 * (R700nm - R550nm))) * (R700nm / R670nm)	Daughtry *et al.* (2000)
Photochemical reflectance Index (PRI)	PRI=(R570nm – R531nm)/(R570 nm + R531nm)	Gamon *et al.* (1997)
Carotenoids Reflectance Index (CRI1)	$[(R510\ nm)^{-1} - (R550\ nm)^{-1}]$	Gitelson *et al.* (2002)
Anthocyanin Reflectance Index (ARI)	$[(R550\ nm)^{-1} - (R700\ nm)^{-1}]$	Gitelson *et al.* (2001)

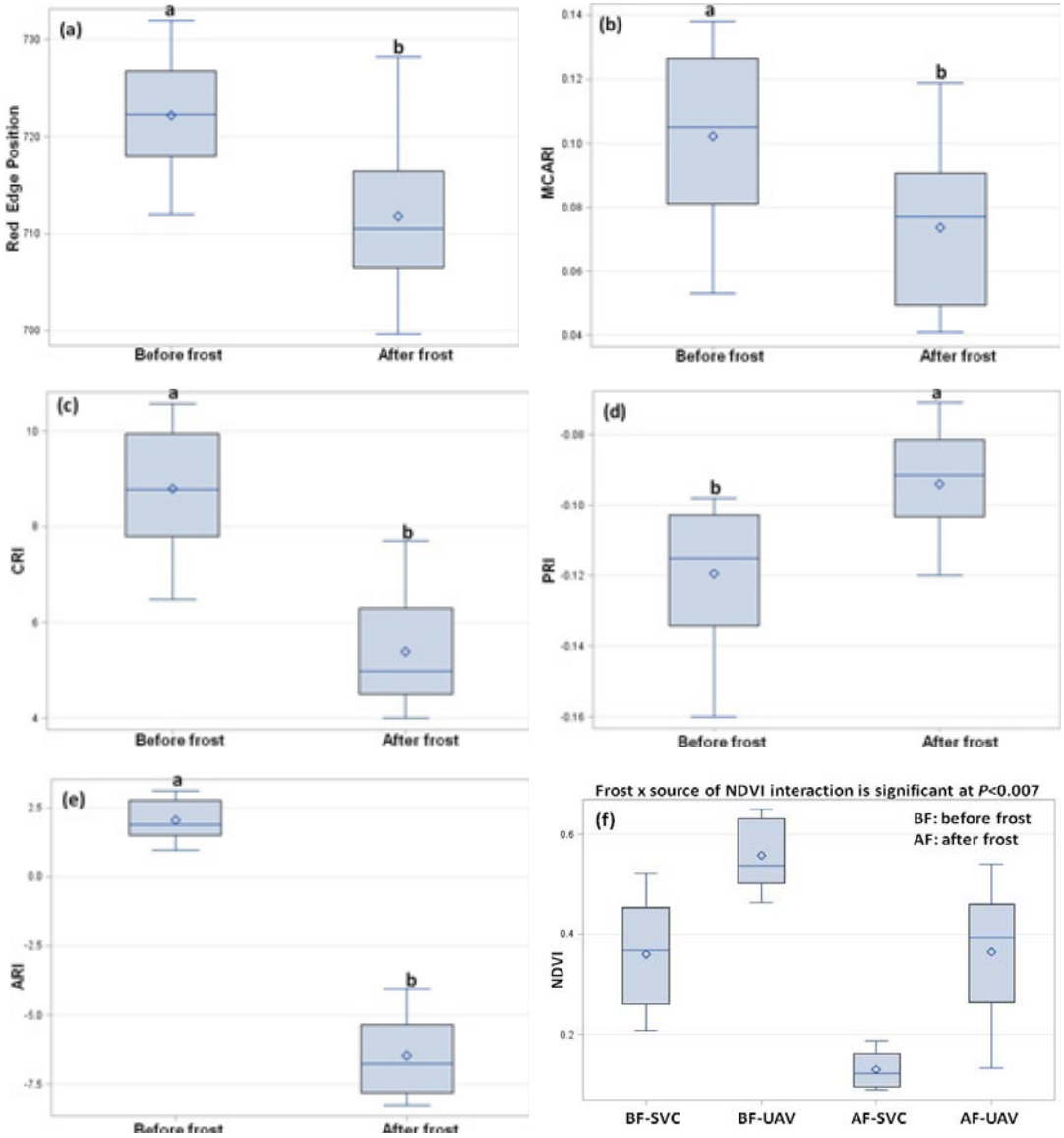


Fig 4. Changes in spectral vegetation indices (a-f) before and after frost injury to maize crop (Means above error bars represented by different letters (a-b) are statistically significant at 5% level of significance)

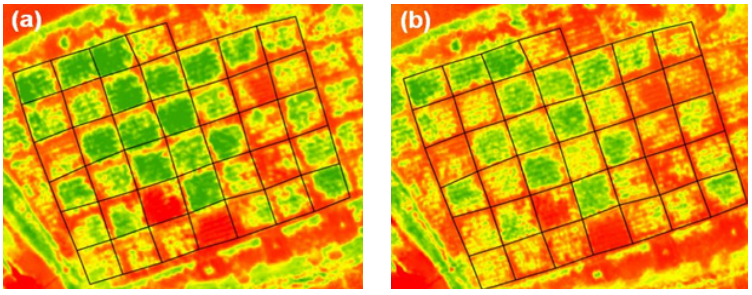


Fig 5. Changes in NDVI values of *in-field* maize crop before (a) and after (b) frost damage estimated from multi-date multi-spectral Drone images

Effect of nutrient management practices on yield of maize-legume intercropping in acid soils of Meghalaya

A field experiment was conducted in the soil science experimental farm to study the effect of maize-legume intercropping on yield and carbon sequestration potential. The leguminous intercrops were soybean, groundnut and French bean. Maize cultivar RCM 1-76 was selected as the main crop. The experiment was laid out in a randomized block design (RBD) with three replications in a plot size of 5 x 3 m^2. The crops were grown with five treatment combinations like recommended management practices (RDF: N, P from SSP, K and FYM as T1); T2:T1 plus lime; T3: as T1 but P - source was rock phosphate; T4: T3 plus lime; and T5: T4 plus mulching (Fig 6). Lime was applied @ 500 kg/ha in furrows and FYM was applied @ 10 t/ha. Crop growth and yield attributing characters were recorded during the harvest of each crop. The sole maize crop produced the highest grain and stover yields than the intercropping of maize with legumes (Table 2). Land productivity in terms of maize-equivalent yield was, however higher in Maize-legume intercropped plots than growing maize as sole crop. Intercropping with legumes improved yield attributes of maize (Fig 7). Amongst the combinations, maize with French bean as intercrop produced the maximum maize yield (24-59% higher) compared to other leguminous intercrops (Table 2). With respect to the nutrient management practices, T2 treatment recorded the maximum maize and legume yield across intercrop combinations. On liming with RDF (T2), the proportionate increase in maize yield was 16 to 44% over other four nutrient management practices (Table 2). The harvest Index (HI) was higher under sole maize while the introduction of leguminous intercrops decreased the HI of maize crop but the changes were non-significant amongst the intercrops (Fig 7). Similarly, application of fertilizers, FYM and lime decreased the HI irrespective of the legume intercrops. Liming with RDF as nutrient management (T2) improved pod yield of soybean, groundnut and French bean by 18%, 27% and 29%, respectively over RDF alone in respective crops.

Soil organic carbon (SOC) stocks for 0-30 cm depths were estimated under different maize-legume intercropping systems from a two year old experiment. The SOC stocks ranged from 47.9 to 61.1 Mg/ha and the highest C- stocks was observed under maize-French bean system (14% more) while the lowest was under sole maize system (Fig 8). Averaged on nutrient managements, introduction of legumes as intercrops increased the SOC stocks by 12% over sole maize. Similarly, application fertilizers along with lime and FYM increased the SOC stocks up to 11% under leguminous intercropping compared to sole maize crop.

Fig 6. Maize-legume intercropping at Soil Science Experimental field

Table 2. Effect of nutrient management practices on grain and stover yield (kg/ha) of maize under maize-legume intercropping in acid soils of Meghalaya

Treat.	Maize sole		Maize + Soybean		Maize + Groundnut		Maize + French bean	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T1	3694	6706	1956	3640	1893	3559	2553	4758
T2	4308	7619	2207	4060	2533	4756	3186	5798
T3	2974	5628	1672	3293	1733	3389	2001	3845
T4	3222	6019	1889	3662	1922	3871	2093	3994
Mean	3550	6493	1931	3664	2020	3894	2458	4599

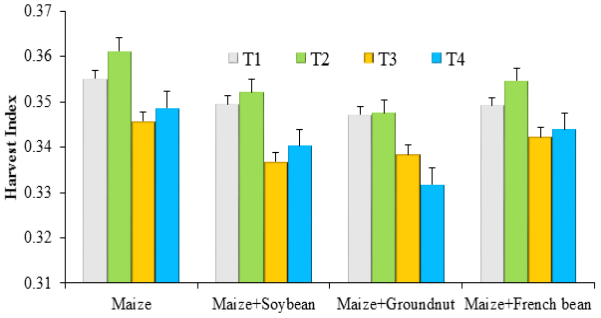


Fig 7. Harvest index (HI) of maize under different nutrient management practices in maize-legume intercropping

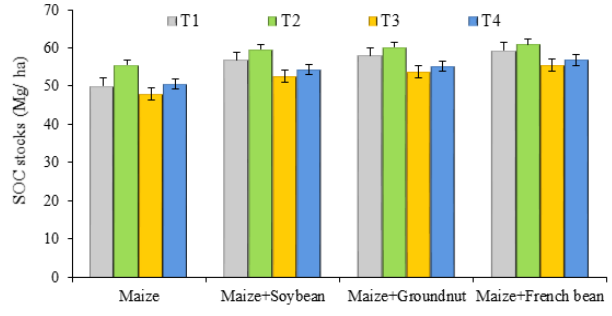


Fig 8. Soil organic carbon stocks (Mg/ha) under different nutrient management practices in maize-legume intercropping system

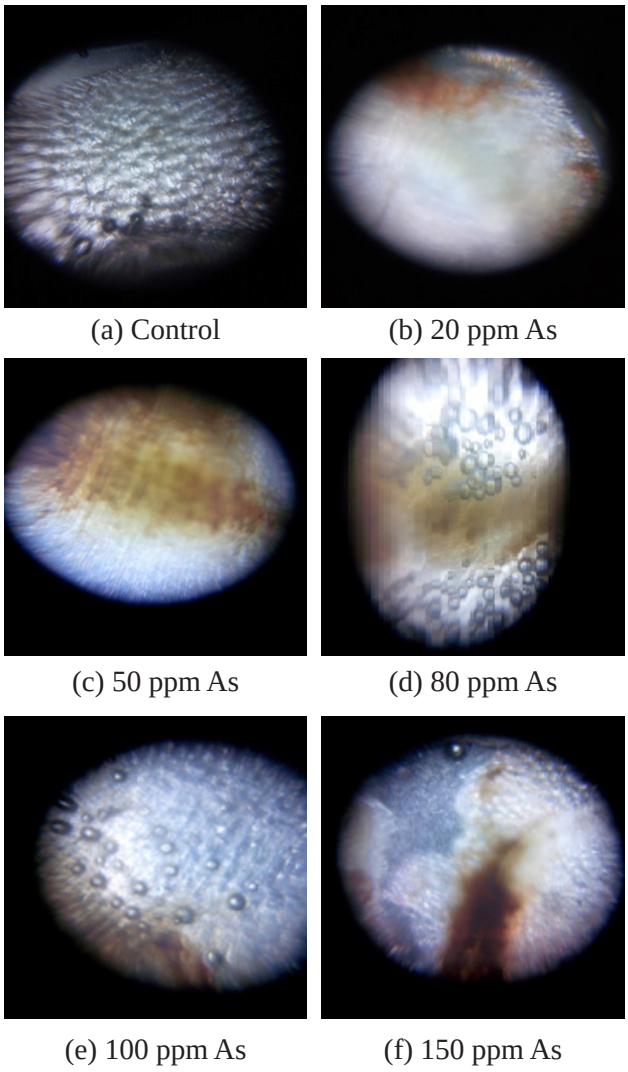
Arsenic induced physico-biochemical changes in French beans *(Phaseolus vulgaris* var. *Selection 9)* roots

The study reports the response of physico-biochemical changes in French bean roots when Arsenic (As) toxicity was imposed in the form of sodium arsenate. Pre-imbibed French bean seeds were induced with differential As concentrations: 0 ppm (Control), 20 ppm, 50 ppm, 80 ppm, 100 ppm, 150 ppm (Fig 9). The seeds in each concentration of As were allowed to imbibe in Petri dishes for different durations: 24h, 48h, 72h and 120 h in triplicated form. In each Petri dish, 6 French bean seeds were imbibed following completely randomized design (CRD) in an environmentally controlled growth chamber under a 16 h photoperiod at 25/18 (±2)°C and 75 ± 2% relative humidity (RH).

Fig 9. Pre-imbibed seeds of French beans exposed to different concentrations of Arsenic in environmentally controlled growth chamber

Exposure to As caused a significant reduction (30-40%) in root lengths of French beans and the rate of decrease was more with increase in duration of exposure from 24h to 124 h (Fig 10). The root growth was almost inhibited at 120 h exposure. Similarly, with the increase in concentration from control to 80 ppm of As, the malondialdehyde (MDA) content increased by 20% and with further increase in As concentration to 150 ppm, MDA content was 40% higher over control. The conjugated dienes (CDs) remained unchanged till 80 ppm but above 80 ppm As concentration, the CD content declined drastically. The exposure of roots to As did not cause any accumulation of hydrogen peroxides (H_2O_2). Increase in MDA content indicates the occurrence of membrane damage due to peroxidation of polyunsaturated fatty acids. This in turn resulted in

production of reactive oxygen species (ROS) and thus, imparted oxidative stress to the roots. Results further showed that when As concentration was at 80 ppm or above, roots started to leak electrolytes and the process of crystallization of As was also observed (Fig 10).



(a) Control (b) 20 ppm As

(c) 50 ppm As (d) 80 ppm As

(e) 100 ppm As (f) 150 ppm As

Fig 10. Assessment of Arsenic (As) induced Membrane damage using Foldscope Microscope

Water Management

Residue management and conservation tillage in rice based system

The effect of tillage and residue management in rice based system for increasing production and resource conservation was evaluated. Zero tillage in *kharif* rice yielded highest grain (5933 kg/ha) and so were the ensuing Rabi crops grown in zero tilled *kharif* rice: buck wheat (1683 kg/ha), toria (1400 kg/ha) and pea (5350 kg/ha over respective conventional tillage practices. Plotting production function for 9 consecutive years of zero tilled rice, grain yield increased consistently over the years with average annual yield remained above 5.5 t/ha in most of the years (Fig 11). Over 9 years of continuous practice of zero tillage, soil organic carbon built up increased marginally: 1.62% in 2018 from 1.45% in 2009.

Effect of mulching and organic manure on growth and yield of Turmeric under terrace condition:

Field experiments were conducted to evaluate the most suitable manure along with straw mulch for higher productivity of turmeric and better soil moisture conservation under terrace condition. It was found that FYM + Straw mulch @ 5 t/ha each recorded 177% higher rhizome yield (10148 kg/ha) and 72% higher water use efficiency (WUE: 10.9 kg ha/mm) with a B:C ratio of 1.43.

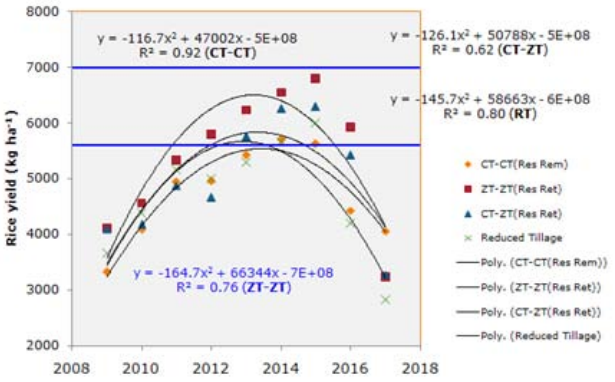


Fig 11. Production functions of rice under different tillage treatments (2009-2017)

(CT: Conventional tillage, ZT: Zero tillage, Res Rem: Residue removal, Res Ret: Residue retention)

Effect of *in-situ* residues on carry over soil moisture conservation and crop growth under hill agriculture:

To develop simple and low-cost technique of *in–situ* moisture conservation for second crop during winter season, two tillage practices combined with intercrop/residue management/manure treatments were evaluated. Results revealed that tillage combined with residue management practices in toria had significant positive effect on succeeding maize.

The MPA treatment (Maize stalk cover + Poultry Manure + Ambrosia @ 5 t/ha) was found as the best residue management option for both toria and maize (81% & 34% yield increase over respective controls). Zero tilled maize in MPA recorded highest B: C ratio of 2.62. Similarly, SOC content was 36% higher in zero tilled plots than control (1.38% in 2009) while in conventionally tilled soils, SOC decreased by 21% over control (Fig 12).

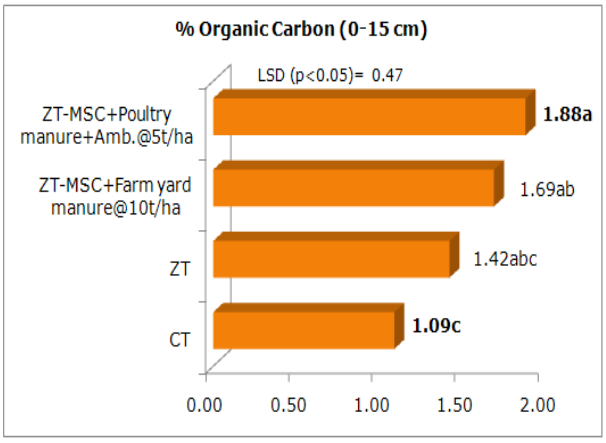


Fig 12. Effect of tillage & residue management on surface (0-15 cm) soil organic carbon

Agroforestry

Genetic Improvement of *Populus gamblei*, an indigenous poplar from the North East India

Populus gamblei is an indigenous species of fast growing poplar found only in India. It has not been reported from any other parts of the world. In India it was reported in the North East India and Darjeeling Hills. The species is said to be fast growing and has potential for use as industrial wood. There was also some report that the species has the potential to match the productivity of *Populus deltoides* which is the most acceptable agroforestry tree species of the North Western parts of India. Therefore, natural distribution zone of *Populus gamblei* was extensively surveyed and three plus trees were identified at Tarkhola and Kalimpong beats of Kalimpong forest Division. To assess genetic diversity among and between the population of leaf samples were collected from West Bengal, Sikkim, Arunachal Pradesh, Nagaland and Manipur (Fig 13). Some of the habitats explored have not yet been reported in any flora or published literature.

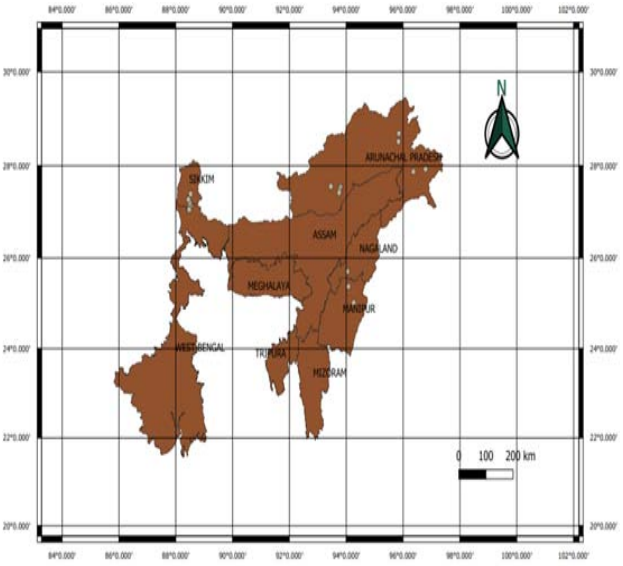


Fig 13. Map showing the natural distribution of *Populus gamblei*

In almost all the localities, the species was found along the streams (Fig 14) and it colonized landslide and land-slip areas as a pioneer species.

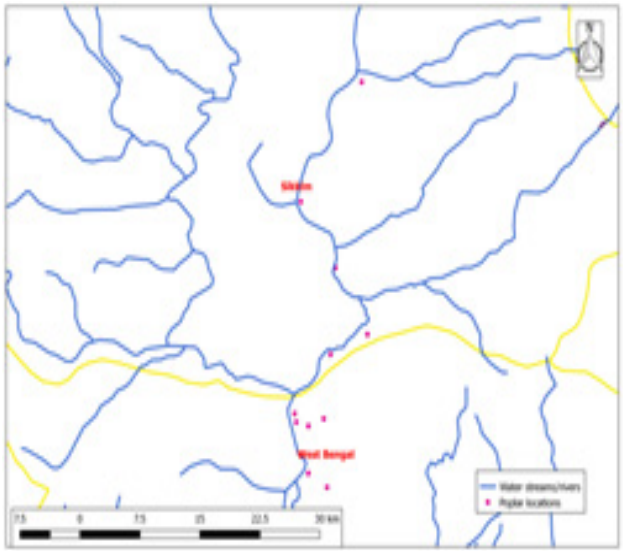


Fig 14. Map showing natural distribution of *Populus gamblei* along the streams

Natural stands of *Populus gamblei* in Tarkhola forest beat, Kalimpong Forest Division was surveyed and mean of important parameters such as mean dia, mean height, stand density, bole height etc. were recorded. The traits were recorded in three plus trees identified using 6 trees as check for further improvement work (Table 3).

Table 3. Traits of the Plus trees of *Populus gamblei* selected from the forests

Parameter	Plus Tree 1 (Tarkhola)	Plus Tree 2 (Tarkhola)	Plus Tree 3 (Gokule)
Girth at breast Height (cm)	162	141	204
Height (m)	39.7	40.3	29.9
Crown diameter (m)	12	13	13
Clear bole length (m)	20.4	17.3	16.1
Straightness of tree (0-10 scale)	10	6	7
Branch angle (0-10 scale) less is better	4	7	7
Disease	Nil	Nil	Nil
Pest	Nil	Nil	Nil

* For brevity of data check trees are not mentioned here

Progeny of these trees are being collected to raise trials in uniform environment to check their genetic worth and further select the elite trees

Development of Empirical Model for Carbon Sequestration of *Pinus kesiya*

Pinus kesiya is the most dominant tree species in the Jhum lands and other cultivated landuses located on the Meghalaya. It is also a principal component of the community forests around the villages. These tree based land use systems have potential to sequester carbon both in above and below ground biomass as well as soil. Since destructive sampling in these woody vegetation is not feasible, predictive models are required to estimate the biomass accumulated in a tree having specific growth. Therefore, an attempt was made to develop a relationship between the growth traits such as Girth at Breast Height, Total height etc with the above ground biomass of individual trees which can help to indirectly estimate the biomass accumulation in a tree with statistically sufficient confidence. We selected community forests where felling was being carried out by the farmers/ villagers. About 50 trees were sampled whose data such as GBH, Girth at Mid height, size and weight of fresh logs, branch wood, leaves, crown size etc. were recorded on the site itself and representative samples from each part were brought to the laboratory for further analysis. The total below ground biomass was taken as 26% of the above ground biomass as per the IPCC guidelines. Carbon percent is taken as 0.50 for the time being till the total carbon is estimated in different parts of the trees such as main trunk, needles, branch wood and barks. Some of the best fit models developed are as below:

SN	Equation	b_1	b_2	C	$P_{0.05}$ for b_1	$P_{0.05}$ for b_2	$P_{0.05}$ for C	R^2	Adjusted R^2
1	$Y_1=b_1 X_1+C$	8.88	-	-405.75	1.3E-15	-	2.3E-06	0.74	0.73
2	$Y_1=b_1 X_1+b_2 X_2+C$	6.76	8.11	-434.46	6.8E-15	0.04	1.8E-06	0.75	0.76
3	$Y_2=b_1 X_1+C$	4.44	-	-202.88	1.3E-15	-	2.3E-06	0.74	0.73
4	$Y_2=b_1 X_1+b_2 X_2+C$	4.26	5.11	-273.71	6.8E-15	0.04	1.8E-06	0.75	0.76

Y_1= Total above ground biomass per tree in kg, Y_2=Total carbon (both above and below ground) per tree in kg, X_1=Girth at Breast Height in cm, X_2=Total Height of the tree in m

From the above models, equation 1 & 2 are for prediction of total above ground biomass with the help of GBH and Height whereas model 3 & 4 are for total carbon per tree accrued both from above and below ground biomass. It was observed that there is not much difference in the adjusted R^2 values between equation 3 & 4. Therefore, only GBH can be used for carbon estimation as GBH measurement

in the field conditions is much simple, easy and cost effective as compared to total height of the tree. Height measurement has also additional sources of error such as lean of the trees, slope of the ground etc.

Population biology and characterization of threatened medicinal plants of the Himalayan Region

Survey was conducted in Himalayan region of all the North Eastern hill States, Himachal Pradesh, Sikkim, Uttarakhand and J&K for collection of germplasm of medicinal species viz. *Valeriana jatamansi*, *Paris pollyphylla*, *Coptis teeta* and *Dicentra scandens*. These species are not only agriculturally important for their potential in improving farmers income but has futuristic therapeutic potential. Among these species *Paris pollyphylla*, *Coptis teeta* and *Dicentra scandens* have extremely restricted habitat and are available in highly specific niches. Abundance of *Valeriana jatamansi* was adequate for which population study was undertaken on it. *Valeriana* spp useful in the health care system because of presence of valproates in the rhizomes which is a potent medicine against epilepsy and seizures. Twenty eight populations each containing 20-30 sample plants were collected from across the Himalayan ranges starting from Arunachal Pradesh to J&K (Fig 15).

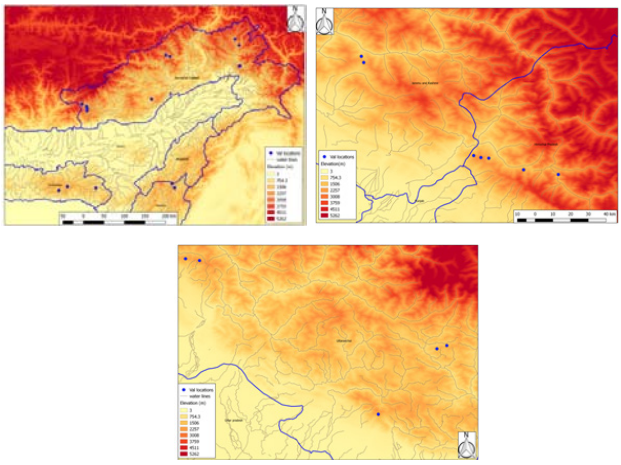


Fig 15. Map showing the locations of *Valeriana jatamansi*
(A: north east region; B Himachal Pradesh and Jammu and Kashmir and C; Uttarakhand)

Out of these populations twenty two populations containing nearly 700 plants were evaluated during 2018-19 in completely randomized block design with three replications. Growth attributes such as leaf area, flowering characters were recorded in the current season and yield will be recorded during winter season of 2019. Wide variation was observed in the plant height, number of flowering stalks per plant, average leaf area per leaf and flowering time. The population from Himachal Pradesh and J&K were early flowering types and flowering time was one month earlier than the other collections. However, the flowering behaviour will be confirmed after two-three cycles of cultivation in an uniform environment. Looking at the leaf shape and size, and trichome on the leaf surface, we could observe at least four different types of *Valeriana jatamani* among the collections. The distinctiveness shall be confirmed after detail morphological, biochemical and molecular characterization. Plant height varied from as small as 13.25 cm to 50.88 cm (Table 4). Similar variation was also observed in number of flowering stalks per plant (1-10) and leaf area of individual leaf (4.25-40.88 cm^2).

DNA samples have been extracted and purified from 700 speciman of *Valeriana jatamansi*, 47 of *Paris pollyphylla*, 16 of *Coptis teeta* and 10 of *Dicentra scandens*. These germplasm will be analyzed for assessing genetic diversity within and between populations.

Table 4. Variation in growth attributes of different populations of *Valeriana jatamansi*

Collections	No. of Leaves	Plant Height (cm)	No. of Flowering Stalks	Leaf Length (cm)	Leaf Width (cm)	Average area of a single leaf (cm^2)	Leaf Perimeter (cm)	Flowering Time
AP1	23	50.88	6	6.93	6.50	17.79	22.52	Feb. -March
AP2	34	36.50	7	6.23	5.27	24.18	25.05	Jan.-March
AP3	62	49.25	10	6.33	4.80	17.06	19.87	Feb.-March
AP4	45	24.25	4	6.57	4.87	12.34	16.44	March

AP5	33	47.50	7	8.43	7.40	18.19	20.82	Feb.-March
AP6	7	13.25	1	6.50	4.43	13.67	16.44	March-April
AP7	3	19.75	1	8.17	5.20	33.43	26.87	March-April
AP8	6	22.25	1	5.23	3.73	20.10	20.76	Feb.-March
AP9	5	9.00	1	4.97	2.57	9.49	15.02	March-April
AP10	16	13.38	1	7.13	5.40	15.77	17.78	Feb.-March
MGH01	59	37.25	6	5.90	4.63	40.88	32.51	March-April
MGH02	16	28.50	1	6.47	5.30	22.06	21.54	Feb.-March
MGH03	50	49.00	3	9.17	8.10	36.81	28.10	Feb.-March
UKD1	28	19.50	2	3.67	2.47	4.51	10.28	March-April
UKD2	35	31.50	2	6.83	5.73	24.41	23.24	March-April
UKD3	49	43.50	2	8.17	7.30	34.27	26.63	Feb.-March
JK1	19	22.75	1	7.87	6.93	21.41	22.38	Jan.-Feb.
JK2	32	13.88	1	6.83	6.77	18.02	20.20	Jan.-Feb.
HP1	26	26.88	1	7.20	7.17	32.06	24.69	March-April
HP2	16	15.50	1	7.97	6.73	33.93	26.54	Jan.-Feb.
HP3	24	22.25	2	7.10	6.50	31.75	24.83	Jan.-Feb.
NGL1	36	50.50	6	5.07	3.83	29.15	26.29	Feb.-March

Rhizomes of *Valeriana jatamani* were extracted with HPLC grade hexane for 72 hours at ambient temperature. The extracts were concentrated in vacuum and yield was determined to be 0.11% to 0.24% on fresh weight basis. The extracts isolated from 242 accessions of 11 populations were analyzed for their chemical composition using GC-MS equipped with flame ionization detector (FID) and a DB-5MS capillary. Total 59 compunds were identified and Valerena-4,7 (11)-diene and Isovaleric acid have been selected as marker compounds for identification of important chemo-types. On the basis of marker compound 11 wild populations were evaluated and out of these populations three populations Ziro (AP), Dirang (AP) and Fputsero Phek were found to be superior.

Resin Productivity in different provenances of *Pinus kesiya*

Pinus kesiya is a predominant forest in the North East India especially in the Khasi hills. This is a hardy species which grows on the stressed sites. Tree from three different provenances of the species were tapped to assess its resin production potential. Tapping was periodically done from April 2018 to Jan 2019 by bore hole method. Resin yield varied from 23.47 to 217.00 g per tree. Maximum production being achieved in January followed by October (Table 5). Oleoresin was distilled through steam distillation process to separate turpentine and rosin from the oleorosin.

Table 5. Effect of tapping season and provenances on resin yield of *Pinus kesiya*

Collection Month	Resin yield (g /tree)								
	Umshing, East Khasi Hills			Umsawkhwan, Ri-Bhoi			Shangpung, West Jaintia Hills		
	Diameter class (cm)								
	30-35	35-40	>40	30-35	35-40	>40	30-35	35-40	>40
APRIL	77.34	70.55	92.93	68.91	90.35	68.92	47.91	114.18	52.39
MAY	83.99	38.72	65.37	59.03	53.49	62.99	88.60	98.07	9.17

JUNE	67.25	43.29	83.98	62.03	54.20	61.49	-	-	-
JULY	46.32	49.36	44.00	31.48	115.15	43.68	95.32	217.00	118.84
AUGUST	62.22	36.15	41.79	29.20	113.23	23.47	96.69	117.64	94.78
SEPTEMBER	54.40	59.18	44.98	29.09	102.93	52.70	114.31	71.11	72.71
OCTOBER	40.12	77.73	41.91	42.02	59.16	43.98	120.01	143.52	188.75
NOVEMBER	45.60	63.66	40.37	53.26	84.99	96.70	97.46	158.85	206.31
DECEMBER	41.81	64.84	26.55	53.07	59.52	109.52	125.40	163.25	91.64
JANUARY	93.77	94.55	95.88	98.02	118.99	123.38	87.59	139.12	190.89

Table 6. Turpentine yield (%) from oleoresin of *Pinus kesiya* samples in different provenences.

	Umshing, East Khasi Hills			**Umsawkhwan, Ri-Bhoi**			**Shangpung, West Jaintia Hills**		
Months	30-35	35-40	>40	30-35	35-40	>40	30-35	35-40	>40
APRIL	17.39	20.43	9.53	8.44	17.86	13.18	16.16	16.48	16.16
MAY	16.2	18.13	18.63	14.07	15.1	12.39	16.68	16.31	20.59
JUNE	19.33	10.12	16.88	15.48	16.94	6.45	0	0	0
JULY	13.74	18.56	17.08	16.76	19.31	13.71	22.57	16.28	24.29
AUGUST	18.08	19.7	12.85	18.55	20.42	21.80	18.19	20.21	21.68
SEPTEMBER	23.14	23.75	15.03	19.91	27.55	29.43	37.9	21.6	23.75
OCTOBER	13.61	14.42	16.72	21.95	30.92	19.71	22.67	23.96	25.13
NOVEMBER	12.93	17.89	16.82	20.3	22.69	21.76	23.12	27.7	25.92
DECEMBER	20.27	25.44	17.97	28.66	30.85	24.03	26.05	42.94	28.52
JANUARY	23.56	23.01	23.75	22.53	21.83	23.92	25.82	24.13	24.07

AGRICULTURAL ENGINEERING

Evaluation of Conservation Efficiency of Grasses on Hill slopes of Meghalaya Region

The project was initiated during 2014-15 for evaluation of conservation efficiency of grasses on hill slopes for conserving natural resources and evaluating economic feasibility. The objectives can be fulfilled by studying the hydrological behaviors of degraded lands under selected local grass covers with their conservation efficiencies and production potentials. Eight numbers of gauging stations were renovated and gauging devices were installed. Transplanted Congo signal, hybrid Napier, broom, guinea, lemon grass and citronella saplings in 6 numbers of Runoff plots (ROP) were monitored for hydrological behaviors and growth. Hydrological behaviors were monitored by installing automatic water stage level recorders on 1ft H-flumes. Sediment samples were monitored through 1' dia Coshocton wheel silt samplers (N-1 type). The area received 2277.9 mm annual rainfall in 121 events with runoff producing storms of 1299 mm in 41 events during 2018. The hydrological behaviors and production potential of different ROPs are presented in table 1.Soil conservation efficiencies were estimated at 31.5, 29.3, 42.2, 44.4, 24.78, 38.5 and 28.7% with water conservation efficiency of 24.6, 27.3, 29.7, 34.4, 30.9, 24.4 and 50.5%, respectively. The overall soil & water conservation efficiencies of Congo signal, hybrid Napier, broom, guinea, lemon grass, citronella and cultivated weeds were 28.0, 28.3, 35.9, 39.4, 27.8, 31.5 and 39.6%, respectively.

Table 7. Hydrological behaviors of ROPs with production potential during 2018

ROP(s)	Grass	Runoff (% rainfall)	Sediment yield (t/ha)	Yield (fresh biomass)
1	Congo signal	17.28	8.99	54.25
2	Hybrid Napier	13.60	8.45	229.62
3	Broom grass	17.04	10.54	155.93
4	Guinea grass	14.16	9.84	26.21
5	Lemon grass	16.40	10.12	15.64
6	Citronella grass	15.20	9.95	28.44
7	Weed biomass in cultivated fallow	17.44	10.57	21.57
8	Weed biomass in natural fallow	14.73	8.43	31.86

Estimation of Water Budget Components for Predominant Farming Systems of Meghalaya Region

The project was started during 2014-15 for assessing farming system (FS) impact on water budget parameters, development of relationship between water budget components and hydro-meteorological parameters, evaluation of suitability of different models/ methods/ approaches for modeling water budget components with assessment of biological and economic productivity of water under different land use options. The FS include agriculture (W_1=0.64 ha), agri-horti-silvi-pasture (W_2=1.03 ha), agro-forestry (W_3=2.94 ha), forestry (W_4=3.89 ha) and natural fallow (W_5=1.03 ha). The soil is of sandy loam and lies in LCC class VIIe. The average slope of micro-watersheds lies in the range of 32.0 to 45.8% with relief of 89-110m. The maximum length and width varies from 250-320m and 65-230m, respectively. Five (5) gauging stations equipped with H-flumes were renovated and installed with automatic stage level recorders. Five farming system micro-watersheds were calibrated for their hydrology during 2015. During the year 2018 the area received 2277.9 mm annual rainfall in 121 events with runoff producing storms of 1299.0 mm in 41 events. The hydrological behavior of FS micro-watersheds is presented in Table 8.

Table 8. Hydrological behavior of FS Micro-watersheds during 2018

FS Micro-watershed No.	Runoff (%)	Sediment yield (t/ha/yr)	Water Conservation Efficiency (%)	Soil Conservation Efficiency (%)	Soil and Water Conservation Efficiency (%)
W_1	20.1	13.16	47.5	47.3	47.4
W_2	19.14	12.51	50.24	50.04	50.14
W_3	20	12.93	47.78	47.58	47.68
W_4	22.84	14.61	39.64	39.44	39.54
W5	36.39	22.16	Control	Control	Control

Runoff was estimated using standardized SCS-CN method for the region and evapotranspiration by following the method of FAO-56 Penman-Monteith using multiple crop option. Recharge contribution was estimated using water balance approach. Estimated water budget components for major land use system (individual and combining composite land use system) are presented in the Table 9 and monthly water budget components is presented in Table 10.

Table 9. Estimated Contribution of Water Budget Components under prominent land uses (2018)

Land uses	Contribution		
	Runoff (%)	AET (%)	Recharge (%)
Agril (W_1)	20.1	35.34	44.56
Agri-Horti-Silvi-Pasture (W_2)	19.14	59.56	21.3
Agro forestry (W_3)	20	46.96	33.04
Forestry (W_4)	22.84	51.7	25.46
Natural fallow (W_5)	36.39	30.92	32.69
Combining Composite	23.69	44.90	31.41

Table 10. Estimated Monthly water budget components for the year 2018

Month(s)	Rainfall (mm)	Runoff (mm)	AET (mm)	Recharge Contribution (mm)
January	8.60	0.00	24.10	0.00
February	24.40	0.00	29.30	0.00
March	31.30	0.00	48.10	0.00
April	208.20	52.05	132.60	21.55
May	281.30	73.14	149.50	55.42
June	424.30	114.14	135.20	163.96
July	354.70	85.13	151.90	107.32
August	435.70	100.21	118.40	190.07
September	258.60	56.89	111.60	89.91
October	214.90	58.02	64.40	87.36
November	7.30	0.00	25.70	0.00
December	28.60	0.00	31.80	0.00
% Contribution	100	23.69	44.90	31.41

Analysis of Historical Weather Variables and Accuracy Assessment of Weather Forecast

The north eastern region of India, highly rich in natural resources and falling under the high rainfall zone of the country is facing the consequences of climate change. To understand the patterns of changes in the extremes, daily weather variables (maximum & minimum temperature along with the rainfall) were analyzed using the methodologies of Expert Team on Climate Change Detection and Indices (ETCCDI). It has been observed that the diurnal temperature range (DTR) have significantly increased in Umiam over the last three decades which is mainly due to increase in the maximum temperature (T_{max}) and decrease in the minimum temperature (T_{min}). Reverse trend was observed in Gangtok, Imphal and Lembucherra where DTR decreased as T_{min} increased at a higher rate than T_{max}. Warm spell duration (occurrences of at least six consecutive warm days) increased significantly in Umiam, Imphal and Lembucherra. Index of warmness, number of summer days (days when daily T_{max} remains greater than 25°C) also increased significantly over Umiam and Gangtok. The results broadly indicate that the extremes of maximum temperature are increasing *i.e.* days are getting warmer while the extremes of minimum temperature have shown mixed trend over the region *i.e.* somewhere it has decreased and in other places it increased. The results of extremes of daily rainfall (RR) show that though there were trends, but for

most of the indices the trend was not statistically significant. It can be seen that, only consecutive dry days indicated by maximum number of consecutive days with RR less than 1.0 mm has significantly increased over Umiam. It points towards the fact that over the area, very light rainfall days have decreased. These types of rainfall are very crucial for the growth of plants as well as for ecological point of view. Decrease in these sorts of rainfall during winter and pre-monsoon season may increase the vulnerability of natural vegetation to fire as they remain too dry during these periods. But in Imphal, the number of heavy and very heavy precipitation days along with maximum five-day precipitation showed significant increasing trend. Overall, the results show that, there has been a significant change in extremes over the whole region especially those related to extreme temperature indices as compared to the extreme rainfall indices.

Table 11. Trends in the extreme weather indices of different places of northeastern India

S. N.	Index name	Rate of change			
		Umiam	Imphal	Gangtok	Lembucherra
1	Diurnal temperature range (DTR)	0.123***	-0.03*	0.048***	-0.033
2	Maximum Tmax (TXx)	0.05***	0.016	0.017	0.097***
3	Maximum Tmin (TNx)	-0.086***	-0.021	0.032**	0.061*
4	Minimum Tmax (TXn)	0.12***	0.013	0.042	-0.068
5	Minimum Tmin (TNn)	-0.005	0.054***	0.003	0.029
6	Cold Days (TX10p)	-0.474***	-0.081	-0.107**	-0.223
7	Warm days (TX90p)	0.861***	0.387***	0.184	0.836***
8	Cool nights (TN10p)	0.095	0.548***	0.982***	-1.078**
9	Warm nights (TN90p)	-0.621***	0.425***	0.546***	0.179
10	Warm spell duration index (WSDI)	0.907***	0.779**	0.07	1.32**
11	Cold spell duration index (CSDI)	0.084	0.865***	1.217***	-2.241
12	Number of summer days (SU)	2.413***	0.433	0.745***	0.21
13	Consecutive dry days (CDD)	1.225**	0.129	0.681	1.097
14	Consecutive wet days (CWD)	0.026	0.037	0.007	-0.106
15	Annual total wet-day precipitation	-2.864	8.984**	-4.01	6.143
16	Number of heavy precipitation days	-0.091	0.093	-0.214	0.052
17	Number of very heavy precipitation days	-0.02	0.178	0.069	0.024
18	Very wet days	-0.978	7.896***	-3.27	6.144
19	Extremely wet days	-4.726	3.817**	-2.352	2.159
20	Max 1-day precipitation amount	-0.531	0.697	0.165	0.994
21	Max 5-day precipitation amount	-1.087	1.825**	-0.406	-0.203
22	Simple daily intensity index (SDII)	-0.013	0.06**	0.008	0.032

****, ** and * denote Mann-Kendall trends at 1%, 5% and 10% significance level, respectively. The rate of change is the slope.*

Evaluation and Development of Power Weeder Suitable for Hilly Region

Feasibility testing of small engine operated (2.2 HP/6500 rpm, Powertec) power weeder/mini-tiller with tilling attachment for weeding operation was conducted at 1.5 to 2 km/hr for cultivation of maize and vegetable crops (tomato & beans). Observations were taken on performance parameters of the equipment for cultivation of maize, tomato and beans on terraces of 2-5 m wide. The effective field capacity was found to be 0.08 ha/hr with the weeding efficiency of 65%. Fuel consumption of the equipment was 0.08 liter/hour. One person can lift the weeder from one terrace to another terrace easily with overall dimension of 950 x 450 x 860 mm and net weight of 14 kg. The equipment can be maneuvered comfortably by the operator on the terraces. There was no breakdown and repairs of components during the field operation. It is suited for small plot in hilly terrain. The results of the field testing revealed that the mini-tiller was found satisfactory for weeding operation under upland condition. However, it was found that the operator had to bend while operating the machine which might lead to human drudgery if it is used for long time. Moreover, handle dimensions (length & diameter) had to be modified for better grip. Therefore, the weeder has to be modified to suit local operators (farmers) for better performance and it adoptability in hilly areas.

Fig 16. Field testing of mini-tiller for weeding operation on terraces

Evaluation of Automatic Solar drip Irrigation System Suitable for Mid Hills of Meghalaya

The microcontroller based automatic control system for gravity drip irrigation system was designed and developed. The system consists of ATmega 16A microcontroller, resistance type soil moisture sensor, LCD display and other peripheral components. The printed Circuit Board (PCB) of the system is also designed in Eagle software and developed by using itching method with ferric chloride solution.

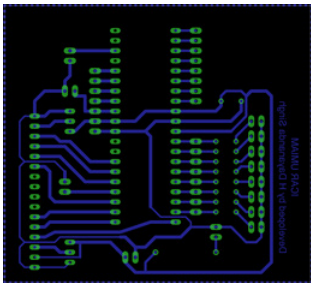


Fig 17. Designed PCB in Eagle software

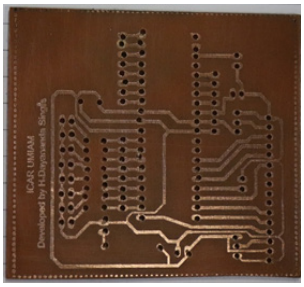


Fig 18. Developed PCB by using itching method

The system need two source of power supply i.e. 5V to supply to the micro controller unit and 12 V to operate relay for the water pump. The overall current consumption of the system is about 180 mA. The soil moisture sensor was calibrated by using soil samples of different moisture content. The calibration curve of soil moisture sensor is shown in Fig 19 (a & b).

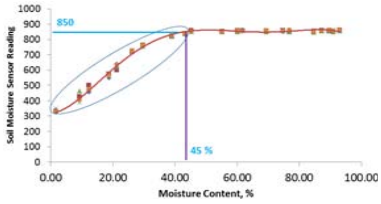


Fig 19a. Calibration curve of soil moisture sensor

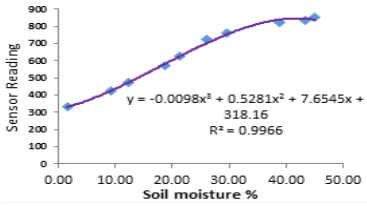


Fig 19b. Calibration curve of soil moisture sensor (up to 45%)

It was found that the moisture sensor can significantly detect soil moisture content up to 45%. Soil is too saturated when the soil moisture content is more than 40%. The sensor cannot differentiate moisture content above 45%. A field experiment was conducted to determine the field capacity of the silty loam to clay loam soil. An area of 1.0m × 1.0m was clean and leveled. It was inundated with water and covered with plastic film. The area was kept for 48 hr and soil sample from the area were collected (Fig 20). Field capacity of the soil is presented in Table 12.

Fig 20. Field experiment for determining Field Capacity

Table 12. Field capacity of soil (oven drying)

Container	Empty weight (g)	Wet soil+ container (g)	Dry soil+ container (g)	Moisture content (%) dry basis	Remark
A1	42.16	181.54	146.19	33.98	
A2	37.99	200.88	159.34	34.23	Highest
A3	39.15	202.1	160.66	34.1	
A4	38.51	210.24	166.77	33.89	
A5	45.5	180.87	147.37	32.89	
A6	65.4	215.69	178.75	32.59	
A7	39.41	178.92	144.38	32.9	
A8	38.83	214.45	170.75	33.13	
A9	37.33	191.03	153.29	32.55	
A10	50.06	180.78	148.3	33.06	
A12	37.11	192.12	154.19	32.4	
A13	47	190.25	155.1	32.52	Lowest
A14	36.64	163.06	131.82	32.82	

It was found that the field capacity of the soil is varying from 32.5 to 34.2 %. The wilting point of silty clay loam soil is about 15%. So, the available water to the plant is in the range of 15 to 34%. The algorithm for operating automatic control system is developed by using calibrated curve of the soil moisture sensor. The algorithm was developed for the soil moisture content in the range of 25 to 32%.

Agri-Consortia Research Platform on Water

One runoff water harvesting pond and one plastic lined *jalkund* was constructed in *Umroiwah* watershed. Runoff water from the watershed area was collected in the pond at the outlet of the watershed. The collected water was pumped to the polyline ponds (*jalkund*) located at the higher elevation of the watershed by using solar water pump. Mild slope terraces were constructed along with raised beds for plantation of crops. Vegetable crops like French bean, tomato, cabbage, chilly, bitter gourd, ginger and turmeric, etc. were planted on the prepared bed. Pits of different dimensions (3' to 1') were constructed for horticultural plantation in the area. Two piggery sheds of 16 m × 20 m were constructed in the watershed. Six piglets were kept in each pig shed. Water from the *jalkund* was used

for domestic use, irrigation of vegetables and for use in the piggery units. Fish culture is being undertaken with supply of fish feeds in both the water harvesting structures. During the year 2018, there was damage of crop planted in the field by hail storm in the area (Fig 21a). The productivity of French bean and chili were hampered due to the damage by hail storm. Only 87.4 kg of French bean and 17.6 kg chili (Fig. 21b) were harvested from 647 m^2 and 440 m^2 respectively. There was no effect of hail storm in the turmeric. The production of turmeric during the year 2018 was 147.3 kg from 240 m^2. All pigs are at the average weight of around 50 kg. Six piglets were born from one of the female pigs (Fig 21c).

Fig 21. (a). French bean crop damaged by hail storm

Fig 21. (b). Harvested French bean

Fig. 21 (c). Pig shed

Forecasting Agricultural Output through Space Agro-meteorology and Land Based Observations (FASAL)

Field experiments on maize (*cv*. RCM 76) and upland rice (*cv*. Bhalum 1) were conducted under FASAL project during 2018. Maize was sown on 26th April, while rice was direct seeded on 15th June. Rainfall during maize growing period (Apr-July, 2018) was 1268.5 mm against water requirement of 750 mm with 64 rainy days, whereas, during rice growing period (June-October), amount of rainfall was 1688.2 mm against requirement of 1000 mm with 81 rainy days. The crops did not suffer from any water stress during its growth periods. Maize and rice took 100 and 124 days, respectively to attain physiological maturity. DSSAT (Ceres-Maize) simulated maize yield of 1995 kg/ ha against observed yield of 1899 kg/ ha with over estimation of 5%. Simulated yield of rice was 2515 kg/ ha against observed yield of 2410 kg/ ha with over estimation of 4%. Considering acreage of maize and rice in Meghalaya as 18,463 and 63,587 ha respectively, expected (simulated) production of *kharif* maize and rice in Meghalaya may be 36.8 and 159.9 thousand tons during 2018, respectively.

Gramin Krishi Mausam Sewa (GKMS)

Agro-advisory bulletin service was started from May 1996 at AMFU, Umiam with the objectives of preparing AAS bulletin based on weather forecast received from state Meteorological Centre (medium range of 3-5 days) on every Tuesday and Friday after consultation with the Agro-Advisory bulletin board. It provides weather forecast to the farmers along with Agro-Advisory guidelines for economic management of farm operations, taking feedback from farmers and analyzing for improvement of AAS, assessing the feasibility of the forecast and communicating daily recorded meteorological data to Regional Meteorological Station, Guwahati, Meteorological Centre, Shillong and uploaded in IMD Agromet website (www.imdagrimet.gov.in) for improvement of weather forecast. Agromet advisories are prepared by expert groups (Scientists of ICAR, Umiam) based on the weather forecast received from Meteorological Centre, Shillong along with Tools & techniques like Normalized Difference Vegetation Index (NDVI) & the Standardized Precipitation Index (SPI) for 11 districts of Meghalaya received from IMD, Pune. Agro-advisories are disseminated to media like AIR, DDK, Local news papers, etc. through e-mail, SMS and Telephonic conversation. Prepared agro-advisory bulletins are uploaded in IMD Agromet website (www.imdagrimet.gov.in) & Kiran website (www.kiran.nic.in) for dissemination. Umiam AMFU has been sending the advisory bulletin as well as sms to all the KVKs of the state, State Agril/Horti officers for

forwarding the sms to beneficiary farmers. During the period under report, 1,122 numbers of AAS bulletins were prepared and disseminated to the farmers. In addition, 95,829 numbers of sms were sent to the farmers through mkisan website (*www.mkisan.gov.in*) portal of Ministry of Agriculture, Government of India.

AICRP on Plasticulture Engineering and Technology

Sub project: 1. Assessment of Gravity-fed Drip Irrigation System for Mid-hills of Meghalaya.

The understanding of solar energy availability in the region becomes the first step for development of the proposed system. Available bright sunshine hours (BSS) data from 1986-2015 were analyzed. The BSS varied from 2.8 hrs/day during July to 7 hrs/day during March with average annual duration of 5.2 hrs/day.

Table 13. Average monthly values of different weather and its derived parameters

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative humidity (%)	Wind speed (km/day)	Bright Sunshine (hours)	Shortwave Radiation (MJ/m²/day)	ETo (mm/day)
January	6.5	19.2	73	71	6.6	13.6	1.93
February	8.8	21.6	69	84	6.8	15.6	2.48
March	12.7	25.4	62	116	7	18.1	3.52
April	16.1	27.1	66	122	6.6	19.1	4.02
May	17.9	27.2	77	96	5.1	17.7	3.67
June	19.9	27.5	83	69	3.2	14.8	3.17
July	20.6	27.6	83	62	2.8	14.1	3.08
August	20.2	27.8	83	57	3	14	3.04
September	19.1	27.1	83	54	3.4	13.5	2.85
October	16.2	25.8	80	54	5.2	14.1	2.72
November	11.7	23.4	75	57	6.5	13.7	2.32
December	8	20.6	74	62	6.5	12.8	1.92
Average	14.8	25	76	75	5.2	15.1	2.89

Using the available weather variables the shortwave radiation was calculated by Angstrom's method. The reference evapotranspiration (ETo) was calculated using the most accepted Penman-Monteith formula using CROPWAT 8.0.The average monthly ETo varied from 1.92 mm/day during December to 4.02 mm/day during April with an average value of 2.89 mm/day. Two sites were selected and detailed topographical survey were undertaken in the field of division of agricultural engineering for developing the complete system of solar drip irrigation system as a prototype for training and demonstration and in the farmers' fields for stake-holders of the region in the Umdohbyrthih village, Ri-Bhoi, district. Seven (7) terraces of the agricultural engineering division farm having a total area of 500 m^2 with the elevation difference of 7.8 m between the top and bottommost terrace were selected. Water from the pond near to the bottom most terrace is to be pumped to overhead tank at the top terrace by using solar powered pump. Another field of 1500 m^2 area with elevation difference of 7.1 m was selected at the field of farmer at *Umdohbyrthih* village at 10 km from the Division. There is a perennial stream which is about

113.8 m away from the top terrace with the elevation difference of 14.83 m between the top terrace and the bed of the stream. Based on the survey capacity of the pump has been estimated as 0.5hp (0.37kW) with discharge capacity of 1100 lph and battery capacity of 120Ah. Assuming efficiency of the system at 80%, power required would be 370/0.8 =462.5W and current required as 462.5/24 = 19.27A. The system can back up at 120*0.8/19.27 =4.9818 hr (4 hr 58 minutes).

Development and Assessment of Microcontroller Based Solar Tunnel Drier Suitable for Heavy Rainfall Region of Northeast India

Solar smart tunnel drier of dimension 6 x 5 m was designed with elliptical roof of height of 1.8 m at side and 2.8 m at middle. Frame was constructed with 1" HS pipe pipe along with rafter of 30 mm × 5 mm Mild Steel (MS) flat. A 3 D model of the designed tunnel drier is shown in Fig 22.

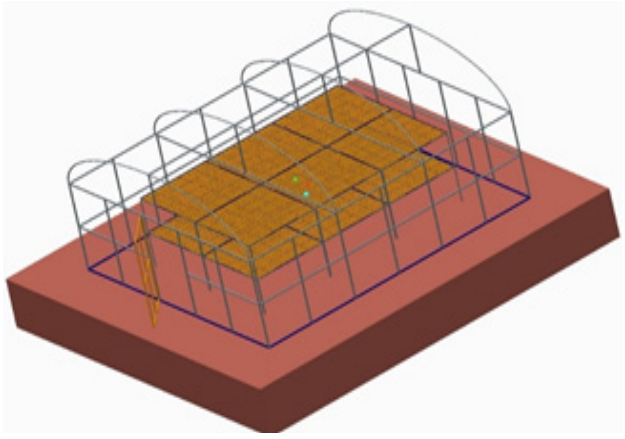


Fig 22. A 3D structural model of smart tunnel drier

12 numbers of trays of the dryer of 1.5 m × 1.5 m (capacity to hold 10 kg of sliced turmeric in a tray) was fabricated from aluminum sheet and wire mesh. The trays are supported by a stand which can support 2 numbers of trays, thus having 6 numbers of stands to hold 12 numbers of trays. The movement of the air to and fro from the tunnel dryer to the surrounding environment is controlled by microcontroller supported by humidity and temperature sensors, solenoid valve and DC Fans. The power required for operating tunnel dryer is supplied by 150 W_p Solar panel.

Fig 23. Construction of frame for Solar smart tunnel dryer

AICRP on Farm Implements and Machinery

Design and Development of Sowing Attachment for Lightweight Power Tiller Suitable for NEH region

A sowing attachment for light weight small engine (BCS make of weight: 69 kg and prime mover: 4.1 kW engine) was designed and fabricated with appropriate metering (Fig. 24a). It consists of main frame, seed box, adjustable furrow opener and ground wheel (Fig. 24b). The rotors type of metering mechanism having cells on periphery was fabricated for use in seed metering. Provision was made in design for changing rotors as per crops requirement. Rotor having 6 cells, 12 cells and 14 cells were used for sowing of maize, soybean and pea respectively. The specifications and test results are as follows.

Specifications of sowing attachment

Overall Dimensions (l x w x h), mm: 700 x 900 x 500

Weight: 21 kg

Type of metering mechanism: Rotor type having cells on periphery

Type of furrow opener: Inverted T-Type

Number of row (with adjustable row spacing): 2

Crop: Maize, soybean & pea

Fig 24 (a). Light weight power tiller

Fig 24 (b). Developed sowing attachment

The sowing attachment with inverted-T furrow opener was used to cover 0.25 ha for pea and total time requirement was 3 hours 41 minutes. Field capacity obtained from field testing is presented in Table 14.

Table 14. Field capacity and field testing observation of developed sowing attachment

Area covered (ha)	0.25
Time (hour)	3.68
Average depth of sowing (mm)	40
Row spacing (mm)	250
Average speed (km/h)	1.6
Average field capacity (ha/h)	0.068
Theoretical field Capacity (ha/h)	0.080
Efficiency (%)	85

The developed sowing attachment with inverted-T type furrow opener is having average field capacity of 0.068 ha/ h when sowing pea with row spacing of 250 mm at the depth of 40 mm.

Development of Complete Mechanization Package for Pineapple Cultivation in North Eastern Hill Region

Pineapple is one of the most important fruit crops both in terms of area under plantation and production in the north-eastern region of India. The sub-project was initiated to identify and evaluate suitable tools and equipment for different operation in pineapple cultivation; and to modify/adopt tools and equipment for mechanized cultivation of pineapple in the region. It was observed that all the farmers are using locally made hand tools and no improved tools or equipment are being used in the Meghalaya and other pineapple growing states of NEH region (Table 15 and Fig. 25) . From the preliminary study it was found that weeding and harvesting are two major operations, which requires more human energy.

Table 15. Various cultural practices followed by farmers for Pineapple cultivation

Operation	Starting Time	Ending	Implement Used	Power source	Power requirement
Land Preparation	December	January	Spade /Dao	Human	35 man-days/ ha
Planting	March	April	Spade	Human	40 man-days /ha
Weeding-I	June	July	Spade/Dao	Human	100 man-days/ha
Weeding-II	September	October	-do-	Human	75 man-days/ha
Weeding-III	February	March	-do-	Human	25 man-day ha
Harvesting-I	July	August	Sickle/Dao	Human	30 man-days ha
Harvesting-II	November	December	- do-	Human	20 man-days/ha
Uprooting and replanting of Sucker	November	January	Dao/Spade	Human	75 man-days/ha

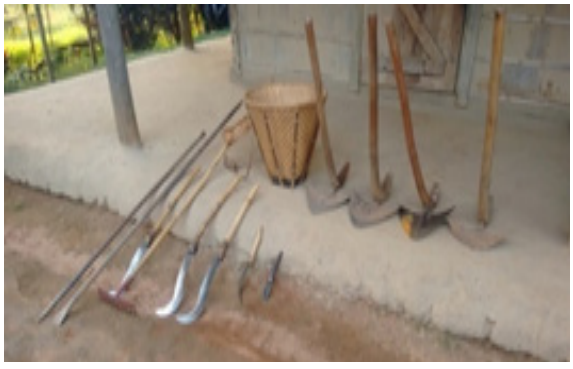


Fig 25a. Tools used in pineapple cultivation

Fig 25b. Sucker preparation with *dao*

Fig 25c. Weeding using local spade

Fig 25d.Pineapple harvesting with local sickle

Fig 25. Pineapple cultivation in Meghalaya

Prototype Feasibility Testing of Farm Machinery

The motorized pineapple harvester developed by the Central Agricultural University (CAU) is tested in the farmer's pineapple field at Ri-Bhoi district. The specifications of the developed equipment are presented in Table 16.

Table 16. Specification of the developed pineapple harvester

Engine Type	4 stroke petrol engine
Make	DKK
Power (kW)	1.5
Cutting unit	Circular saw having diameter of 130 mm with 100 numbers of teeth
Pineapple Holding unit Caliper Holder with the provision to contract and release by operating a lever (similar to caliper brake of bicycle)	

The harvesting performance of the machine was compared with the manual harvesting. It was found that a person can harvest manually on an average 50 fruits/hr against 32 fruits/hr by motorized pineapple harvester. The efficiency of the motorized pineapple harvester is 64% of that of manual harvesting. The reduced in the efficiency for motorized harvester may be due to the difficulty in using Pineapple holding unit while harvesting lodged fruits. The operator has to hold the pineapple first and push the equipment to cut the pineapple. In many attempts, the pineapple holder could not hold the harvested fruits and need for minor adjustment. There seems to be problem with the lever. As the lever is fixed with the harvesting equipment, there is difficulty in harvesting lodged fruits as it has to turn in different position.

Frontline Demonstration of Farm Tools and Machinery

Front line demonstrations of self-propel vertical conveyor reaper, power paddy thresher cum cleaner, hand operated winnower and posthole digger were conducted in the farmers' field. VST make self-propel VCR having 1000 mm cutter bar length, 4 Nos. of crop divider and 5 hp diesel engines were demonstrated for harvesting paddy in terraces and valley lands. STIHL make engine operated posthole digger having 635 mm length and 150 mm diameter augur was demonstrated for digging holes. Power paddy thresher cum cleaner and hand operated winnower developed by Division of Agricultural Engineering of the institute were demonstrated in 9 villages for threshing & cleaning paddy in the farmers' field for popularization (Figure 26).

Fig 26. Frontline demonstration of farm tools and machinery

Prototype Manufacturing of Farm Tools and Equipments

Prototypes of farm tools and equipments (593 numbers) were fabricated during January to December, 2018 under AICRP on FIM and Revolving Fund Scheme on "Commercialization of farm tools and Machinery for Hill Agriculture" and supplied to government, non-government organizations, KVKs and individual farmers of NEH states (Table 17).

Table 17. Prototypes of farm tools and equipments manufactured and supplied during 2018

Prototypes Fabricated and Supplied	Quantity/No.	Prototypes Fabricated and Supplied	Quantity/ No.
Maize sheller	165	Zero till furrow opener	10
Garden rake	42	V-blade weeder	24
Wheel hoe	23	SRI row marker	07
Grass slasher	57	Briquetting mould	19
Cono weeder	13	Groundnut decorticator	05
Straight blade weeder	15	Metallic tip dibbler	07
Hand Fork	49	Hand operated winnower	16
U-blade weeder	67	Manual Trolley	05
Adjustable Row Marker	38	Paddy thresher pedal type	08
Manual Fruit harvester	23		

SOCIAL SCINECES

District level crop production dynamics in north eastern states of India

The crop–climate relationship was quantified using Seemingly Unrelated Regression Model. The food grain yield of eight (8) states located in the region called North Eastern Region (NER) of India is likely subject to similar disturbances. In many national programs and policies, many a times this region is regarded as one unit. This is because, agronomic inputs, soil behaviour, agro-economic scenario, climatic situations, land use patterns, food habits, traditions and many more of the region are in a similar line of business in spite of its interstate variations and differences. Moreover, the practices, the activities, the policies etc. are of the same sector called agriculture and any change in agriculture policy regulations will affect all the states in this sector. Hence, there is a strong possibility that the unexplained disturbances which affect the eight states' food grain yield are contemporaneously correlated (i.e., the unexplained factor that affects a state's food grain yield at time t may be correlated with a similar factor that affects another state's food grain yield at the same time). OLS regression of individual states cannot capture this correlation. Therefore, the observations are pooled and treated the model as a joined-eight-equation system. The jointness of the equations is explained by the structure of the Seemingly Unrelated Regression Equations (SURE) model and the co-variance matrix of the associated disturbances. Such jointness introduces additional information which is over and above the information available when the individual regression equations are considered separately. Therefore, this study analyses the effect of minimum temperature and rainfall on food grain yield of states of north eastern India taking the states in the form of simultaneous joint equations based on historical data from the year 1967 to 2013.

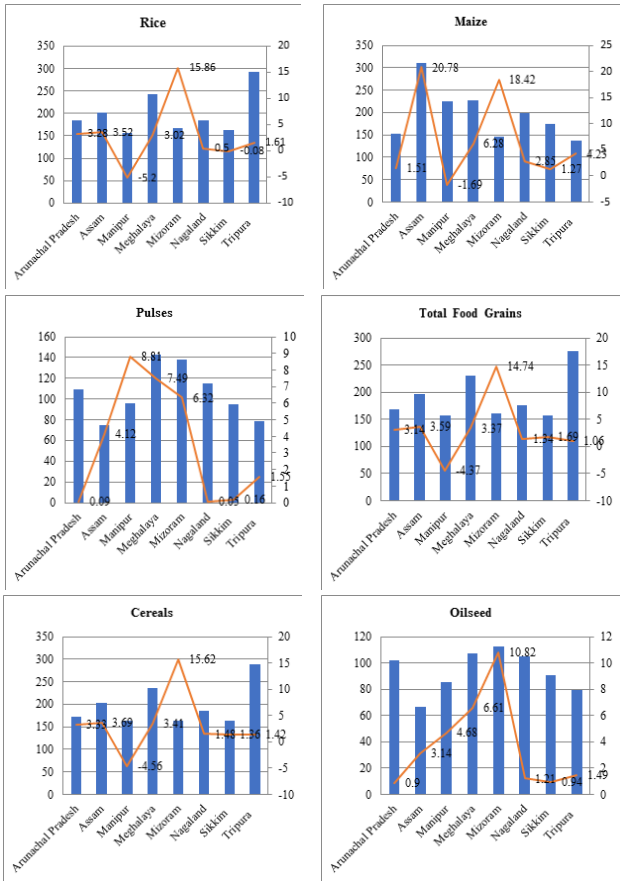
A family of SURE models had been explored in the study where cross-state correlation of the unexplained disturbances are detected significantly and came up with the best fit model namely Restricted Iterative SURE (RITSURE). The restriction imposed in the model is that the coefficients of rainfall of each state were equal and it was found that the restriction imposed were statistically valid (Table 18 & Fig. 27). The coefficients of minimum temperature were all positive and significant except Arunachal Pradesh where minimum temperature had a negative impact on food grain yield of the state and Mizoram where

the food grain yield was unaffected by minimum temperature as coefficients were insignificant. Effect of rainfall for each equation had been equalized by imposing restriction and it was found nearly significant at 5% level of significance but quite significant if we considered at 7% level of significance since the p-value was 0.0649.

Table 18. Parameter estimates of ITSURE with restriction of equal rainfall coefficients.

Minimum Temperature	Parameter estimate	Pr > |t|
Arunachal Pradesh	-39.5	0.0433
Assam	103.4	0.0271
Manipur	280.7	0.0189
Meghalaya	240.4	0.0024
Mizoram	92.3	0.6082
Nagaland	195.7	0.0355
Sikkim	61.8	0.0204
Tripura	509.7	<.0001
*Rain	13.7	0.0649

* coefficients of rainfall of each state are not significantly different.



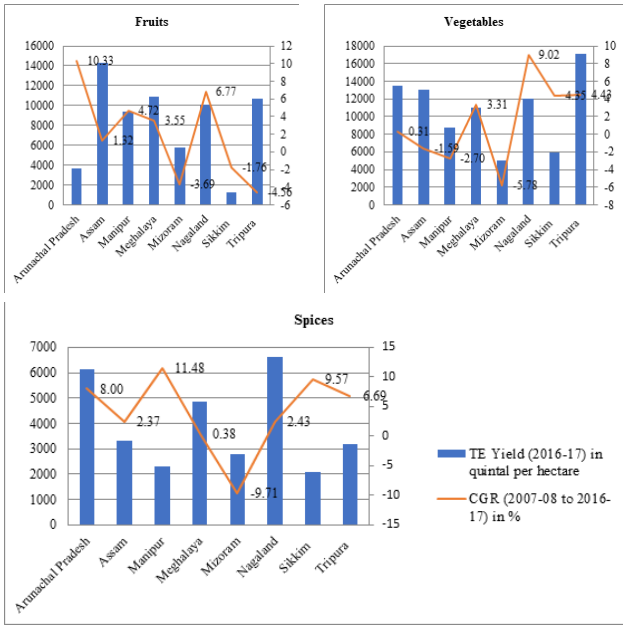


Fig 27. TE yield (2016-17) and CGR (2007-08 to 2016-17) of agricultural and horticultural crops in north eastern states of India

Study on Impact of Climate Change on Livestock and Local Adaptation Measures in Meghalaya

Seasonal variations of different livestock production viz., milk, egg and meat in Meghalaya were analysed. The time series seasonal data on three categories of livestock production, viz., meat, milk and egg for the period 1983 to 2015 were decomposed into trend, seasonal and random components. In all the districts as well as for the overall state, the seasonal components were found maximum in monsoon season (July-Oct) and minimum in winter season (Nov-Feb) for milk production. For the overall state, milk production from indigenous cows during winter was 497 tonnes lower than the average production over the seasons and highest during monsoon which was 543 tonnes higher than average. Milk production from crossbred cows during winter was 631 tonnes lower than the average and highest during monsoon which was 560 tonnes higher than average. Milk production from buffaloes accounted lesser seasonal variation since the winter production was only 21 tonnes lower than the average and monsoon production was 25 tonnes higher than average. Regarding egg production, in all the districts as well as for the overall state, the seasonal components were found maximum in monsoon season (July-Oct) and minimum in winter

season (Nov-Feb). For the overall state, fowls egg production during winter was 668 thousand numbers lower than the average production over the seasons and highest during monsoon which was 663 thousand numbers higher than average. Duck egg production during winter was 32 thousand numbers lower than the average and highest during monsoon which was 28 thousand numbers higher than average. However, as far as meat production was concerned, no consistent seasonality was observed in meat production across the districts of Meghalaya. For overall state, cattle meat production was highest during winter having 32 tonnes more production than the average across the seasons. Pig meat (pork) production was also highest during winter having 108 tonnes more production than the average across seasons. Poultry meat production was highest during monsoon having 50 tonnes more production than the average. The seasonality of average temperature in Meghalaya also showed maximum temperature in monsoon season (2.6°C higher than average of the seasons) and least in winter (4.05°C lower than the average of the seasons). The results imply that livestock production in Meghalaya is higher in warmer season and least in coldest season. The current status of climate in Meghalaya is at such that temperature is positively affecting the livestock production. The seasonality in meat production, which showed highest production in winter, has more to do with economic nature of the system such as trade and demand rather than climate.

Development of Strategies for Improving Effectiveness of Convergent Model of Extension Services in Meghalaya

Data obtained from the farmers' respondents regarding the extent of effectiveness of extension service provisioning revealed that among Central Govt. Organizations, most of the services in terms of inputs, information & advisory and Capacity Building were provided by ICAR (16.7%) followed by Krishi Vigyan Kendra (2%). Among the State Govt. Organizations, the greater role is played by State Agriculture Dept. (2.7%), State Horticulture Dept. (2.7%) and Community & Rural Dev. (2.7%). While among the Bank and private sector organizations, the major stakeholders were State Bank of India (SBI) and Rural Resource Training Centre (RRTC). The extent of need of extension services of farmers revealed that highest number of farmers require inputs (87.4%), Information & Advisory (69.8%) and Capacity Building (57.1%) for growing vegetables. The most prominent enterprises where the farmers needs assistance in terms of extension services are rice, maize, vegetable & ginger cultivation, piggery and poultry. To get the information about existing nature and extent of convergence among different extension organization (organizational perspective), a schedule has been developed and being used for data collection from different stakeholders. Data from different organizations is being collected which will be analysed for developing the suitable strategies for improving the effectiveness in delivering the extension services.

Designing of Participatory Decision Support System for Horticultural Crops in Meghalaya:

Data collected from the farmers' revealed that farmers' need assistance in form of visual description about the Production Technologies, Protection Technologies, Post-Harvest Processing & Value addition and Marketing through ICT means to save the time and resources for which information is being collected from the different credible sources. The experts were also being consulted to design and develop the appropriate and user-friendly Decision Support System covering major horticultural crops of Meghalaya which will be further evaluated for its usefulness, easiness and applicability in the extension system through different stakeholders. The Decision Support System will help the farmers and other extension professionals in addressing the framers queries and problems at their door step with their own convenience of time.

ANIMAL SCIENCES

LIVESTOCK PRODUCTION

Characterization of Burmese Black Pig: An Indigenous Germplasm of North East India

The North East region of India is one of the tribal community dominating regions where pig husbandry is a vital component of farming system. There are the 8 registered pig breed in India of which 4 breed belongs to this region, besides many indigenous pigs described by their local name yet to be characterized. One of the local pigs known as Burmese black pig are native to Indo Burma bordering states of India. They are mostly distributed in Champhai, Kolasib

and Siaha districts Mizoram; Ukhrul, Chandel, Churachandpur and Tamenglong districts of Manipur; and Phek, Kiphire, Tuensang and Mon district of Nagaland. Besides the Indo Burma bordering areas, these pigs are also found in East Khasi hills, West Khasi hills and Ribhoi districts of Meghalaya. In total, 251 pig farmers across 70 villages in 14 districts of Mizoram, Manipur, Nagaland and Meghalaya were surveyed, interviewed and information was collected regarding production system, rearing pattern, physical characteristics and performance of Burmese black pigs. In each district, a two stage stratified sampling technique was done. At least five villages within each district and two pig farmers within each village were chosen on random basis for the study. Data were collected from 674 pigs which include 613 pigs (270 male and 343 female) at different age groups viz. birth, weaning (3 month), 6 month, 8 month and 10 month for growth and body measurement traits, 61 sows for reproductive and litter performances traits. The present study revealed that this breed of pigs is reared by backyard system (64.94%), tethering system (3.59%), semi intensive (9.96%) and intensive system (21.51%) of management. The herd size ranges from 1 to 5 in backyard, 1 to 2 in tethering, 4 to 9 in semi intensive and 2 to 14 in intensive system of management. Majority of the farmers (83.27%) reared Burmese black pig for fattening purpose and very few farmers (16.73%) reared this pig for breeding purpose. Burmese black pig has unique physical characteristics and production performance that distinguished them from other indigenous pig breed of India. They are physically characterized by medium in size with a pure black colour, short hair or mostly sparse hair with dry skin and concave dish shaped head. The unique characteristics of these pigs have short upward curve snout and well build rotund body structure with short legs. The ear orientation has variation according to the age's viz., from birth to weaning it has pricked ears pointed upwards and with the advances of ages ear become projected forward to the head. Top line is almost straight in both sexes; however, it became gradually concave with the advances of age. The average body weight at birth, weaning (3 month) and 10 month were 0.91 ± 0.02,15.10± 0.32 & 82.33± 1.74 kg in male and 0.87 ± 0.01, 14.33 ± 0.25 and 77.92±1.10 kg in female (Table 1).

Fig 1. Burmese Black sow

Body weight of male was found to be significantly heavier than female in all the age groups except for birth where no significant effect of sex on body weight was observed. The different body measurement traits viz. body length, height at withers, heart girth and neck girth at different age group of Burmese black pig are given in Table 2. There was no significant effect of sex on different body measurement at birth and weaning except for heart girth where male piglet revealed significantly higher heart girth than female at weaning age. However, male pig revealed significantly higher body length, height at withers, heart girth and neck girth at 8 month and 10 month of age. The reproductive trait performances of Burmese black pig are represented in Table 3. The average litter size at birth and weaning were found to be 10.76 ± 0.87 and 8.86 ± 0.61. From the present study it was observed that the body weight of Burmese black pig was higher than the indigenous pigs of India. Besides this pig has very good reproductive efficiency and also produce higher number of litter size at birth and weaning under field condition which can improve further providing optimum managemental condition. Till now there was no documentation on distribution, physical characterization and performance evaluation of Burmese black pig. Hence, information from the present study can be use as base line information for implementation suitable breeding policy for its genetic improvement and conservation strategies under the existing production system of North east region of India.

Table 1. Body weight (kg) of Burmese Black Pig at different ages under field condition

Age Group	Male	Female
Birth	0.91 ± 0.02 (61)	0.87 ± 0.01 (73)
Weaning	15.10[a]± 0.32 (93)	14.33[b]± 0.25 (117)
6 Months	46.16[a]± 0.96 (52)	43.90[b]± 1.01 (67)
8 Months	68.17 [a]± 1.14 (36)	64.82 [b]± 1.02 (47)
10 Months	82.33 [a]± 1.74 (28)	77.92 [b]±1.10 (39)

Table 2. Body measurement (cm) traits of Burmese Black Pig at different age group under existing production system

Age group	Body length		Height at withers		Heart girth		Neck girth	
	Male	Female	Male	female	Male	female	Male	female
Birth	21.09 ± 0.34 (61)	20.87 ±0.32 (73)	14.34 ±0.25 (61)	13.96 ±0.23 (73)	22. 15 ±0.36 (61)	21.53 ±0.37 (73)	19.03 ±0.42 (61)	18.26 ±0.48 (73)
weaning	54.62 ±0.72 (93)	53.07 ±0.77 (117)	37.04 ±0.44 (93)	36.16 ±0.49 (117)	54.06[a] ±0.81 (93)	52.41[b] ±0.79 (117)	50.01 ±0.88 ((93)	48.65 ±0.68 (117)
6 months	70.17 ±1.07 (52)	69.35 ±0.96 (67)	54.37 ±0.85 (52)	53.77 ±0.79 (67)	72.42[a] ±0.98 (52)	67.69[b] ±0.83 (67)	65.16[a] ±0.85 (52)	61.85 [b] ±0.78 (67)
8 moths	78.94[a] ±0.91 (36)	76.29[b] ±0.86 (47)	58.95[a] ±1.67 (36)	57.20[b] ±1.51 (47)	81.09 [a] ±1.55 (36)	77.21[b] ±1.66 (47)	74.19[a] ±1.04 (36)	69.02[b] ±0.85 (47)
10 months	84.86 [a] ±1.76 (28)	81.66[b] ±1.70 (39)	61.94[a] ±1.52 (28)	60.15[b] ±1.60 (39)	87.06[a] ±2.41 (28)	83.05[b] ±2.10 (39)	78.27[a] ±1.98 (28)	75.02[b] ±1.81 (39)

Table 3. Reproductive performance traits of Burmese Black Pigs under field condition

Reproductive Parametres	Mean ± SE
Age at first heat (days)	220.32 ± 23.61 (60)
Age at first conception (days)	248.43 ± 20.96 (57)
Age at first farrowing (days)	365.00 ± 20.75(53)
Gestation period (days)	116.57 ± 1.78 (53)
Inter farrowing interval (days)	191.80 ± 6.72 (38)
Litter size at birth (no)	10.76 ± 0.87 (53)
Litter size at weaning (no)	8.86 ± 0.61 (53)
Litter weight at birth (kg)	9.57 ± 1.01 (53)

Value chain and Production economic of pig production system in Meghalaya

The main purpose for the development of livestock value chain management is to enhance income of the farmers and promote entrepreneurship development of the livestock sector. Most of the producer farmers reared pig up to adult for fattener purpose. Successful farmers required some important impute like feed, veterinary services (drugs), financial support. Around 70% of pig production cost goes to feed only and it can be reduced by incorporating locally available feed ingredients.Majority of producer, 80% reared pig goes for fattener purposed and remaining 20% goes for breeding. Around 90%

products go to aggregator and remaining 10% goes to retailer and then 70% of product goes to consumer. Again a 15% buying product goes to hotel/restaurant and finally goes to consumer of rural and urban.

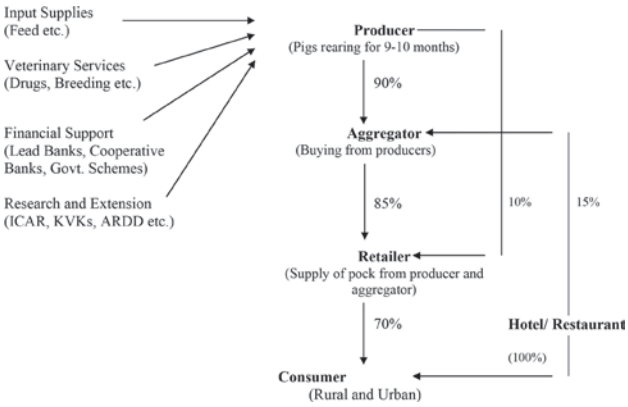


Fig 2. Value chain of Pig production system in Meghalaya

Among the 152 households surveyed, 78.8% of the farmers were smallholders having only one to two pigs, and the remaining farmers practiced pig farming in either semicommercial (18%) or commercial (3.2%) scale. In the study area, the majority of pig population (77%) was of nondescript local type. In general, the pig sties were made up of locally available materials. The floor of pigsty was madeup of concrete (36%), wooden plank (26%), bamboo pole (22%), or earthen floor. The sidewalls were made of wooden plank (62%), bamboo pole (26%), stems of some plants (9%), and brick-cement (11%). Tin roof (68%) was the most commonly used material in covered area of the house, followed by thatched roof with locally available grass and weeds (23%), and other materials like plastic etc (9%). Generally, the pigs were fed with local vegetation, agro-wastes, and household kitchen wastes. About 73.8% of farmers fed the pigs solely with locally available materials. Remaining farmers fed their pigs with different level of concentrate feed purchased from market in additionto the locally available agro-waste.

The present cost of buying piglets for one piggery unit *i.e.* three female and one male is Rs. 10,000 and feeding cost per day per unit is Rs. 94 by comprising mixture of concentrate feed with locally available feed like rice bran, broken riceand kitchen waste.Feeding and veterinary cost upto 10 month are Rs.28, 200 and Rs.14, 00. Monetization labour charge of 1 hour per day for 37.5 man-days is Rs. 11,250. The average litter size per pig per farrowing is 8 numbers. The total cost of 22 piglets selling is Rs. 66,000 by considering10% mortality. A net profit of piglets per farrowing per unit is Rs. 26,550. The total cost of feed is Rs 6,300 by continuing upto 10 month of age *i.e.* 15-300 days. The cost of veterinary expenditure like medicine and vaccine is around Rs. 350. The labour charge goes around Rs. 1800 per pig for 10 month duration of rearing pig. The cost of selling pig at 86 kg live weight is Rs. 8450. The cost of production per kg pock is Rs 136 by considering 72.33% of dressing percentage.

Retort pouch processing of ethnic pork delicacies of North East India

Ethnic pork delicacies prepared from indigenous recipes of North East India could be popularized and made accessible for consumption beyond geographic boundaries using retort processing technology. Retorted products can be stored at room temperature which aids in long distance distribution and marketing. In this study, experiments were conducted using horizontal retort for two different pork delicacies (pork with bamboo shoot; pork with sage (*Salvia officinalis*) to develop standard formulations and respective process parameters to produce shelf stable products. Several repetitions resulted to standard formulations for pork with bamboo shoot (60% pork; 7% bamboo shoot; 33% spices and condiments) and pork with sage (60% pork; 5% sage; 35% spices and condiments). Deboned pork chunks (30-40 mm^2) were semi-cooked (□ 20 min) along with spices and condiments previously fried in hot oil with water (16%) to produce a curry like consistency for both products; however, one is added with bamboo shoot; another with sage. About 180 g were filled into four layered retort pouches (dimensions: 20 cm x15 cm) and sealed using retort pouch sealing machine. Thermal processing was carried out at 121°C and 18 ± 2 psi at three different F_0 values (7.5, 8.0 and 9.5) for both the products in three runs respectively. Total process time at F_0 value of 7.5, 8.0 and 9.5 took 40±3 min, 45±2 min and 50±5 min respectively. Retorted samples of different products at three different F_0 values were stored for shelf life study and analyzed for storage stability based on the results of proximate analysis, texture analysis and microbiological enumeration.

Effect of silage feeding on the milk quality parameters in the Tharparkar cross cattle

A comparative study was conducted to study the effect of silage feeding on the productive performance of the Tharparkar cross cattle in terms of milk fat, Density, Lactose, SNF, Protein and salt content. The silage was fed to the animals @ 4kg per day and the amount of the concentrate given to animals was reduced to half. The feeding was continued upto 20 days and the milk analysis was done thereafter with the help of automatic milk analyzer. The statistical analysis revealed that the Fat content, SNF, Protein and density of the milk increased following the silage feeding though the results did not vary significantly. As it is evident that the silage was fed to the animals only for 20 days due to limited amount, it may be assumed that silage feeding over a period of time may significantly improve the milk quality parameters and can be a source of fodder during the lean periods.

Table 4. Effect of silage feeding on the milk quality

Parameters	Before Feeding	Post-feeding
Fat	4.42±1.23	4.45±1.09
Density	29.25±4.69	31.01±3.64
Lactose	4.63±0.92	4.77±1.01
SNF	8.45±1.66	8.69±1.23
Protein	3.13±0.98	3.18±0.68
Salt	0.70±0.05	0.66±0.03

Training of the bulls for semen collection at the Institute Dairy Farm

Three HF cross bull were trained for the semen collection at the dairy farm of the institute. The process of onset of sexual behaviour took about 3 months in two bulls. Another bull did not start to mount on the dummy though he showed mounting behaviour in the open paddock. Both the bulls were found to of high libido on the basis of reaction time. The various parameters that were measured for the libido assessment were licking of preputial area, protrusion of penis, nudging and time taken to show Flehmen's response. The reaction time in two bulls was found to be less than one minute. All the bull showed penile protrusion following the exposure to the dummy.

POULTRY SCIENCE

Evaluation of fresh semen characteristics of Turkey birds in Meghalaya

A preliminary study was carried out to evaluate the fresh semen characteristics of turkey birds under the agro-climatic conditions of Meghalaya. Six turkey toms of six months age were trained for semen collection through massage method. A total of 48 ejaculates (8 per bird) were collected during study. Immediately after collection the volume was recorded. The ejaculates were transferred to laboratory and evaluated for initial motility, livability percentage, sperm concentration and percentage of intact acrosome. For initial motility, semen was diluted in 0.3M glucose and one drop diluted semen was placed on a pre-warmed (37°C) glass slide with cover slip and examined under low power magnification. The livability percentage was calculated following Eosin-Nigrosine stain. Sperm concentration ($x10^9$/ml) was estimated by use of Neubauer's counting chamber. The acrosomal status was studied after Giemsa stain. The average values of different parameters are given in Table 5.

Table 5. Fresh semen characteristics of turkey birds

Parameters	Mean ± SE
Volume (ml)	0.18 ± 0.01
Initial motility (%)	85.50 ± 0.72
Livability (%)	91.23 ± 1.18
Sperm concentration ($x10^9$/ml)	4.34 ± 0.68
Intact Acrosome (%)	96.35 ± 0.67

The different parameters are within the acceptable range. Artificial insemination will be further exploited and standardized for use in turkeys.

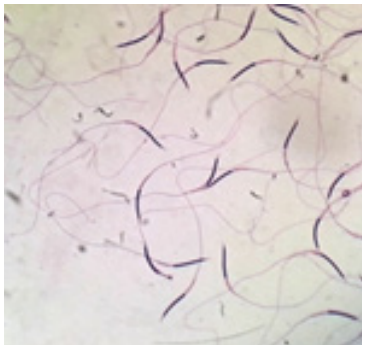


Fig 3. Turkey semen stained with Giemsa stain for acrosomal morphology (100x)

Fig 4a. Flock of Male Turkey bird

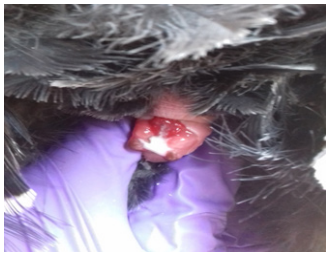


Fig 4b.Collection of semen by abdominal massage method

Effect of dietary supplementation of commercial feed additive on the performance of Vanaraja and Srinidhi parents under the agro-climatic condition of Meghalaya

An experiment was conducted to evaluate the effect of a commercially available feed additive on the performance, egg quality and certain stress biomarkers in Vanaraja and Srinidhi parent layers maintained under the agro-climatic conditions of Meghalaya. The study consists of 210 Vanaraja and 240 Srinidhi parent layers maintained under deep litter system. The Vanaraja parents were randomly divided into two groups*viz.* treatment and control, consisting 105 birds in each group. Similarly, Srinidhi parents were also randomly divided into treatment and control groups comprising of 120 birds each. The treatment groups of both the varieties were fed with basal layer mash supplemented with a commercial feed additive containing a combination of probiotics (*Propionibacterium freudenreichii*), neem (*Azadirachta indica),* MOS and toxin binder at the level of 1 kg/ton of feed for 4 months (28^{th} to 43^{rd} weeks of age). However, both the control groups received only basal layer mash. Statistical analysis was performed to compare means of treatment and control groups in both varieties for significant difference.

There was significant ($P<0.05$) increase in the hen day egg production (%) in Vanaraja treated group compared to control (57.57±1.57 and 40.27±3.71 percent, respectively). However, in Srinidhi parent groups a non-significant increase in the hen day egg production was reordered in comparison to control. Vanaraja parents showed no significant difference between treatment and control groups in terms of fertility and hatchability percentage. In Srinidhi parents, fertility percentage showed significant ($P<0.05$) improvement in treatment (78.86 ± 6.62) than control (67.84 ± 5.81) group. Different egg quality traits did not differ significantly between treatment and control groups in both varieties. The mean values of serum catalase, superoxide dismutase, glutathione peroxidase and cortisol also did not differ significantly between treatment and control groups in both Vanaraja and Srinidhi parents. Supplementation of feed additive containing a combination of probiotics (*Propionibacterium freudenreichii*), neem (*Azadirachta indica),* MOS and toxin binder in the diet revealed moderate improvement in performance traits of Vanaraja and Srinidhi parent layers maintained under the agro-climatic conditions of Meghalaya.

Studies on the modulation of energy in the ration of Srinidhi chicks in starter phase during summer season in Meghalaya

An experiment was conducted to compare the effect of feeding different energy levels on performance of Srinidhi chicks during summer season in Meghalaya. A total of 270 day-old Srinidhi chicks from a single hatch were randomly divided into three groups, *viz.* T_1, T_2 and Control, consisting of 90 chicks in each group which was further subdivided into 3 replicates of 30 chicks. The birds under T_1, T_2 and control groups were fed with Diet-1 (Containing 2700 ME Kcal/Kg and 18% protein); Diet-2 (Containing 2900 ME Kcal/Kg and 18% protein) and Diet-3 (Containing 2800 ME Kcal/Kg and 18% protein as per recommendation) respectively upto 8 weeks of age under battery brooder maintaining uniform managemental practices. The performance traits *viz.* total feed consumption, final body weight, body weight gain, FCR and serum catalase level were studied.

Srinidhi chicks fed rations with Diet-3 (Control group) and higher energy level of 2900 ME Kcal/Kg (T_2 group) during starter phase showed significant ($P\leq0.05$) higher final body weight, body weight gain, and improved FCR than chicks fed with lower energy level of 2700 ME Kcal/Kg (T_1 group). The total feed consumption per chick for different experimental groups was highest in T_1 group (2253.74g ± 36.22) and lowest in T_2 group (1425.55g ± 28.74). The final body weight per chick was highest in T_2 group (546.40g ± 16.25) followed by control group (541.55g ± 11.23) and T_1 (480.05g ± 16.72). The overall FCR was recorded best in T_2 group (2.79 ± 0.51) followed

by control (3.34 ± 0.47) and T_1 (5.09 ± 0.93) group. Serum Catalase level (nmol/ml) among the different experimental groups did not differ significantly. Present study showed higher final body weight, body weight gain, and improved FCR up to 8 weeks of age in Srinidhi chicks fed with diet having higher energy content. Thus, higher energy level may be incorporated in the diet of Srinidhi chicks during the starter phase to improve the overall performance.

Comparative performance of vanaraja and srinidhi chicken under backyard system of rearing in Meghalaya

Attempts have been made to improve the income of tribal farmers in Meghalaya by scientific intervention in rural poultry farming under the ST component of Poultry Seed Project of the institute. In this experiment, 50 tribal farmers of different villages of Ri-Bhoi district were selected and imparted training on scientific rural poultry farming. On completion of training, 25 farmers were provided 20 numbers of one month old Vanaraja chicks to each and rest 25 farmers were provided 20 numbers of one month old Srinidhi chicks to each. The chicks were reared under backyard system. The periodical vaccination of birds and technical guidance were given. The comparative performance of Vanaraja and Srinidhi birds in terms of mean body weight at various ages, mortality, age at first egg, egg weight and average monthly egg production per bird up to 40 weeks of age were recorded and finally overall income from sale of eggs and live birds were calculated. There was no significant ($p<0.05$) difference in mean body weight of Vanaraja (1835.36 gm ± 76.49 gm) and Srinidhi (1953.48 gm ± 67.50 gm) birds at the age of first egg but at 40 weeks of age, the body weight of Srinidhi (2667.65 gm ± 114.40 gm) birds was higher compared to Vanaraja (2311.11 gm ± 198.74 gm) birds. The average age at first egg was recorded to be earlier in Srinidhi compared to Vanaraja birds. The overall mortality up to 40 weeks of age was recorded to be higher in Srinidhi (12.66 %) than Vanaraja (9.44 %) birds. There was no significant difference in egg weight between two varieties, however average monthly egg production per bird was higher in Srinidhi (12.63 gm ± 1.76 gm) than Vanaraja (9.35 gm ±2.20 gm) birds up to 40 weeks. The study revealed that overall the income from both Vanaraja and Srinidhi birds were found to be similar and equally accepted by the farmers in Meghalaya.

Performance of Vanaraja and Srinidhi under intensive system at farmers doorstep

Five farmers were selected for rearing of four weeks old Vanaraja and Gramapriya chicks. Two farmers were given 100 Srinidhi chicks each and three farmers were given 100 Vanaraja chicks each from nearby villages of Nongpho. The chicks were supplemented with broiler starter feed and standard vaccination schedule was followed. The farmers were visited at bi-weekly interval. Body weights were recorded and proper medication was given as and when required. The body weight at 4,6,8,10,12,14 and 16 weeks of age on combined sex basis was 140, 356, 818,1046, 963,1088 and 1161 g and corresponding body weights on combined sex basis in Vanaraja were 155, 404,753,924, 998, 1089 and 1210g, respectively. The female body weights at 18,20, 22and 24 weeks of age were 1209,1495, 1960 and 2050g in Srinidhi and corresponding body weights for Vanaraja were 1210, 1341, 1564 and 1989g. The male body weights in Srinidhi were 2012, 2753, 3254 and 3428g and corresponding body weights in Vanaraja were 2431, 2794, 3195 and 3392g, respectively. The Vanaraja and Srinidhi body weights were almost similar under intensive system at farmers level.

ANIMAL HEALTH

Genomic epidemiology of antimicrobial resistant (AMR) *Escherichia coli* from food of animal origin and humans

Whole genome sequencing (WGS), assembly and phenotypic analysis indicated that isolates of beef, chicken and human origin were considerably more resistant to antibiotics (Fig 5a). Comparison of average nucleotide identity (Fig 5b) of 15 whole genome sequenced isolates identified clear difference in isolate LBA (SE37). Alignment of whole genome sequences revealed multiple instances of inversions and rearrangements in the genomes of MDR *E. coli* (Fig 5c). Phylogenetic analysis of isolates (Fig 5d) highlighted clear clonal overlaps among pork and chicken origin isolates and also between human and mutton origin isolates. Overall the study indicated that horizontal transfer of AMR genes as well as clonal dissemination of AMR *E. coli* across sources were major pathways for spread of MDR *E. coli* and therefore needs a multipronged strategy to combat this evolving health crisis.

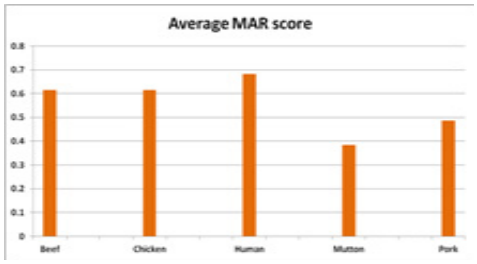


Fig 5a. Multiple antibiotic resistance score of E. coli isolates from various sources

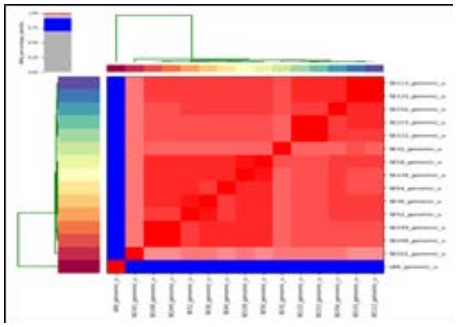


Fig 5b. Heatmap of average nucleotide identity of genomes showing distictnessn of LBA (SE37) genome

Fig 5c. Alignment of genomes of AMR *E. coli* showing multiple occurrences of inversions and additional genomic content for strain SE 161

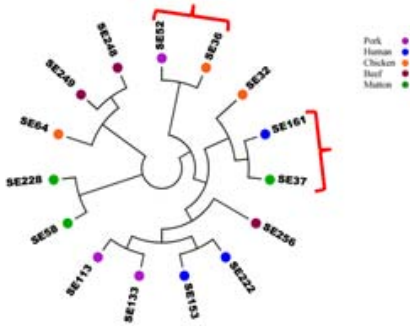


Fig 5d. Phylogenetic tree based on Whole Genome Sequences of AMR E. coli showing clonal overlaps among pork and chicken and also between human and mutton origin isolates

Whole genome sequencing of *Mycobacteriodes chelonae* M77 isolate

The whole genome analysis has been carried out in illumine NextSeq500 platform. Mauve analysis for alignment of isolate M77 with *M. cheloane* MOTT3W & *M. chelonae*strain CCUG genomes was carried out which revealed no significant re-arrangement of genomic segment. The synteny was carried out by SiBELia and represented by Circos plot for these three sequences which also strengthen the finding of Mauve. PathogenFinder1.1 for probability of being human pathogen showed that it was non-pathogenic with 0.324 values.

All India coordinated research project on Animal disease monitoring and surveillance (AICRP on ADMAS)

Serosurveillance of important livestock diseases namely Brucellosis, Bovine Viral Diarrhoea (BVD), Infectious Bovine Rhinotracheitis (IBR), Porcine reproductive and respiratory syndrome (PRRS), Classical swine fever (CSF), Porcine circo virus (PCV), Porcine parvo virus (PPV), Blutongue and peste des petis ruminants (PPR) were carried out (Table 6).

Table 6. Serosurvelliance report for 2018

Disease	Species	Sample number	ELISA positivity (%)
Brucellosis	Bovine	242	92 (38.02 %)
Brucellosis	Swine	319	7 (2.20 %)
IBR	Bovine	192	22 (11.46%)
BVD	Bovine	192	2(1.04 %)
PRRS	Swine	358	10 (2.80 %)
CSF	Swine	344	239 (69.5 %)
Trypanosoma evansi	Bovine	81	4 (4.93 %)
PCV	Swine	165	148 (89.70 %)
PPV	Swine	252	196 (77.78 %)
PPR	Goat	598	43 (7.20 %)
Bluetongue	Goat	598	360 (60.20%)

Seroprevalence of Leptospirosis in cattle of Meghalaya

A total of 276 bovine sera samples were collected from Ri Bhoi (n=92) and East Khasi Hills (n = 184) district of Meghalaya. All the serum samples were screened by Bovine *Leptospira Hardjo* Antibody Test (Linnodee Diagnostics) for detection of *Leptospira Hardjo* serovar antibody. Out of the total of 276 sera samples 23 samples were found positive for *L. hardjo* antibody.

Table 7. Serosurveillance of Leptospirosis in cattle

District Name	No. of samples screened	No. of +ve samples	Percentage positivity
Ri Bhoi	92	7	7.60%
East Khasi Hills	184	16	8.69%
Total	276	23	8.33%

Prevalence of *Clostridium perfringens* in rural duck population of Meghalaya

A total of 50 cloacal swabs were collected from rural duck population of Assam. All the samples were processed for the isolation of *Clostridium perfringens* by enriching in Robertson cooked meat broth media followed by plating in sheep blood agar. The isolation rate was found to be 34% (17/50). Followed by the isolation, all the susceptible isolates were confirmed by polymerase chain reaction (PCR) targeting species specific *cpa* gene. The prevalence of *C. perfringens* among rural duck population was found to be 34%.

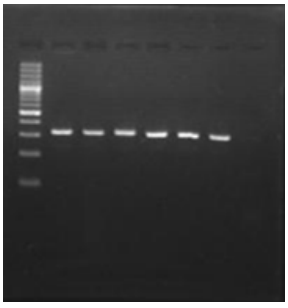


Fig 6. Confirmation of *C. perfringens* employing PCR targrting *cpa* gene

Collection of samples and screening of various viral diseases and bacterial pathogens (DBT ADMAC)

Serum and tissue samples were collected and screened for various diseases from Meghalaya and other North East region.

Table 8. Screening of porcine serum and tissue samples for various viral diseases and Brucellosis

Porcine serum samples						
State	**Sample**	**PRRSV (%)**	**CSFV (%)**	**PCV2 (%)**	**PPV (%)**	**Brucellosis (%)**
Meghalaya	460	16 (3.8)	341 (74.1)	297 (64.6)	284 (61.7)	7 (1.5)
Nagaland	380	21 (5.5)	149 (39.2)	-	-	-
Manipur	25	0	25 (100)	6 (24.0)	18 (72.0)	-
Mizoram	221	137 (62.0)	50 (22.6)	115 (52.0)	77 (34.8)	0
Ar. Pradesh	31	0	20 (64.5)	-	-	-
Assam	6	4 (66.7)	5 (83.3)	0	-	-
Total	**1123**	**178 (15.9)**	**590 (52.5)**	**418 (58.7)**	**379 (53.7)**	**7 (1.03)**
Porcine tissue samples						
Meghalaya	39	27 (69.2)	29 (74.4)	5 (12.8)	0	2 (5.1)
Mizoram	16	16 (100)	6 (37.5)	0	0	0
Tripura	5	0	3 (60.0)	0	-	-
Ar. Pradesh	13	0	0	-	-	-
Nagaland	11	Screened for JE (Result all negative)				
Total	**84**	**43 (58.9)**	**38 (52.1)**	**5 (8.3)**	**0**	**2 (3.6)**

Table 9. Screening of various samples for CDV

State	Species	Sample	No. of Sample	CDV (%)
Meghalaya	Canine	Serum	23	10 (43.5)
		Nasal swab	21	6 (28.6)
		Oral swab	24	6 (25.0)
Assam	Indian Jackal		10	10 (100)
	Leopard cat		2	2 (100)
	Jungle cat		1	1 (100)
	Himalayan black bear		1	0
	Leopard		2	2 (100)
	Stripped Hyena		1	1 (100)
Total samples			**85**	**38 (44.7)**

Table 10. Screening of Clinical samples (Livestock) of Meghalaya for bacterial pathogens

State	Sample	Sample	Bacterial pathogens observed
Meghalaya	Porcine tissues	14	*E. coli* (9), *S. aureus* (1)
	Canine	2	Negative
	Poultry egg	10	*S. aureus* (1), *Bacillus*sp (1)
Assam	Goat	1	*Mycobacterium* sp
Nagaland	Cattle tissue	2	*Staphylococcus* sp, *Proteus* sp
Total samples		**29**	

En-mass screening of manure samples for antimicrobial resistance

A total of 45 livestock manure including bovine (15), porcine (15) and poultry (15) samples were randomly collected from organized farms of Ri Bhoi district in Meghalaya. The pattern observed by conventional disc diffusion method showed 100% resistance to antibiotics belonging to each class. But the genotypic data obtained showed some variations in the prevalence of resistance genes. In order to analyze the load of antimicrobial resistance (AMR) genes in per gram of livestock manure (both organized and un-organized livestock farms), Real Time PCR protocols were standardized for 11 AMR genes (including at least 2 genes for each class of antibiotics). Standardization of qPCR protocols for the remaining AMR genes (Table 11) and 10 mobile genetic elements (MGEs includes *tp614, is1216, is4, is26, is6100, tnpA, is613, intI1, intI2, tn21* and *tn23*) are being carried out. These Real-Time PCR protocols would used to screen AMR and MGE genes load in manure of both organized and un-organized livestock farms.

Table 11. Antimicrobial resistance genes used to study AMR in manure samples by qPCR

Antibiotic groups	Targeted genes	Resistance against/Antibiotics
Aminoglycosides	*aac A, aphA, strA, aadA*	Gentamicin, Amikacin, Neomycin, Tobramycin
Beta-Lactams	*blaCTXM, blaTEM, blaSHV, blaOXA, mecA,ampC, imp,vim, ampC, cmy*	Penicillins, Cephalosporins, Monobactams, Carbapenems
Macrolides	*ermA, ermB, mphA*	Erythromycins, Azithromycins, Clarithromycin

Quinolones/ Fluoroquinolones	*qnrA, qnrB*	Norfloxacin, Ciprofloxacin, Nalidixic acid
Tetracyclines	*tetA, tetB*	Oxytertracyclines, Chlorotetracycline, tetracycline
Sulphonamides	*Sul1, sul2*	Co-trimoxazole, Trimethoprims
Chloramphenicol	*cat1,cmlA, cmxA*	Chloramphenicol
Glycopeptides	*vanA, vanB*	Vancomycin
Polymixin/Colistin	*mcr-1*	Polymixin E, Colistin

Cell lines used for isolation of viruses

Seventeen cell lines are maintained in the laboratory for various research purposes and these are shared with various research institutes and universities of North East region. In addition, to the previous work isolation of other viruses like Canine Distemper Virus (CDV) in MDCK (Madin–Darby Canine Kidney) cell line, Peste des petits ruminants (PPR) in Vero and MDBK (Madin-Darby Bovine Kidney) cell line, Marek's Disease Virus (MDV) in MDCK cell line and also Classical Swine Fever Virus (CSFV) in ESK-4 cell line are also going on.

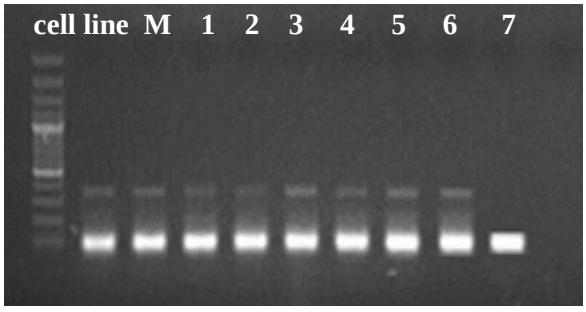


Fig 7. Amplification of CDV N gene by PCR from wildlife samples collected from Assam. Lane M: 100bp DNA ladder; Lane 2-7: CDV

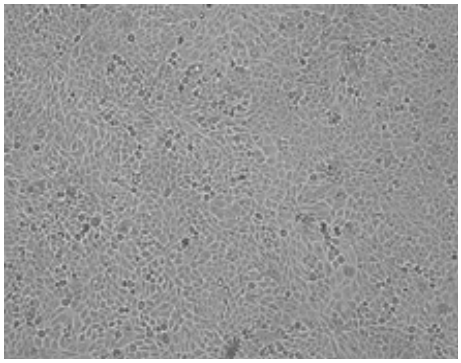


Fig 8a. Healthy (uninfected) MDCK

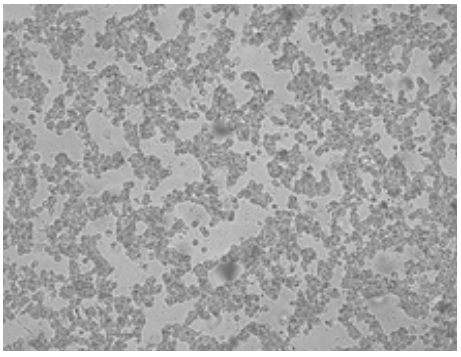


Fig 8b. MDCK cell line infected with CDV from Jackal brain

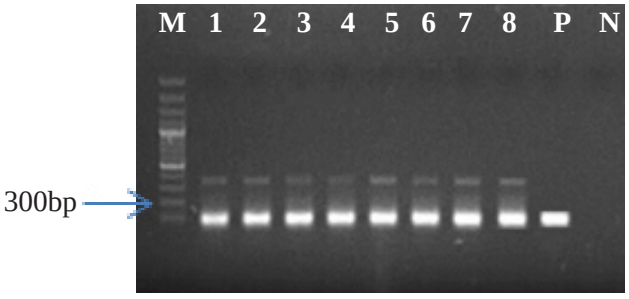


Fig 8c. CDV detection by PCR by amplification of partial N gene (320 bp)

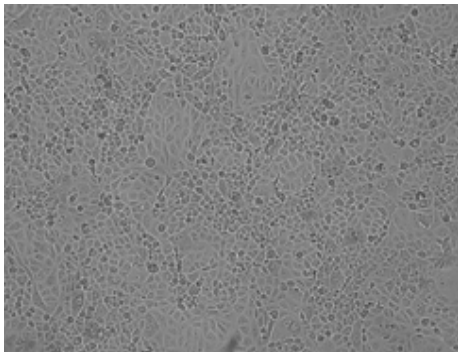


Fig 8d. Healthy (uninfected) Vero cell

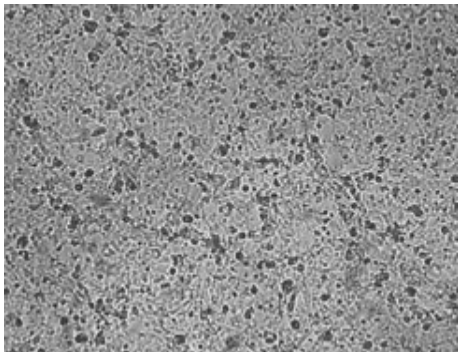


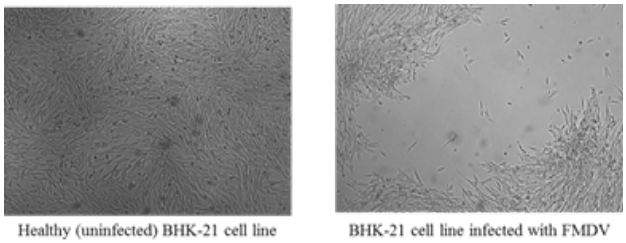
Fig 8e. Vero cell line infected with CDV from Jackal brain

Isolation of CSF virus (CSFV) in ESK-4 cell line

PCR positive tissue samples were subjected to virus isolation in ESK-4 cell line. The inoculum comprised of lung, intestine, liver, kidney and spleen from two piglets that positive for CSFV.

Isolation of Foot and Mouth Disease Virus (FMDV) in BHK-21 cell line

BHK-21 cells grown in DMEM (Dulbecco's Modified Eagles Medium, Sigma) with 10% foetal bovine serum (Himedia) were infected with skin lesions from pig (PCR positive for FMD Virus) collected from ICAR pig farm by co-precipitation method. The cells were passaged upto P 15 and all passages were confirmed by conventional PCR using partial 5'UTR region specific primers.



Healthy (uninfected) BHK-21 cell line | BHK-21 cell line infected with FMDV

Fig 9. Isolation of FMDV in BHK-21 cell line

Development of prototype RK-13 Cell line adapted CSFV live attenuated vaccine

Seven batches of experimental RK-13 adapted CSFV vaccine vials have been lyophilized and each batch contains 70-80 vials. 7th batch is from P-45 passage. Quantification of P-45 passage and freeze-dried vaccine from respective passage has been done by qPCR (StepOnePlus, Applied Biosystem). Phase I trials have been initiated in pigs using a total of 5 post weaned piglets of 4 month of age.

Association of PCV2 and CSF for the effects and severity of the disease (PWMS)

The study provided data of high prevalence of concurrent infection in the region sharing international borders (Garo Hills Division) which depicted a reflection of disease incidence in this region.

Fig 10a. Phylogenetic tree of PCV2 isolates from Meghalaya based on the cap gene sequences

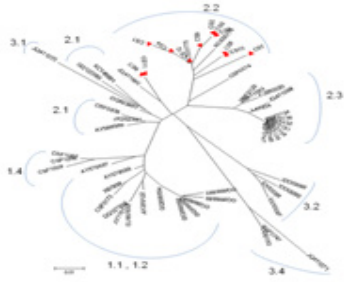


Fig 10b. Neighbour joining phylogenetic tree constructed from a 150nt 5'UTR fragment of Classical Swine Fever Virus (CSFV). Number of substitutions per site was 0.01.

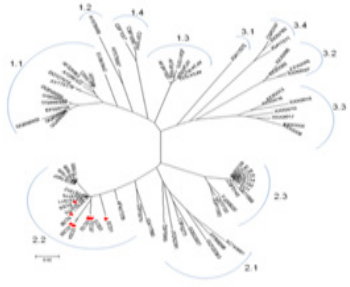


Fig 10c. Neighbour joining phylogenetic tree constructed from a 190nt E2 fragment of Classical Swine Fever Virus (CSFV). Number of substitution per site was 0.02.

This confirms that pigs in this region harbour these pathogens as reported by earlier studies on outbreaks of PCV and CSFV in pigs due to unrestricted animal movements through international borders. This also reveal the ubiquitous presence of PCV2 in all CSFV positive animals indicating that PCV2 being immunosuppressive, challenges CSFV vaccine efficacy and the need of PCV2 vaccination in this region. The genetic variability and phylogenetic analysis of the isolates was done based on the ORF2 fragment. The comparison of ORF2 fragment with other Indian isolates reveals nucleotide identity of 95-97%. The genetic clustering and phylogenetic analysis rooted by a PCV 1 isolate (AY184287 USA) indicates that four newly detected isolates (KY852347, KY863448, KY863446 and KY852356) clustered with PCV2b-1c isolates from China and five previously recorded Indian isolates. Two isolates (KY863444 and Ky863445)from this study clustered with PCV2d isolates from China and one Indian isolate from Manipur (NE India). Thus these two isolates are probably the first report of PCV2d genotype prevalent in Meghalaya.Three isolates (KY852355, KY852353 and KY852354) of this study clustered in PCV2a genogroup from China, Canada and Indian isolates from North India (KJ729073.1) and NE India. Interestingly, four isolates (KY852351, KY852352, KY852350 and KY863450) of this study did not cluster into both PCV2a and PCV2b genotypes. Instead these four isolates congregated into a new cluster with a distinct branch located between PCV2a and PCV2b along with two previously reported Indian recombinant isolates.The prevalence of CSF genogroup 2.2 was noted and detailed molecular epidemiology using both E-2 and 5' NTR sequences were carried out. Thus a general conclusion of the replacement of 1.1 viruses may be due to the higher replication rate and endurance and affinity to cellular receptors of subgroup 2.2 viruses.

Development of RTPSR technique for RNA viruses

The template target used in this study was the RNA from Classical swine fever virus isolated in embryonic swine kidney (ESK) cell line and from field outbreaks. The detection sensitivity of RTPSR method was as low as 0.053 ng/µl viral RNA per reaction and the detection time was within 60 minutes, the results can easily be distinguished through simple color changes, indicating that RT PSR can also be applied in biosensor based gene analytical instruments.

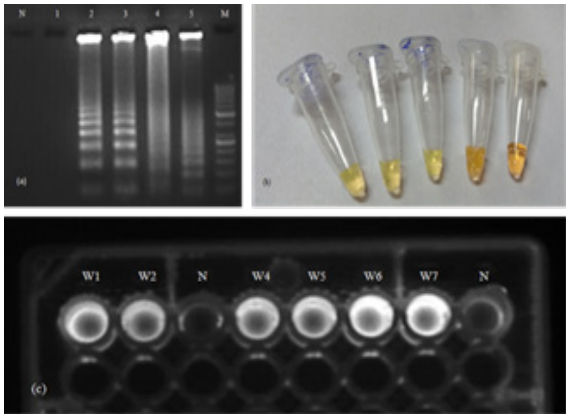


Fig 11a-c. Different mode of visualization of RT-PSR product in different mode. (a) Electrophoretic pattern of CSFV RT-PSR. (b) Normal light visualization after addition of SyBR green I dye. (c) Visualization of RTPSR product under UV light.

Protozoan parasitic infections of swine in Meghalaya

Monthwise highest and lowest infections of gastrointestinal protozoan parasites was recorded in the month of June (36.78%) and January (20.54%), respectively (Fig 12). The oocyst per gram (OPG) of feces ranges from 50-1250. Maximum and minimum OPG was recorded in the month of July (510.16) and January (115.06), respectively. Seasonwise, infections was recorded highest during rainy season (33.33%) followed by cool (27.87%), hot (24.23%) and cold (22.09%) seasons (Fig 13).

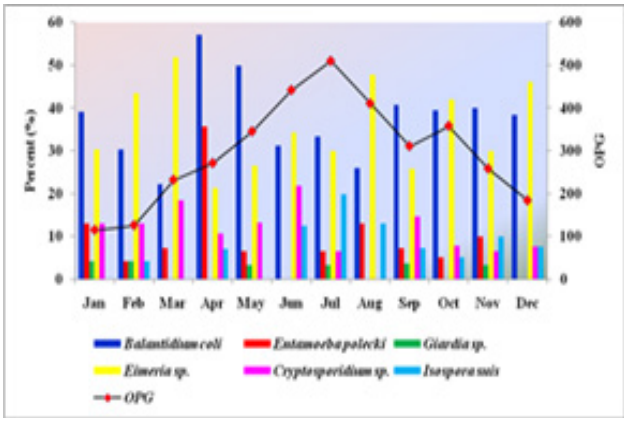


Fig 12. Month wise prevalence of G.I. protozoan parasites in pigs of Meghalaya

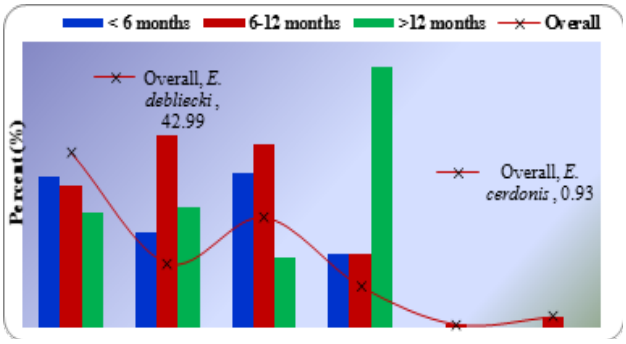


Fig 13. Agewise variations in the prevalence of Eimeria

Agewise, variations in the prevalence of *Eimeria* species in pigs was observed (Fig 13).

Molecular diagnosis of Cryptosporidiosis and Balantidiosis in pigs

SSU rRNA gene of *Cryptosporidium* sp. and *Balantidium coli* were amplified by Nested PCR. The positive samples showed 840 bp and 1543bp bands in *Cryptosporidium* sp. and *Balantidium coli* infections in pigs, respectively.

Characterization of Immunogenic Proteins of *Rhipicephalus* (*Boophilus*) *microplus* Tick and its effect as a Vaccine in Experimentally infested Rabbits

Boophilus microplus ticks were collected from naturally infested cattle and identified morphologically. SDS-PAGE analysis of salivary glands antigen of *B. microplus* ticks revealed presence of 150 kDa, 92 kDa, 74 kDa,, 64 kDa, 37 kDa, 24 kDa and 16 kDa polypeptides.

Studies on Drug sensitivity and Genetic diversity of *Eimeria* isolates from Meghalaya

Studies on the sensitivity of anticoccidials against *Eimeria* isolates in poultry revealed that mortality in poultry chicks (3-4weeks) is mostly due to *Eimeria* sp. where as in poultry (> 8weeks) is mostly due to mixed infections with *Ascaridia galli*, *Heterakis gallinarum*, *Capillaria* sp., *Eimeria* sp., *Choanotaenia infundibulum* and *Strongyloides avium* (Fig 14).

Trematodes in *Wallaga attu* (Boal fish)

In swim bladder of *Wallaga attu* (Boal) fish collected from Kynshi river at Ranikor, South West Khasi Hills, trematode *Isoparorchis hypselobagri* was found (Fig 15).

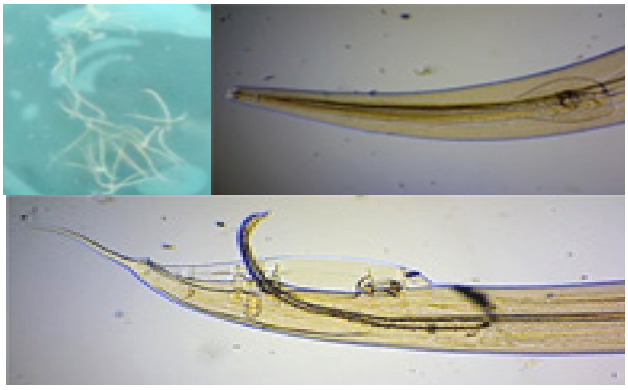
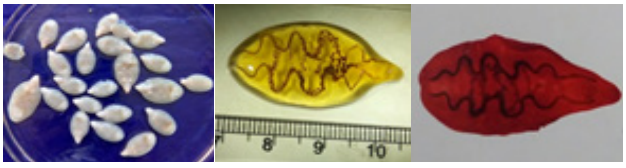


Fig 14. *Heterakis gallinarum*

Wallaga attu (Boal fish)



Isoparorchis hypselobagri

Fig 15. Trematodes in Boal fish

Detection of *Cysticercus cellulosae* in pigs

Study on presence of *C. cellulosae* in pigs was initiated during the period under report and it has detected in muscles of pigs. Molecular diagnosis of *C. cellulosae* also standardized.

Fig 16a. *C. cellulosae* in muscles of pigs

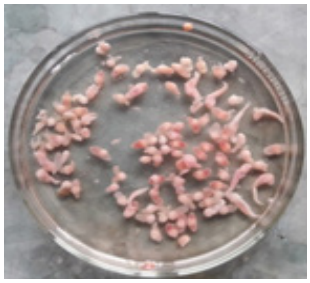


Fig 16b. Isolated *C. cellulosae*

Gastro Intestinal Parasitic infections in Poultry of North Eastern Region of India

A total of 601 numbers of faecal samples were collected from different states of North East to detect GI parasitic infections. Out of these 50.0% faecal samples were found positive for GI parasitic infections.

Table 12. Prevalence of Gastro Intestinal Parasitic infections in Poultry of North Eastern Region of India

State	Nos. Exam.	Nos. Positive (%)	GI Parasites Recorded
Meghalaya	260	150 (57.69)	*Ascaridia galli*, *Eimeria* spp. and *Strongyloides* spp.
Manipur	151	96 (63.57)	*Eimeria* spp., *Ascaridia galli*, *Strongyloides* spp., *Capillaria* spp., *Heterakis gallinae*
Tripura	38	14 (36.84)	*Eimeria* spp.
Nagaland	112	33 (29.46)	*Eimeria* spp., *Ascaridia galli*, *Strongyloides* spp., *Capillaria* spp., *Heterakis gallinae*
Mizoram	40	8 (20.00)	*Eimeria* spp.
Overall	601	301 (50.08)	*Eimeria* spp., *Ascaridia galli*, *Strongyloides* spp., *Capillaria* spp.

Post mortem examination of G.I. tracts of poultry birds of both local birds and organized farms collected from butcher shops of Meghalaya revealed overall 19.133% as positive for G.I. parasitic infections.

Table 13. Prevalence of Gastro Intestinal Parasitic infections in Poultry of Meghalaya after post mortem examination of GI tracts

Types of Birds	Numbers Examined	Numbers (%) Positive	GI Parasites Recorded
Indigenous poultry birds	48	20 (41.66%)	*Ascaridia galli*, *Raillietina* spp.
Birds maintained in farm condition	67	2 (2.98%)	*Eimeria* spp. in intestinal scrapings
Total	115	22 (19.13%)	*Raillietina* spp., *Ascaridia galli*, *Eimeria* spp.

Fig 17a. *Raillietina* spp.

Fig 17b. *Ascaridia galli*

Parasitic infections in Buffaloes of North Eastern Region of India and its Management

A total of 65 numbers of faecal samples of buffaloes were collected from Meghalaya, Manipur and Tripura states. Out of these overall 30.76% buffaloes were found infected with gastrointestinal parasites (Meghalaya-31.81%, Manipur-40.00% and Tripura-27.27%). Eggs of Amphistomes, Strongyle spp., Oocysts of *Eimeria*spp. and cysts of *Balantidium coli* were identified from these faecal samples.

Preparation of oil in water Nanoemulsion and its characterization

Z. armatum oil, nonionic surfactant (tween 80) as organic phase and water as aqueous phase combined to form Nanoemulsion by ultrsonication at 1:1 and 1:2 ratio. The nanoemulsion was translucent in nature. The formulated nanoemulsion were stable after 30 min centrifugation at 3500 rpm, however 1:2 ratio was much more stable. Likewise it was also more stable when stored at different temperature compared to conventional without sonication. Similar pattern of

1:2 ratio more stable was observed. The pH reading ranges from 3- 3.6 for emulsions prepared. Overall the results suggest that the *Z. armatum* incorporated nanoemulsion was successful. Besides, *Vitexneguno* extract was prepared from shade dried leaves powder and neem bark extract was also prepared. The antibacterial property of leave *Vitexneguno* was found effective against *E.coli* and *Staphyloccus aureus*.

Evaluation of the effect of probiotic fermented feed to mitigate climate stress in pig

Probiotic @ 10^6 CFU/gm feed was used to ferment the local feed. The probiotic contains a combination of organisms viz. *Lactobacillus rhamnosus, Lactobacillus acidophilus, Bifidobacteriumlongum, Bifidobacteriumbifidium, Saccharomyces boulardii* and *Streptococcus thermophiles*. Feeding trial was done on control (Deep litter housing fed with conventional diet), treatment 1 (T1): Deep litter housing fed with fermented diet (20%) and treatment 2 (T1): Deep litter housing fed with fermented diet (40%). Average initial body (Kg) at the start of the experiment for the treatment (1 & 2) and control are 81.50±6.13, 81.50±5.72 and 81.25±4.13, respectively. Average body weight (Kg) for monthly interval month for the treatment (1 & 2) and control are 92.00±5.59, 93.12±5.68 and 90.25±3.94, respectively. Average daily weight gain observed was 350 gm/day, 387gm/day and 300 gm/day. Overall the treatment 20% group had the lower coliform growth and more of *Lactobacillus* spp. and *Bifido bacterium* spp. as compared to treatment 40% and control respectively. This indicates a better gut health with less pathogenic bacterial growth and more beneficial bacterial growth in treatment 20% followed by treatment 40% and control respectively.

Animal Health Camps

Organized two animal health camps for farmers at Nongagang and Sarikhushi village, Ri Bhoi, Meghalaya under Farmer's FIRST Project on 2.5.2018 and 30.10.2018, respectively. A total of 77 farmers from different villages (Lalumpam, Borgang, Nongagang, Nalapara, Mawphrew, Umtham, Mawthlen, Mawtnum, Sarikhushi, Purangang, Borkhatsari, Madanleh) have participated in the programme. Pigs (238), poultry (2044), goats (8), cattle (40) and rabbits (12) were treated under this programme.

Fig 18a.Vaccination in poultry against Ranikhet Disease

Fig 18b. Vaccination in Pigs against Swine Fever

FISHERIES

Growth of Amur (*C. carpio amur*) and thermal tolerance at varied temperature

The water temperature beyond tolerable limits adversely affects the growth and reproductive competence of teleost fish. The effect of such temperature rise will be more prominent in hill aquaculture. Hungarian strain of improved common carp (*Cyprinus carpio*), also known as Amur common carp introduced in the North East by the Division of Fisheries, ICAR NEH, Umiam in recent years has become a major cultivable species especially in mid hill aquaculture. The spawn of this variety with average length 10.35 mm and weight 0.00786 gm were reared under three different temperatures of 20°C, 25°C and 30°C in aquarium tanks for 28 days to evaluate the growth and survival. They were fed *ad libitum* daily with rice polish and plankton (collected from fish ponds of the farm). The highest growth of 3.42±0.240 in terms of length was recorded at 30°C with survival percentage of 95.

Fig 19a. Initial length of Spawn

Fig 19b. Final length of Fry

To determine critical (CTMax) and lethal (LTMax) thermal tolerance, the fry of Amur common carp were initially acclimatized at 18°C for 30 days. The fishes were then constantly reared at temperature regime of 20, 25 and 30°C separately in aquariums for 28 days. The acclimated fishes (Mean wt: 0.321 g and Mean Length: 2.783 cm) were then subjected to constant rate of increase at 1.0ºC/ min until loss of equilibrium (LoE) in order to determine CT Max. Similarly, lethal LT Max was determined by observing the cessation of operculum movement. The results implicate significant increase ($p<0.05$) in CTMax (39.5±0.18, 40.5±0.12, 41.5±0.12) and LTMax (40.3±0.09, 41.6±0.1, 42.7±0.11) in *Cyprinus carpio* var amur with increasing acclimation temperatures.

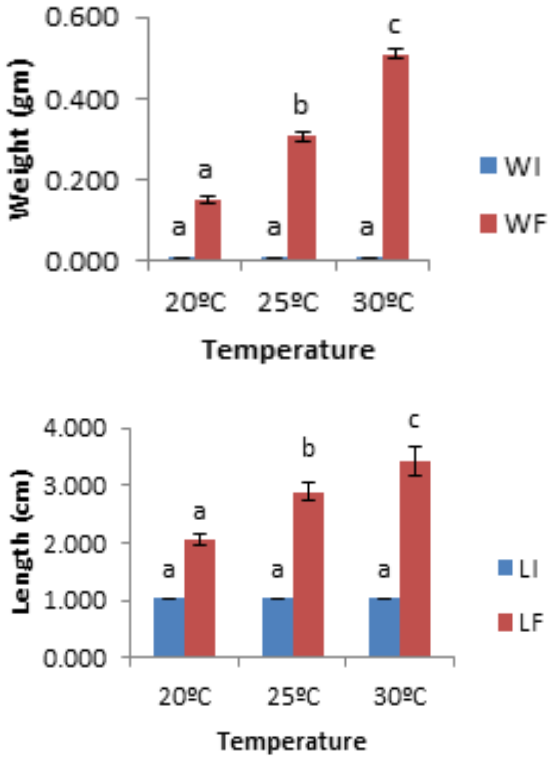


Fig 20. Growth of Amur common carp at varying temperature in terms of length and weight

Fish diversity and limnology of Umtrew River

To explore the diversity of fish fauna in Umtrew River in Meghalaya , a study has been taken up to collect and document the indigenous fish species of this river system. Till date a total of 23 indigenous fish species have been collected and identified. In addition to the endangered chocolate mahseer (*Neosocheilus hexagonolepis)*, various other upstream fish species of *Schistura, Glyptothorax, Badis species* etc were collected and studied. The planktonic community study is also being undertaken. The planktonic community study recorded a mean value of 1,330µ/L. A few important limnological parameters were analyzed to assess the productivity of the river (Table 14).

Fig 21a. *Neosocheilus hexagonolepis*

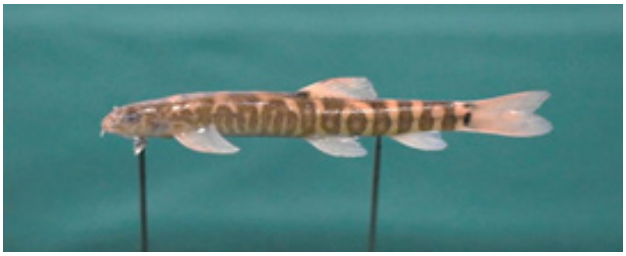


Fig 21b. *Schistura Spp.*

Fig 21c. *Glyptothorax Spp.*

Fig 21d. *Badis Spp.*

Table 14. Limnological parameters of Umtrew river

Parameters	Mean±SD
Temperature	22.02±2.41
Transperancy	194.88±13.64
pH	7.95±0.57
DO	8.07±0.42
Free CO2	0.40±0.43
Alkalinity	27.14±5.51
Hardness	20.35±1.97
TDS	24.82±1.58

Assessment of antibacterial activity of integumentary secretions of fish species and neem extracts.

An investigation on integumentary secretions' antibacterial activity in cultivable freshwater fish species *viz.*, Singhi (*Heteropneustes fossilis*) and Mrigal (*Cirrhinus mrigala*) were conducted. In this study, two bacterial strains i.e. *Staphylococcus aureus* (gram +ve strains) and *Aeromonas hydrophila* (gram -ve strains) were selected and the disc diffusion method was employed to assess the diameter of the inhibition zone (mm). Ciprofloxacin was used as a positive control. It was observed that *Heteropneutes fossilis* integumentary extract showed maximum antibacterial activity against *Aeromonas hyprophila* (22 mm) in comparison with the *Cirrhinus mrigala* integumentary extract (20 mm). However, the performance of positive control Cirpofloxacin (20 mm) was found to be similar in both the selected bacterial strains. The ethanol extract of neem leaves and bark against *Aeromonas hyprophila* and *Staphylococcus aureus* have shown that the leaves extract possesses higher inhibition ability as compared with bark extract. Ethanol extract of Neem leaves possess maximum antibacterial activity against *Staphylococcus aureus* (13 mm) and 12 mm similar zone of inhibition observed in *Aeromonas hyprophila*. While, Ethanol Neem bark extract showed highest inhibitory activity against *Staphylococcus aureus* (12 mm) and least activity against *Aeromonas hyprophila* (10mm). From this study it can be concluded that integumentary secretions of singhi, mrigal and neem (leaves and bark) extracts can be considered as a viable antibacterial agent.

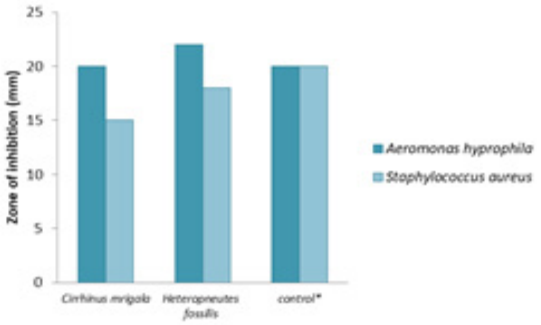


Fig 22. Antibacterial activity of integumentary extract of fish and control Cirpofloxacin

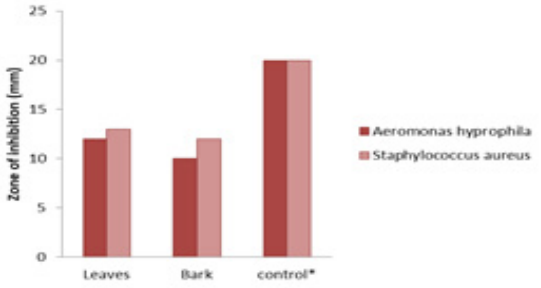


Fig 23. Antibacterial activity of neem (leaves and bark) extract and control Cirpofloxacin

Entrepreneurship development in Fisheries: Two months training under Agri-Business Incubation (ABI) Programme

The Division of Fisheries, ICAR-Research Complex for NEH Region, Umaim, Meghalaya has successfully organized a two months long Hands-on Training on "Entrepreneurship development in Fisheries" under the Agri-Business Incubation (ABI) Programme of the institute from 5th June to 4th August, 2018 with the objective to train four young educated unemployed youths of Manipur state to develop new entrepreneurs in aquaculture, fish seed production technology, ornamental fish culture and fish feed preparation.

Fig 24. Entrepreneurship development in Fisheries; Hands-on Training

State Level Aqua Fest 2018

The Division of Fisheries, ICAR-Research Complex for NEH Region, Umaim, Meghalaya participated in the State level Aqua Fest 2018 organized by the Directorate of Fisheries, Government of Meghalaya on the 6th of November 2018 to display and popularize the different avenues of Fisheries for the welfare of the farmers and entrepreneurs in Meghalaya.

Fig 25. State level Aqua Fest 2018

Training cum workshop on "Emerging Technologies in Aquaculture and Fish Processing for Enhancing Farmers's Income"

Two days training cum workshop on "Emerging Technologies in Aquaculture and Fish Processing for Enhancing Farmers's Income" was organized by the Division of Fisheries, ICAR Research complex for NEH Region, at Umiam, Meghalaya in collaboration with the Directorate of Fisheries, Government of Meghalaya, the Asian Fisheries Society (Indian Branch) and Pillay Aquaculture Foundation, Indian Chapter from 19th– 20th November, 2018. The two days programme was sponsored by the department of Fisheries, Govt. of Meghalaya to train the selected field level extension officers of the department on the subject. A total of 25 officials representing all the eleven districts of the state participated where Prof. (Dr.) B.A. Shamasundar, Prof. (Dr.) P. Keshavanath, Secretary, Asian Fisheries Society (Indian Branch), Dr. S.C. Pathak, President, Pillay Aquaculture Foundation, Indian Chapter, Prof. (Dr.) M. N. Venugopal and Dr. S.K. Das acted as resource persons with supports from the scientists and technical officers of the Fisheries division.

Training cum workshop on "Gold fish- an ornamental fish for entrepreneurship development" under Agri-Business Incubation Programme

One day training cum workshop on "Gold fish- an ornamental fish for entrepreneurship development" was organized by the Division of Fisheries, ICAR –RC-NEH Region, Umiam, in collaboration with the Department of Fisheries, Government of Meghalaya, Shillong on 28th September, 2018 at Directorate of Fisheries, Shillong. Thirty potential farmer entrepreneurs representing all the 11 districts of the state participated in the day long programme where Smt. I.R. Sangma, IAS, Secretary, Fisheries, Government of Meghalaya acted as Chief Guest, Smti. A.L. Mawlong, MCS, Director, Department of Fisheries, Government of Meghalaya as the Guest of Honour and the workshop was presided by Dr. N. Prakash, Director, ICAR RC for NEH Region, Umiam. Dr. S.K. Das and Dr. G. Kadirvel delivered lectures to motivate the potential entrepreneurs towards Gold fish breeding and rearing.

Fig 26. Training cum workshop at Directorate of Fisheries, Shillong

Skill development training on 'Fish Breeding and Seed Production' for progressive fish farmers of West Jaintia Hills District, Jowai

The Division of Fisheries, ICAR Research Centre for NEH Region, Umiam, Meghalaya organized 4 days long skill development training programme on "Fish Breeding and Seed Production" in collaboration with the District Basin Development Unit, West Jaintia Hills District, Jowai for selected progressive fish farmers of West Jaintia Hills District, Jowai during 4th-7th July, 2018. The training programme was sponsored by MIE, MBDA Shillong and DRDA, West Jaintia Hills District, Jowai. A total of 15 fish farmers hailing from Amlarem, Laskein and Thadlaskein C&RD Blocks, West Jaintia Hills District, Jowai participated in the four days long training programme.



Fig 27. Skill development training programme

Ranching cum fish fingerling distribution at Umniuh khwan fishing Village

A daylong training cum fish seed distribution programme with the theme "Enhancing fish production through distribution of quality fish Seeds to the fish farmers of Ri-Bhoi Dist. Meghalaya" was organized by Division of Fisheries, ICAR-RC for NEH Region, Umiam, on 23rd August, 2018 at Umniuh khwan – a fishing village near the Umiam Lake under the TSP project in collaboration with the Ribhoi Fish Farmer's Association. Dr. J. K. Jena, the honourable Deputy Director General for Fisheries and Animal Science, ICAR New Delhi, graced the occasion as Chief Guest and distributed the quality fish seeds of indigenous cultivable fish species to a group of 75 progressive farmers and fishing community for fish farming. To improve the fish production of Umiam lake, 10,000 no. of quality fish seeds were also stocked under an open ranching programme on the day.


Fig 28. Dr. J. K. Jena, DDG, Fisheries and Animal Science, ICAR New Delhi as Chief Guest and distributed quality fish seeds

Sensitization cum fish seed distribution programme on the occasion of "World Environment Day"

To commemorate the World Environment Day, day long sensitization cum fish fingerlings distribution programme was successfully organized by the Division of Fisheries, ICAR-RC-NEH Region, Umaim under the Tribal Sub Plan programme of the Institute in collaboration with the Umroi Block Youth Congress Assembly (UBYCA), Bhoirymbong, Ri-Bhoi district, at Mwatneng Village, Ri-Bhoi district, Meghalaya on 5th June 2018.


Fig 29. Ranching of fish fingerlings in the local community pond

FAMERS FIRST PROJECT

Livelihood Improvement of Hill Farmers through Sustainable Farming Systems in North Eastern Hill Region (Farmers' FIRST Project)

Crop based modules

Under the crop based module, line transplanting of paddy was introduced in three villages (Nalapara, Sarikhusi and Mawtnum) with 2-3 seedlings per hill. It was found that average grain yield increased with the recommended practice (2.3 t/ha) as compared to the conventional (1.5-1.8 t/ha). The average greed pod yield for pea was found to be 58-65 q/ha giving an income of Rs.80,000-1,00,000/ha. Demonstration of no-till/minimum till cultivation of French bean in maize fallow was also carried out in which average yield was found to be 7 t/ha.

Livestock based module

Under the livestock based module, 5709 poultry chicks (Vanaraja, Srinidhi, and Kuroiler) have been distributed to 146 beneficiary farmers from the 10 adopted villages. Successful poultry farmers managed to sell on an average 1100 nos. of eggs from 15 birds @ Rs. 8 to 10 per egg and earned about Rs. 8,800 to 11,000 by selling eggs per year in addition to personal consumption. Live birds (3.5–4 kg) were sold @ Rs 250 to 300 per kg live body weight and earned about Rs. 875 to 1200 from each bird after rearing for 8-10 months. In addition to poultry birds, 95 Hampshire Cross bred piglets were also distributed to 69 beneficiary farmers. After rearing for a period of one year, 7 nos. of sows produced 61 nos. of piglets both by natural breeding and A.I. Eleven numbers of boars were sold after one year and the pig farmers earned about Rs.1,64,200 within one year.

Fig 1. Poultry chicks and piglets distributed to beneficiaries

Enterprise based module

A pig breeding cluster has been developed under this module. Thirty piglets were borne through Artificial Insemination in the month of September and December, 2018. Out of the 30 piglets, 17 were sold @ Rs.2600 each giving a total income Rs. 44,200.

Fig 2. Pig breeding cluster, Borkhatsari village

Integration of scientific beekeeping was also introduced by distributing fifty numbers each of Modern bee box Type B and Excluder sheets among the interested farmers/unemployed youths of the different villages @ 2 bee box/person.Financial aid for construction of low cost mushroom production units were also given. The farmers obtained an average harvest of 160 kg mushroom in duration of 3 months with an average income of Rs. 32,000.

Integrated farming systems (IFS) module

Under the IFS based module, one IFS model was developed in Nalapara village with various components like fishery-cum- poultry unit, fishery-cum-duckery unit, piggery unit, rabbitery, goatery, dairy, vermicomposting and crop component. The average annual income of the IFS model has been found out to be Rs. 1,34,140. After the successful venture of the IFS model in Nalapara, three more IFS units are under development in Umtham and Borkhatsari villages.

ARUNACHAL PRADESH

WEATHER REPORT

Total annual rainfall received during the year was 2170.1 mm which was 12% below normal (lone term annual average). The rainfall deficit was most prominent during southwest monsoon season (17.3%). The monthly rainfall distribution compared to normal is depicted in Fig 1. The number of rainy days during 2018 was 119 which was 24 days below normal (143 days). The sharp decrease in number of rainy days resulted in increase rainfall intensity consequently leading to occurrence of extreme weather events like flash flood and mid-season drought in adjoining areas.

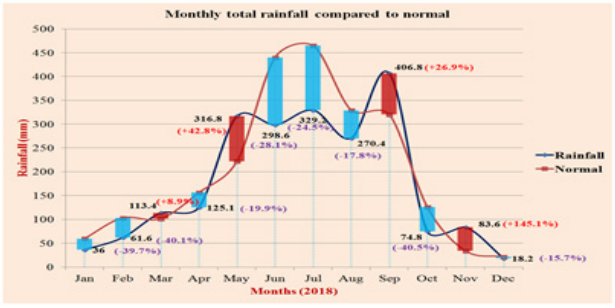


Fig 1. Monthly total rainfall compared to normal. The red bar depicted increasing and blue bar depicted decreasing trend during the period.

The monthly average maximum temperature during the period remained constantly above normal except during post-monsoon season. However, the monthly average minimum temperatures during entire year remain below normal. The year witnessed cold waves during later part of December adversely affecting agricultural activities.

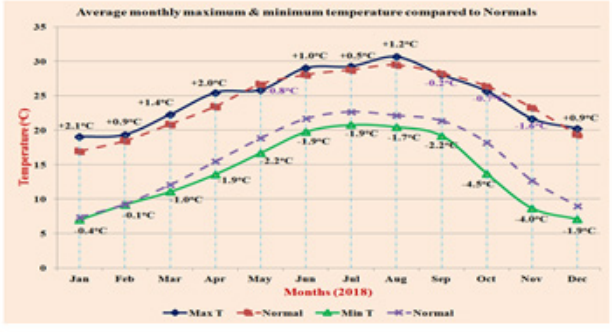


Fig 2. Average monthly maximum & minimum temperatures compared

AGRONOMY

Maize Production Technology

Currently, comparison studies of Maize monocropping with Maize intercropping with radish (variety-Pusa Chetki), pea (variety-Sweet Pearl), lentil (variety: KLS 218) and French bean (variety: S 9) are going on under the project on "Promoting improved technology of Maize production in NEH region - Arunachal Pradesh" at Basar Research Farm. Maize and the intercrops were sown on 9th October, 2018.

Fig 3. On farm demonstration of maize production technology, Arunachal Pradesh, 2018

Fig 4. Maize crop grown at Gori Farm, ICAR RC NEH, Arunachal Pradesh Centre.

SOIL SCIENCE

Standardization of nutrient management practices of *Phaseolus vulgaris* in Eastern Himalaya, Arunachal Pradesh

The total area under vegetable cultivation in Arunachal Pradesh is 1770 ha which is 0.02% of the total area under vegetable production of the country. French bean is a remunerative crop grown in every household and has a high local demand in Arunachal Pradesh. However, due to lack of standard nutrient management, productivity of the crop is sub-optimal in the region. Visualizing the problem, it has been discussed that low production and productivity of French bean can be enhanced by nutrient management practices. In view of the necessity to increase French bean production, a project under the heading "Standardization of nutrient management practices of *Phaseolus vulgaris* in Eastern Himalaya, Arunachal Pradesh" was proposed and carried out. Thereby, an area was selected in Soil Science block at Gori Farm, ICAR RC NEH, Arunachal Pradesh Centre, Basar. Presently, land preparation is being carried out for sowing of the French bean crop during February, 2018.

To study impact of multipurpose trees (MPTs) on the soil organic carbon and soil reaction at Basar, Arunachal Pradesh

The soil organic carbon (SOC) percentage in Arunachal Pradesh has been generally very high. However, this surface soil organic carbon is sensitive to erosion as a consequence of heavy rainfall. Thereby, it is crucial to conduct this study in the face of climate change. To study the impact of multipurpose trees on changes in SOC and soil reaction, soil samples were collected from 0-20 cm and 20-30 cm soil depths under 30 multipurpose trees at Forestry block, Gori Farm, ICAR Arunachal Pradesh Centre. The results shows that SOC ranged from 1.6% to 9.7% across the MPTs at 0-20cm and decreased as depth increased to 20-40 cm. Soil pH ranged from 4.75 to 5.18 at 0-20 cm. Among the MPTs, highest SOC was in *Pinus Wallichiana*. There was a slight increase in soil pH as depth increased to 20-40 cm. The increase in soil pH is primarily due to decrease in SOC as depth increased. The soil EC ranged from 21.6 to 121 µS/m at 0-20 cm depth and decreased as the depth increased.

Fig 5. Soil sampling from multipurpose trees planted at Forestry block, Gori Farm, ICAR, Arunachal Pradesh Centre.

ENTOMOLOGY

Network project on integrated management of soft rot complex of ginger

An experiment was conducted for evaluation of different treatments to develop integrated management strategies for management of soft rot complex in ginger (Variety-Nadia). Eleven different treatments were taken for evaluation *viz*., T_1 – Ginger rhizome in hot water (HW) + *Trichoderma viride* treatment, T_2 - Ginger rhizome in HW + *Pseudomonas fluorescens* treatment, T_3 - Ginger rhizome in HW +*T. viride* treatment +*P. fluorescens* treatment, T_4- Ginger rhizome in HW + Copper oxychloride 0.3%, T_5- Ginger rhizome in HW + treatment with *Schima wallichi extract 50%*, T_6- Ginger rhizome in HW + treatment with *Artemisia vulgaris 50% extract*, T_7- Ginger rhizome in HW +treatment with *Schima wallichi* extract 50% + *T. viride* treatment *P. fluorescens* treatment, T_8- Ginger rhizome in HW + treatment with *Artemisia vulgaris 50% extract* +*T. viride* treatment+*P. fluorescens* treatment, T_9- Ginger rhizome in HW +treatment

with *Schima wallichi extract 50%* + treatment with *Artemisia vulgaris 50% extract+T. viride* treatment *+P. fluorescens* treatment, T_{10}- Negative control, T_{11}- Positive control. Among these treatments, minimum disease incidence was recorded in the plots of T_4- Ginger rhizome treated with hot water in 47^0C for 30 minutes+Copper oxychloride 0.3% with highest yield.

AGROFORESTRY

Evaluation of Multipurpose trees and to develop Agroforestry based farming system

The block plantations of 53 Multipurpose Tree species were raised at Agroforestry section at ICAR Research farm, Gori, Basar during years 1997-2001. Out of these, 47 species are established successfully. Among 16 tree species established in 1997, *Pinus kesia* attained maximum basal girth (139.8 cm) followed by *Michelia obtusifolia* (131.1cm). Highest plant height was recorded in *Michelia obtusifolia* (18.8m) followed by *Castonopsis indica* (18.1m). Highest light intensity in inter-rows was recorded highest in *Terminalia myriocarpa* (681.15 lux) followed by *Gmelina arborea* (532.4 lux). Canopy spread was recorded highest (8.8m x 8.92m) in *Pinus kesia* followed by *Cuppressus torulosa* (7.87m x 7.37m) after 17 years of planting.

Pinus kesia | *Acacia mangium* | *Manglietia insignis* | *Eleocarpus spharicus*

Fig 6. Best performing MPTs in agro forestry section, Arunachal Pradesh

During the year 1998, 20 tree species were planted. Among these, *Acacia mangium* recorded the highest basal girth (148.0cm) followed by *Pinus wallichiana* (121.9cm). *Acacia mangium* attained maximum height (26.8m) followed by *Pinus wallichiana* (19.0m). Highest interspacing light intensity was recorded in *Gravelia robusta* (861.2 lux) followed by *Alnus nepalensis* (582.2 lux). The canopy spread was found highest in *Acacia mangium* (11m x 9.85m) followed by *Pinus wallichiana* (9.5m x 8.7m).

During the year 1999, six tree species were planted. Among these, *Manglietia insignis* recorded the highest basal girth (107.0cm) followed by *Aleurites montana* (94.4cm). *Manglietia insignis* attained highest plant height (17.5m) followed by *Parkia roxburghii* (15.9m). *Aleurites montana* showed the highest inter spacing light intensity (848.6 lux) followed by *Emblica officinalis* (705.4 lux). *Aleurites montana* recorded the highest canopy spread (7.11m x 6.59m) followed by *Manglietia insignis* (6.08m x 5.99m).

During the year 2000, five tree species were planted. Among these, *Eleocarpus sphaericus* recorded the highest basal girth (122.9cm) followed by Kobolakso (53.0cm). The plant height was recorded highest in *Eleocarpus sphaericus* (22.93m) followed by Kobolakso (11.08m). The inter row light intensity was recorded highest under Kobolakso (503.2 lux) followed by *Chukrasia tabularis* (369.8 lux). *Eleocarpus sphaericus* also recorded the highest canopy spread (8.89m x 8.53m) followed by Kobolakso (5.82m x 5.6m).

During the year 2001, four tree species were planted. Among these, Hiko recorded the highest basal growth (63.7cm) followed by *Litsea lacta* (55cm). Hiko recorded the highest plant height (8.9m) followed by *Litsea lacta* (8.7 m). The inter-spacing light intensity was recorded highest in *Litsea lacta* (134.6 lux) followed by Hiko (92.2 lux). The canopy spread was recorded highest (5.56m x 5.9m) in *Lithocarpus sperma* followed by Hiko (5.1m x 5m).

Performance of different intercrops in combination with different MPTs

The intercropping of different crops such as guinea grass, broom grass, turmeric, ginger and canes are also being carried out in the plantations of MPTs. Among different combinations of MPTs

and 5 species of canes, *Alnus nepalensis+Takek* was reported best in terms of basal girth (38.8cm) followed by *Pinus khasiana+Takek* (34.0cm). Among 28 combinations of MPT species and guinea grass, the combination *Terminalia myriocarpa+Guinea* recorded the highest guinea grass yield (30.1 kg/row) followed by Kobolaxo+*Guinea* (22.8 kg/row). In all combinations of MPTs and other crops, the length of row was 30 meters. Among 22 combinations of MPT species and broom grass, the combination *Gravelia robusta+* broom grasss recorded the highest yield (31.0 kg/row) followed by *Bombax ceiba + broom* (23.2 kg/row) and *Lagerstroemia speciosa+Guinea* (18.5 kg/row).

Effect of tree densities on the growth performance of Ghamari (*Gmelina arborea*)

The spacing trial of Ghamari was established in 1999. In 20th year of establishment, Ghamari obtained highest plant height (19.8m) in the spacing 2m x3 m followed by the height in spacing 4m x 3m (18.9m). The girth at breast height was found highest (127.9cm) in the spacing 4m x 4m followed by 6m x3 m spacing (107.2cm).

Fig 7. Plantation of *Gmelina arborea* (Ghamari)

Spacing Trial of Bola *(Morus laevigata)*

The spacing trial of Bola was established in 1998. After 21 years, maximum plant height (9.95 m) was attained in the spacing 3m x 3m followed by 4m x 3m spacing (9.0m) . The average girth at breast height was also found highest (27.8 m) in the spacing 5m x 3m followed by 3m x3 m (23.3cm).

Spacing Trial of 13 Bamboo species

Out of 13 species of bamboo grown under three spacing, maximum clump circumference was recorded in *Bambusa cacharensis* (16.7m) at 5m x 5m spacing followed by the same species (14.6 m) planted at spacing 6m x 6m. But in spacing 7m x7m, *Bambusa nutans* recorded the highest clump circumference (12.3m). Highest number of culms per clump (85) was recorded in *Bambusa pallida* at 7m x 7m spacing followed by *Dendrocalamus sahnii* (72) at 6m x 6m spacing and *Dendrocalamus hamiltonii* (69) at 5m x 5m spacing.

Bambusa cacharensis

Bambusa pallida

Fig 8. Plantations of Bamboo

Development of Bamboo based agroforestry systems for *Jhum* improvement in Arunachal Pradesh

Three species of bamboo namely Eso (*Bambusa pallida*), Ejo (*Bambusa tulda*) and Eni (*Dendrocalamus hamiltonii*) have been selected on the basis of local preference of the farming community. The seedlings of these bamboos were raised in nursery and transplanted in the field in April, 2018.

Evaluation of Toko palm (*Livistonia jenkinsiana*) resources and standardization of agro-techniques

The spacing trial of Toko palm was established in the year 2017. After 2 years of planting, the highest plant height (48.0cm) was recorded in the spacing 2m x 2m followed by the spacing 4m x 2m (35.0cm). The number of leaves per plant was also recorded highest (8) in the spacing 2 m x 2 m followed by 2m x 4m (6).

ANIMAL SCIENCE

Dynamics of Mithun (*Bos frontalis*) population and technological intervention for sustainable production in mid hills of Arunachal Pradesh

The study was carried out at Gori village, Basar, Leparada District in a strategic location where Mithuns usually flock together also known

as Lura. The geographical coordinates of the study area is 94°42.44E and 27°59.51N at about 660-880 meters ASL. During the study around 21 common fodder consumed by the Mithun in five different location viz. (East, West, North, South, River Side) of Lura were identified (Table 1). Among them the most commonly found fodder was *Sarchochlamys pulcherrima* (26.78%) and the least was *Macaranga denticulate* (0.53%). Further, in order to study the chemical composition of these fodders, samples were sent to ICAR Research Centre, Kolasib, Mizoram.

Table 1. List of common fodder plants consumed by Mithun in the study site.

Sl.no	Family	Scientific name	Vernacular name	Parts consumed	Life form
1	Urticaceae	*Sarchochlamys pulcherrima*	Taktu pulu	Leaves, stems	Herb
2	Malvaceae	*Sterculina coccinea*	Remmin	Leaf, stem	Climber
3	Moraceae	*Ficus hookeri*	Takshin	Leaf	Tree
4	Thelypteridaceae	*Cyclosorus cyatheoides*	Rukke	Leaf, stem	Grass
5	Poaceae	*Bambusoideae*	Eso Aeih	Leaves	Shrub
6	Euphorbiaceae	*Macaranga denticulata*	Ripum	Leaves	Tree
7	Poaceae	*Dendrocalamus giganteus* Munro	Hurung	Leaves & tender culms	Tree
8	Caricaceae	*Carica papaya* L. Omri	omita	Tree Fruits	Tree
9	*Poaceae*	*Cephalostachyum pergracile* Munro	Madang	Leaves	Tree
10	Moraceae	*Ficus auriculata* Lour	(Takuk)	Leaves ,	Tree
11	Moraceae	*Ficus hispida* L.f.	Takshin	Leaves	Tree
12	Moraceae	*Ficus racemosa* L.	Kobu acho	Leaves	Tree
13	Moraceae	*Ficus semicordata* Buch.-Ham. ex Sm.	Takuk (kugri kugma)	Leafy shoot	Tree
14	Asteraceae	*Gynura nepalensis DC.*	Jogen (ogen)	Whole plant	Herb
15	Convolvulaceae	*Ipomoea batatas* (L.) Lam	Engin tare	Leafy shoot	Climber
16.	Arecaceae	*Livistona jenkinsiana* Griff	Tek/Taa-eek	Fruits & leaves	Tree
17.	Melastomataceae	*Melastoma malabathricum* L.	Acha kaya	Leaves	Shrub
18	Rutaceae	*Citrus* spp.	(Tanyum)	Fruits	Tree
19	Rutaceae	*Citrus reticulata* Blanco	Tasing/Unturang	Fruits	Tree
20	Rutaceae	*Citrus* spp.	Belensing (Tanyum)	Fruits	Tree
21	Musaceae	*Musa paradisiasa*	kolu	Fruits	Tree

Ficus hirta

Sarchochlamys pulcherrima

Crassocepahlum crepidioides

Sterculina coccinea

Ficus auriculata

Ficus auriculata Lour

Macaranga denticulate

Gynura nepalensis DC.

Cyclosorus cyatheoides

Bambusoideae

Fig 9. Photographs of some Fodder species consumed by Mithun in the project site

All India Coordinated Research Project on Oilseeds

An experiment was conducted to find out the suitable sowing date of Niger (Variety-JNS) in mid hill conditions of Arunachal Pradesh. Seven different dates were taken for evaluation as treatments and all the treatments were replicated thrice. Among the treatments (different sowing times), the crop sown on 15th February was found best with highest yield of Niger (2.5 q/ha) followed by 1st February (2.20 q/ha). March sown crop cannot perform better due heavy rainfall during flowering and fruit setting. A Field Day was organized on 12th April, 2018 for popularization of niger among the farmers of Arunachal Pradesh.

Network Project on Organic Farming

An experiment was conducted to evaluate the efficacy of four different bio-pesticides viz., neem oil 1500 ppm @ 4 ml/litre, petroleum oil based agrospray @ 10 ml/litre, *Bacillus thuringiensis* @ 2 ml/litre and spinosad 45 SC @ 0.4 ml/litre with a check dimethoate 30 EC @ 1.5 ml/litre and control against insect pests of mustard. The first application was given during 25% flowering stage of the crop and second application was followed after 15 days. Among the treatments, dimethoate 30 EC @ 1.5 ml/litre reduced maximum aphid population (88.24% reduction of aphid population over control). Among four biopesticides, petroleum oil based agrospray @ 10 ml/litre and neem oil 1500 ppm @ 4 ml/litre were found effective for controlling of aphid population (68.14-72.56% reduction of aphid population over control).

Integrated Horticulture including Fisheries in North East India (NEC Funded)

The main objective of this project was improvement of livelihood of the farmers through intervention of Horticulture and Fishery. Since January, 2018, for expansion of area of fruit crops in different districts of Arunachal Pradesh, several training cum distribution programmes were organized. During 2018-19 training cum distribution programme was organized for plantation of Kiwi (50 ha), Walnut (20 ha), Orange (100 ha), Pineapple (24 ha) and large cardamom (5 ha) covering various districts of Arunachal Pradesh *viz.*, West Kameng, Lower Subansiri, East Siang, West Siang, Longding, Upper Siang and Anjaw.

AICRP on Mushroom

Two varieties of mushroom (Flabellatus and Florida) were evaluated for production in mid hill condition of Arunachal Pradesh and both of them performed very well. Besides production of mushroom, spawn production is being done to fulfill the requirement of farmers of different district. During the reporting year, 90 kg spawn have been produced and farmers from different districts are takers of the spawn from ICAR Centre.

Seed Project

The availability of quality seed is one of the most important factors to increase the production of various crops. So under this project, seeds of various crops like mustard (variety-TS 36, TS 46 and TS 38), lentil (variety-HUL 57), black gram, green gram, soybean (variety-JS 9560), French bean (variety-Selection 9), local maize (Tapo poli and Sago local) have been cultivated for production of seeds to cater the requirement of farmers as well as departments.

Fig 10. Vegetative stage of black gram variety (SBC 40) sown on two different DOS at Gori Farm, ICAR Arunachal Pradesh Centre, Basar. A) DOS- 8/8/2018 B) DOS- 8/9/2018

KU 301 (DOS- 8/8/2018)

KU 301 (DOS- 8/9/2018)

KU 301 (DOS- 8/9/2018)

PU 31 (DOS- 8/9/2018)

SGC 16 (DOS- 8/8/2018)

SGC 16 (DOS- 8/9/2018)

Pratap (DOS- 8/8/2018)

Pratap (DOS- 8/9/2018)

SGC 20 (DOS- 8/8/2018)

SGC 20 (DOS- 8/9/2018)

Fig 11. Vegetative stage of green gram varieties sown on two different DOS at Gori Farm, ICAR Arunachal Pradesh Centre, Basar.

EXTENSION PROGARMME

Under TSP and NEC programmes, around 425 farmers of Lepparada, West Siang, East Siang, Anjaw, Namsai, Lower Subansiri, Lower Siang and Longding District of Arunachal Pradesh were benefitted .They were provided various inputs like piglets (20 nos), poultry (200 nos) along with veterinary medicines and feed supplements, Knacksack sprayer (251), Jalkund (41), polyhouse (44), organic manure (15,500 kg), bio-fertilizer (8000 kg), neem oil cake (12000 kg), trichoderma (220 kg), copper oxy chloride (400 kg), neem oil (300 ltrs), mandarin seedlings (40,000), Kiwi seedlings (20,000), walnut seedlings (5400), pineapple slips/suckers (285000), large cardamom suckers (2000) and apple seedlings (6000).

Fig 12. Various training and distribution programme conducted by ICAR, AP Centre, Basar during 2018

MANIPUR CENTRE

WEATHER REPORT

During the period January to December 2018, the monthly average maximum temperature ranged from 21.8°C in Jan to 30.3°C in September while the monthly average minimum temperature ranged from 6.5°C in January to 22.6°C in July. Average maximum R.H. during 2018 varied from 92.3% to 86.4%. and minimum R.H. varied from 41.5% to 71.1%. An annual rainfall of 1325.7 mm was recorded during 2018. Highest rainfall of 71.3 mm in a day was recorded on 5th May, 2018. The month with highest rainfall was June with 365.7 mm and least was November with 0.4 mm during 2018 (Fig 1).

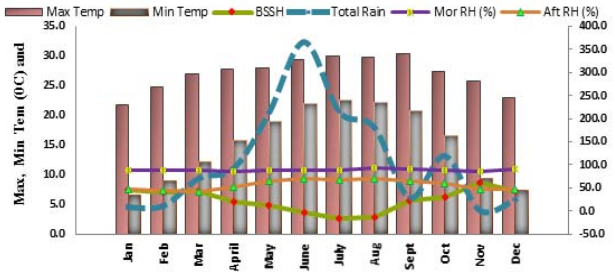


Fig 1. Graph of Monthly Average Maximum and Minimum Temperatures (°C), Relative Humidity (%) for morning & afternoon, Rainfall (mm) and bright sunshine hours during 2018

FIELD CROPS

RICE

Nomination of rice varieties in AICRIP trials from ICAR-Manipur Centre

The entry line number IET 25841 (MC 457217; RCM 33) has been promoted from AVT I M(H) to AVT II M(H) in *Kharif* 2018. Two entries namely, MC 4112186 (RCM 36) and MC 4811 (RCM 37) have been nominated for inclusion in initial varietal trial, IVT M(H) of *Kharif* 2018. Both the lines are of medium bold grain type with good cooking quality and taste.

Advanced Yield trials of rice

Two on-station advanced yield trials, AYT I and AYT II had been conducted during *Kharif* 2018 (Fig 2-3). In AYT-I, 18 advanced breeding lines including four checks were evaluated for the yield performance. Four lines namely, MC 4136125, MC 413447, MC 49432 and MC 49441 outperformed all the four checks with more than 6.4 t/ha. In the AYT II, 21 lines with three checks were evaluated and two entries, MC452211 and MC457317 significantly outperformed all the three checks with yield more than 5.5 t/ha. Consistently outperforming lines in the previous trials would be identified and would be nominated for IVT M(H) trial *kharif* 2019. These lines' parentage includes KD 263, Phougak, IR 64, RCM 9 and RCM 23

Fig 2. Wet nursery plots

Fig 3. Advanced rice breeding lines

Improvement programme on Black rice, *Chakhao*

Advanced lines of F_6 generation from seven crosses with *Chakhao* as one parent were evaluated for the anthocyanin expression in grain, its aroma, number of filled grains/panicle, test weight, plant architecture and performance. Ten promising lines from mild to strong aroma with better expression of anthocyanin in grain were selected. These *Chakhao* breeding lines are from the crosses with parentage *Chakhao*, RCM 9 and RCM 23. These advanced lines will be evaluated through on-farm preliminary yield trials in *kharif* 2019.

DUS testing and grow out test (GOT) of farmers' rice varieties under PPV & FRA

DUS characterization of 7 farmer varieties and 5 reference varieties of Rice of North eastern states, received from PPV&FRA, New Delhi were carried out in transplanted condition during *kharif* 2018. Observations have been recorded for 44 morphological characters and 15 post harvest characters on five randomly chosen plants of each genotype per replication. Out of 7 varieties, 5 were

found to be distinct. Farmers' varieties namely Langphou chahao, Darum, Rajen/Marjen, Kathei and Sanayambi phou were found to be distinct by 44 morphological characters and these varieties need to be further revalidated and registered.

Mapping for leaf and neck blast resistant gene

Under the institute project, identified twelve leaf and neck blast resistant and seven susceptible landraces were crossed in various combination to derived F_1(s). F_2 segregation populations will be derived from true F_1(s) in *kharif* 2019 for mapping leaf and neck blast resistant gene through BSA.

All India Co-ordinated Rice Improvement Project (AICRIP)

Two trials were conducted during *kharif* 2018 namely, AVT 1 M(H), IVT M(H) under randomized bock design (Fig 4). Under IVT MH, twenty two entries were tested including checks and two entries namely, IET 2903 (2425 kg/ha) and IET 2915 (2386 kg/ha) were found promising than the local check, RC Maniphou 13 (2350 kg/ha). Under AVT 1 MH, nineteen entries were tested including checks and none of the entry was found superior than the check RC Maniphou 13 (2202 kg/ha).

Fig 4. Visit of monitoring team of AICRIP

Screening of rice entries under National Screening Nursery-Hills (NSN-H), National Hybrid Screening Nursery (NHSN) and Donor Screening Nursery (DSN) for Leaf and Neck blast diseases

A total of 338 rice entries constituting NSN H (101), NHSN (108) and DSN (129) entries received from ICAR-IIRR, Hyderabad were screened for leaf and neck blast diseases under modified uniform blast nursery (UBN) and natural disease pressure respectively. Moderate to high disease pressure was recorded during the *Kharif* 2018. In NSN-H trial, 4 entries exhibited low disease score (0-3) for leaf blast and 39 entries for neck blast. 3 entries in NSN-H trial showed resistance to both leaf and neck blast. In NHSN trial, 20 entries showed resistance (low disease score of 0-3) to leaf and neck blast. In DSN, 27 entries showed resistant reaction (score of 0-3) for leaf blast and 63 entries for neck blast. 21 entries in DSN trial showed resistance to both leaf and neck blast.

Field monitoring of virulence of *Pyricularia oryzae* under Manipur valley conditions

The virulence spectrum of rice blast pathogen population was monitored on 25 cultivars consisting of international differentials, donors, and commercial cultivars during *Kharif* 2018. None of the genotypes showed resistant reaction. Four genotypes (Tetep, Zenith and NP 125) showed moderate reaction (score 4-6). Remaining all genotypes in the differential set showed highly susceptible reaction (score above 6) to leaf blast pathogen. Differential virulence pattern as compared to years was observed which indicated changes in the virulence pattern of rice blast pathogen in Manipur region.

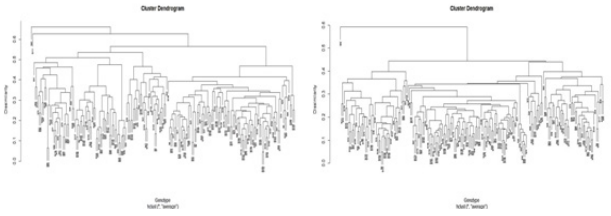
Development of DNA fingerprinting and Barcoding of local Rice Varieties for varietal identification and genetic diversity among landraces of Manipur

100 SSR markers were used for the first set of eight RC Maniphou varieties viz: RC Maniphou 6, RC Maniphou 4, RC Maniphou 5, RC Maniphou 7, RC Maniphou 10, RC Maniphou 11, RC Maniphou 12 and RC Maniphou 13. Amongst them, some varieties showed polymorphism with markers RM11073, RM12521, RM12623, RM13880, RM15041, RM15351, RM16341, RM16401, RM16782, RM18061, RM169 and RM18389, respectively.

DNA fingerprinting of rice by SRAP and TRAP markers for genetic variability analysis

The comparison of TRAP (and SRAP dendograms (Fig 5) showed a consistent level of genetic relationship among some genotypes, which persisted in the same group regardless of marker type. The six TRAP primer combinations were found to be more polymorphic than the ten SRAP in 199 rice cultivars, which reflect the influence of the type

of marker and variability captured in the sample. This study showed that a combination of factor analysis and diversity analysis can give a better understanding of the diversity of a set of accessions.



A B

Fig 5. Dendrogram generated by TRAP (A) and SRAP (B) markers based on the UPGMA method with 199 rice germplasms using Gower's general coefficient of similarity and average method of agglomeration

Management of major stored grain pests of rice with indigenous plants

Three indigenous plants from Manipur namely, *Zanthoxylum acanthopodium* (local name: *mukthroobi thingkhang-panbi*), *Plectranthus ternifolius* (local name: *khoiju*) and *Goniothalamus sesquipedalis* (local name: leikhaam) which were traditionally used as grain protectants since time immemorial were identified and collected. The last two plants are used by the local people together in combination in no known fixed ratio. An experiment was laid out to study the effects of these indigenous plants in deterring the growth of rice weevil, *Sitophilus oryzae*, the most common and dominant pest in stored rice grain. A pair of rice weevils i.e. male and female were released in treated rice grains. Different doses of the plant powders (shade dried and ground) were mixed with rice grains and observations were recorded every week for growth in population. Preliminary results show that the order of efficacy in deterring insect growth among the indigenous plants tested was *P. ternifolius* > *G. sesquipedalis* > *Z. acanthopodium.*

MAIZE

Development of single cross maize hybrid(s) for north- eastern hilly states

Second generation of selfing (S_2 generations) of 106 maize accessions was completed during *kharif* 2018 and S_2 seeds were obtained. These S_2 seeds were further planted during *rabi* 2018-19. Seeds of only 75 accessions germinated and further selfing were done for these accessions. In addition, sixteen maize germplasm from different districts/ places of Manipur were collected during 2018 (Fig 6).

Fig 6. Collection and evaluation of maize germplasm

Enhancing productivity and resource use efficiency of Maize-pulse cropping systems in hill of Manipur

Seven maize based cropping system (CS1-Maize (sole), CS2-Vegetable cowpea-Maize + Rice bean, CS3-Vegetable cowpea-Maize + soybean, CS4-Vegetable cowpea-Maize + Cowpea,CS5- Summer black gram-CS6-Maize + Rice bean summer black gram-Maize + soybean and CS7-Summer black gram-Maize + Cowpea) were experimented under various land management practices [LM1-CT-CT (Residue removal), LM2- CT-CT (Residue retention), LM3-ZT-ZT (Residue retention) and LM4-CT-ZT (Residue retention)]. The maximum system productivity was observed in (maize equivalent yield, MEY) under LM2 (8.47 t/ha) followed by LM4 (7.64 t/ha) (Fig. 7). Among the cropping system, significantly maximum system productivity was recorded under CS4 (10.33 t/ha) followed by CS3 (9.54 t/ha) as compared to other cropping system (Fig 7). Intercropping system fetched higher net returns as well as B: C ratio over sole maize due to more combined yield. Similarly the moisture extraction pattern and water productivity also recorded maximum under intercropping system as compared to sole cropping. Maximum nitrogen was spared by cowpea followed by soybean and rice bean in maize based cropping system.

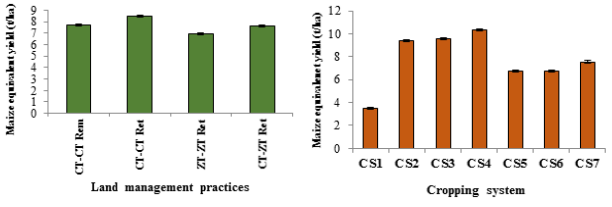


Fig 7. Effect of land management practices and cropping system on system productivity, Vertical bar represents significance value (P=0.05)

Promoting Improved Technology of Maize Production in NEH region

Under the collaborative project of ICAR Research Complex for NEH Region and ICAR-Indian Institute of Maize Research, twenty two (22) numbers of capacity building programme covering 1886 farmers from all North East states were organized during 2018. Similarly, one regional workshop and one national workshop were also organized at ICAR Manipur, Imphal during 2018. Participatory demonstration on improved varieties of maize was conducted in 306 ha areas comprises 954 farmers in various North East states during 2018 and on an average farmers harvested 39.05, 39.05, 37.30, 31.32, 31.25, 37.50 and 35.28 q/ha as compared to farmer practice 26.70, 26.70, 19.00, 23.61, 24.16, 19.50 and 22.60 in Manipur, Meghalaya, Nagaland, Tripura, Sikkim, Mizoram and Arunachal Pradesh, respectively. The yield gain under front line demonstrations (FLDs) over farmers practice (FP) was 46.60, 46.60, 49.11, 36.26 22.67, 48.00 and 40.53 percent in Manipur, Meghalaya, Nagaland, Tripura, Sikkim, Mizoram and Arunachal Pradesh, respectively (Fig 8).

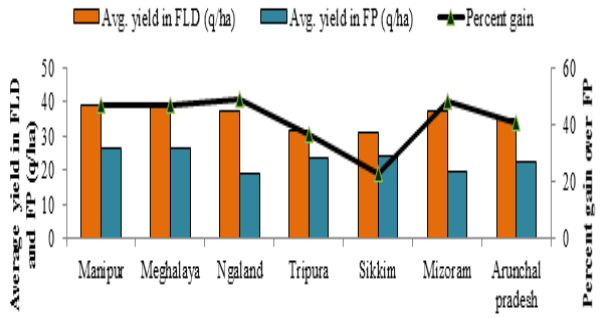


Fig 8. Average yield in FLD and FP and yield gain (%) over FP in various North Eastern States

In Manipur, demonstration on improved maize production technology was undertaken in cropping system mode in 23 ha area on 47 farmer's field (Fig 9). On an average, the maximum system productivity (Maize equivalent yield) was recorded in maize-vegetable (cabbage) cropping system (11.51 t/ha) followed by maize-broad bean (9.02 t/ha), maize – pea (8.79 t/ha) and maize-rapeseed and mustard (7.66 t/ha) cropping system. Consequently, net returns varied from Rs 79,300 to 1,17,600/ha with 2.30 to 2.55 benefit cost ratio.

Fig 9. Maize-pea, maize-mustard, maize-broadbean and maize-cabbage demonstrated in Kanglatombi (Imphal West), Ukhongshang (Thoubal), Chandanpokpi (Chandel) and T. Champhai (Churachandpur), respectively

Intensification of maize based organic cropping system

Different cropping system *viz.* Maize-sweet corn-vegetable pea, maize sweet corn-rapeseed and mustard, maize sweet corn-lentil, maize-sweet corn- vegetable broad bean under organic inputs were conducted (Fig 10). The maximum system productivity was recorded in maize-sweet corn- veg. broad bean (24.65 t/ha) followed by maize-sweet corn-vegetable pea (24.03 t/ha). Similarly, highest net returns (Rs 2.71 lakh/ha) was also recorded in maize-sweet corn-broad bean with 2.69 benefit:cost ratio. The soil quality in terms of enzymatic activities (Dehydrogenase, acid and alkaline phosphatase, Beta glucosidase) and available and total nutrients were higher under maize-sweet corn-vegetable broad bean followed by other pulses included cropping system, while minimum was recorded under maize sweet corn-lentil.

Fig 10. Intensification of maize based organic cropping system

POTENTIAL CROPS

All India Coordinated Network project on Potential Crop

Among 29 perilla genotypes, RC Thoiding 8 (IC-0615369) (56.5 g/plant) recorded the highest seed yield per plant followed by RC Thoiding 10 (IC-0615371) (39.2 g/plant), RC Thoiding 15 (IC-0615376) (37.0 g/plant), RC Thoiding 16 (IC-0615377) (36.7 g/plant) and RC Thoiding 9 (IC-0615370) (34.9 g/plant), respectively (Fig. 11). Similarly, genotype RC Thoiding 23 (IC-0615384) (0.21) recorded the highest seed test weight followed by RC Thoiding 3 (IC-0615364), RC Thoiding 15 (IC-0615376), RC Thoiding 24 (IC-0615385) and RC Thoiding 32 (IC-0615393) with the same value (0.20). Maximum oil content (47.20%) was recorded in RC Thoiding 10 (IC-0615371); followed by, RC Thoiding 29 (IC-0615390) (46.93%), RC Thoiding 32 (IC-0615393) (46.73%), RC Thoiding 28 (IC-0615389) (46.43%), RC Thoiding 4 (IC-0615365) (46.30%) and RC Thoiding 20 (IC-0615381) (46.23%),.

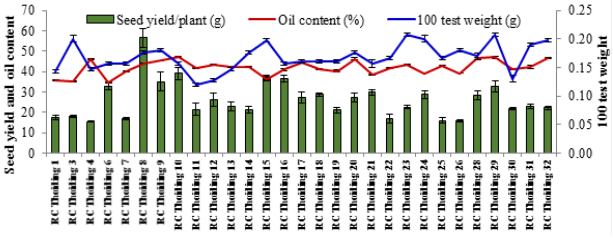


Fig 11. Genotypic variation of perilla on seed yield, oil content and 100 test weight (Vertical bar represents standard error of mean)

In addition, all total 53 winged bean genotypes received from ICAR NBPGR under AICRN Potential crops were also evaluated. IC-31981 (187.09 g/plant) recorded the highest fresh green pod yield/plant followed by EC-27885-1 (180.85 g/plant) and IC-26946 (180.53 g/plant) respectively. While, genotype EC-27886A-2 (33.00 g/plant) recorded the highest dried seed yield/plant followed by genotype IC-95227 (24.00 g/plant) and IC-95237-1 (23.00 g/plant) respectively.

Application of agrotextiles materials for enhancing crop and water productivity

Maize based cropping system (Maize-Sweet corn-pea) experiment was conducted under agrotextiles based ground cover and open field at Langol farm. Under ground cover crop (agrotextiles woven fabric mulching materials, 108 GSM), 62.5, 35.4 and 35.2 percent higher yield of maize, sweet corn and vegetable pea were observed compared to open field, respectively. The system productivity in terms of maize was recorded 15.5 t/ha in ground cover as compared to 11.1 t/ha under open field. Under ground cover, higher water use efficiency and very less weed infestation were recorded as compared to open field.

Network Project on Organic Farming

An experiment was conducted on various nutrient management practices (control, poultry manure @ 2.0 t/ha, vermicompost @ 2 t/ha and FYM 12 t/ha) under two cropping system i.e. paired maize row + groundnut (Fig 12) and paired rice + groundnut under rainfed conditions. Paired maize row + groundnut cropping system (6.3 t/ha) observed higher maize equivalent yield (MEY) than paired rice + groundnut (5.5 t/ha). Application of 2 t/ha vermicompost gave higher maize equivalent yield (6.91 t/ha) followed by poultry manure (6.5 t/ha) than control (4.34 t/ha).

Fig 12. Maize/rice +groundnut grown under various organic nutrient management practices

SEED TECHNOLOGY

Maintenance Breeding of Locally Released Varieties of Rice and other Recommended Crop varieties (BSP:NSP)

Rice varieties released from Manipur Centre are being maintained through panicle row selection and basic seeds have been produced. Seeds were supplied to the farmers either directly under demonstration programmes or participatory seed production programmes. RC Maniphou 4, 5 and 12 are the pre-*kharif* rice varieties and main *kharif* varieties RC Maniphou 6, 7, 10 and 13 are taken up (Fig 13). During the year, altogether 111.30 q of basic seeds of rice were produced. In other crops, maize composite variety Pusa Composite 3 have been maintained since 2005 with time isolation by sowing during *rabi* season (Fig. 14) and 1.50 q of basic seed was produced. In oilseeds, breeder seed of soybean variety JS 335 (0.57 q) and groundnut variety ICGS 76 (2.65 q) was maintained (Table 1).

Table 1. Seed production during 2018

Rice Variety	Quantity (in quintals)			
	Breeder seed	Foundation seed	Certified seed	Total
RC Maniphou-4	3.00	0.00	0.00	3.00
RC Maniphou-5	0.85	0.00	0.00	0.85
RC Maniphou-6	5.80	0.00	0.00	5.80
RC Maniphou-7	15.50	80.00	139.34	234.84
RC Maniphou-10	10.00	5.00	9.35	24.35
RC Maniphou-11	0.65	0.00	0.00	0.65
RC Maniphou-12	35.00	150.00	379.13	564.13
RC Maniphou-13	40.50	200.00	769.90	1010.4
Total rice	**111.30**	**435.00**	**1297.72**	**1844.02**
Soybean (JS-335)	0.57	0.00	0.00	0.57
Groundnut (ICGS 76)	2.65	0.00	135.00	137.65
Maize (Pusa Composite 3)	1.50	0.00	0.00	1.5
Maize (1-76)	0.00	1.00	4.63	5.63
Rapeseed (M-27)	0.00	0.00	20.00	20
Other crops Total	**4.72**	**1.00**	**159.63**	**165.35**
Total Seed	**116.02**	**436.00**	**1457.35**	**2009.37**

Fig 13. Maintenance breeding of rice

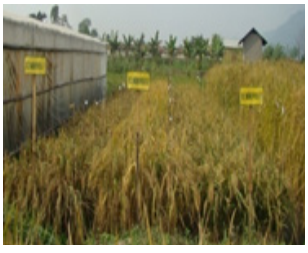
Fig 14. Maintenance breeding of maize

Influence of terminal heat stress on seed set, seed yield and quality in field crops

An experiment in Rice varieties RC Maniphou 7, 10 and 13 was carried out under stress and non-stress condition with seven different treatments *viz.* T_1-Control, T_2-Salicylic acid (800 ppm), T_3-Salicylic acid (400 ppm),T_4-Ascorbic acid (10 ppm),T_5-KCL(1%),T_6-Thiourea (400 ppm) and T_7-Cycocel (2ml in 350 ml water) given at two stages *i.e*., Vegetative stage and Anthesis stage. Among the two conditions, treatment T_6 (Thiourea 400 ppm) of variety V_1 (RC Maniphou-13), T_3 (Salicylic acid 400 ppm) of varieties V_2 (RC Maniphou-10) and V_3 (RC Maniphou-9) was found to be highest in plant height under stress condition. The highest grain yield (4191.78kg/ha) was recorded with treatment T_7-Cycocel of V_2 (RC Maniphou-10) of non-stress conditions and the lowest grain yield (743.73kg/ha) was recorded with treatment T_7-Cycocel of V_3 (RC Maniphou-7) of stress conditions. There were also significant differences in seed set percentage and harvest index among the varieties under the two conditions, T_3- Salicylic acid (400 ppm) of V_1(RC Maniphou-13) of non stress conditions had better performance in seed set percentage and T_2-Salicylic acid (800 ppm) of V_3 (RC Maniphou-7) under Non stress conditions had 31.35% harvest index as against 5.31% of T_4 - Ascorbic acid (10 ppm) under stress conditions of V_2 -RC Maniphou 10 (Fig 15).

A-1. Vegetative stage (Non-stress)

B-1. Flowering stage (Non-stress)



C-1. Maturity stage (Non-stress)

A-2. Vegetative stage (Stress)

B-2. Flowering stage (Stress)

C-2. Maturity stage (Stress)

Fig 15. Performnce of rice under terminal heat stress and non-stress condition

Participatory development of quality seed production practices for seed village concept

The project involving KVKs, NGOs, Self-help Groups and Farmers Clubs under Famers' Participatory Seed Production approach aimed at developing a sustainable seed production system for the NEH Region in major crops was taken up in six different districts of Manipur *viz*., Imphal West, Imphal East, Thoubal, Bishnupur, Chandel and Churachandpur for production of some major crops like rice, maize, groundnut, rapeseed, *etc.* Participatory Seed Production of rice covered 41.25 ha with 58 farmers growing rice varieties RC Maniphou 7, 10, 12 and 13 with a production of 573.78 quintals and average seed yield of 45.0q/ha in pre-*kharif* and 1270.24 q from main *kharif* rice with an average yield of 54.6 q/ha was obtained from different districts of Manipur (Fig 16). Similarly, 135.00 quintals from 15 ha of labelled seeds of groundnut (ICGS 76), 24.63 quintals of maize (RCM 176) and 20.00 quintals Pusa Mustard (M 27) are expected from 8 ha of farmers' farm land. Selected farmers were properly trained and demonstrated with technologies like isolation (compact area, time isolation), line transplanting, use of conoweeder and leaf colour chart (LCC), seed harvesting and packaging and use of RC Seed Bin.

Fig 16. Rice Seed Production at Farmers' Field and Inspection of Seed Plots by Certification Team

HORTICULTURAL CROPS

CITRUS

Multiple shoot regeneration from shoot tip and nodal explants of *Citrus jambhiri*

Nodal segments and shoot tips obtained from *in-vitro* grown seedlings of Kachai lemon were used as explants for multiple shoot regeneration studies. The shoot induction was achieved as early as 14.7 days in BAP (0.5 and 1.0 mg/L, respectively) to 21 days in BAP (2.0 mg/L) from the nodal explants. BAP (1.0 mg/L) showed higher explant response (100%) with 2.3 mean number of shoots at four weeks (Fig 17). Similarly, shoot tip explants exhibited early shoot induction (7 days) in ADS (1.0-1.5 mg/L) followed by BAP (2.0 mg/L) with 60-100% response. The combination of BAP (1.0 mg/L) + GA_3 (1.0 mg/L) resulted in highest mean number of shoots (6.4) and shoot length (1.7 cm) per explant at 6 weeks of subculture. The root initiation (Fig 18) was observed in ½ MSN at 7 DAI with higher no. of roots (4.3). Better internal and external root structure was observed in ½ MSN through SEM (Fig 19).

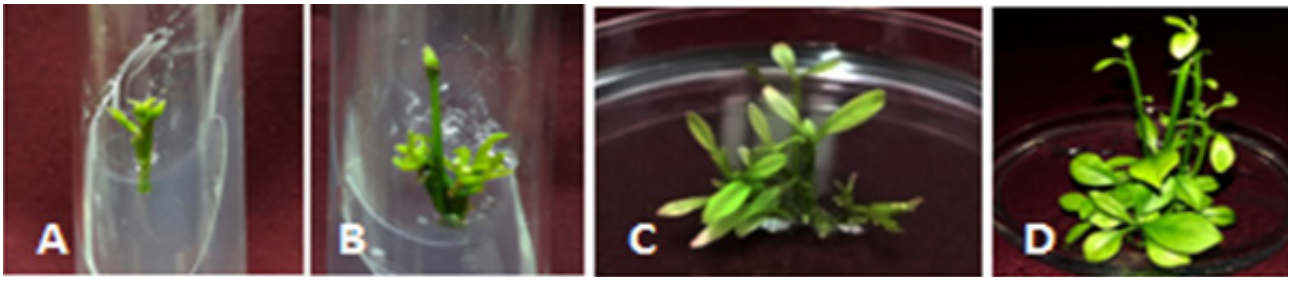


Fig 17. Multiple shoot induction from nodal culture of Kachai lemon

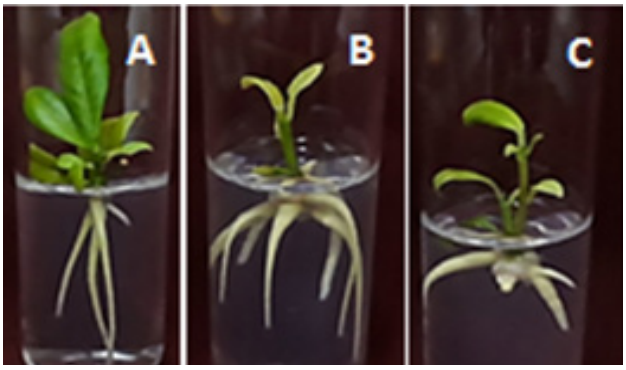


Fig 18. Effect of (A) MSN, (B), ½ MSN and (C) NAA on root induction of shootlets of Kachai lemon

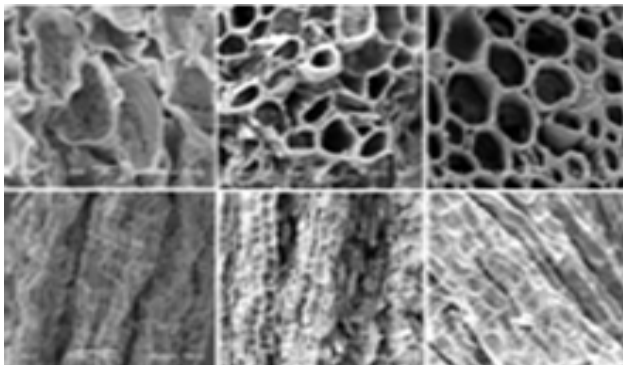


Fig 19. SEM analysis of internal and external root structure obtained from (A) MSN, (B), ½ MSN and (C) NAA

Prevalence and genetic diversity of citrus tristeza virus: development of robust diagnostics for routine indexing

Eleven newly sampled citrus tristeza virus (CTV) isolates were characterized based on variable ORF1a region of viral genome. The characterized CTV isolates segregated in to five distinct major clusters (Fig 20). CTV isolates Mnp-A4 and Mnp-A7 although being genetically distinct but shared closest relatedness with isolates reported from Kalimpong hill, India and USA. Isolates Mnp-A11 was genetically related to Kpg1 (Kalimpong hill, India) and VT genotype (Israel). CTV isolates Mnp-A1 and Mnp-A10 shared clustered with the CTV isolates reported from North and North East India. Interestingly the CTV isolates Mnp-A3, Mnp-A6 and Mnp-A5 were genetically very distinct and were in a group comprising of isolates from Taiwan and Hawaii. CTV isolate Mnp-A2 shared genetic relatedness with the isolate from New Zealand. CTV isolate MNp-A8 was genetically very distinct and did not cluster with any of reported CTV isolates.

This study conclusively reported the existence of high genetic diversity in CTV population of North East India. Based on the conserved genomic region of ORF1a in Indian CTV isolates recombinase polymerase amplification (RPA) based detection system was standardized for simplified detection of CTV in crude sap.

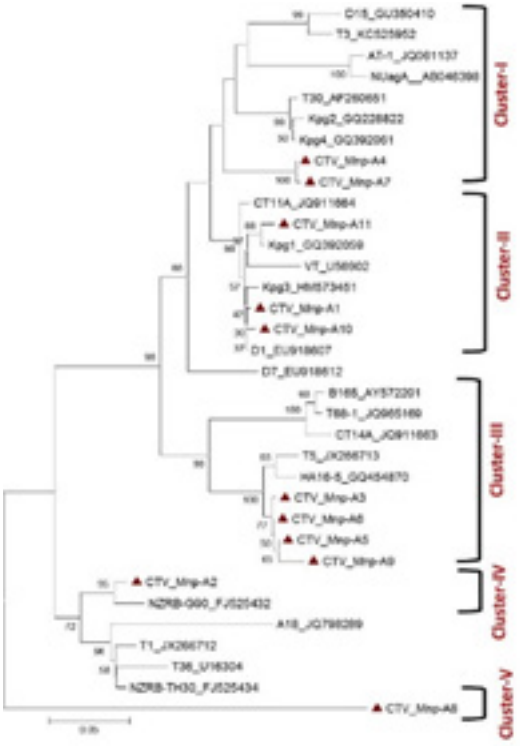


Fig 20. Phylogenetic inference of CTV isolates sampled from NE based on variable ORF1a genomic region

Prevalence and genetic diversity of *Candidatus Liberibacter asiaticus* the causal agent of huanglongbing disease in North East India

Systematic surveys were carried out in different citrus growing pockets of NE India (Manipur, Nagaland, Tripura, Mizoram, Arunachal Pradesh and Sikkim) to assess the prevalence and diversity of CLas causing huanglongbing (HLB) disease. Varied kind of symptoms ranging from yellowing of leaves, branches, irregular patches of yellowing on leaf lamina (blotchy mottle), interveinal chlorosis, mineral deficiency like appearance (symmetrical chlorosis on both side of leaf lamina) were observed in different citrus orchards. Out of the 194 samples collected, 114 samples were tested positive for HLB (58.76%) in PCR using specific primers targeting 16S rDNA. 58 CLas isolates sampled from different citrus groves of NE India were characterized for partial 16S rDNA gene sequences. CLas isolates from NE India had genetic divergence up to 2.3% among them, up to 3.4% compared to CLas isolates from other parts of India and up to 9.8% with the CLas isolates from other parts of the world. The genetic variability of CLas population was also analyzed on the basis of tandem repeat numbers (TRN) in variable CLIBASIA_01645 genomic loci. Fifty five CLas strains sampled from different groves of NE Hill (NEH) region of India were in single amplicon group (SAG), but there was remarkable genetic variability in TRNs. The TRN in HLB-associated CLas strains varied from 0-21 and a novel repeat motif was also identified. Among the NE population of CLas, TRN5 and TRN9 were most frequent (total frequency of 36.36%) followed by TRN4 (14.55%) and TRN6, TNR7 with a frequency of 12.73% each. Class II type CLas genotypes (TRN>5≤10) had highest prevalence (frequency of 52.73%) in the samples characterized in present study. Class I (TRN≤5) genotypes were second highest prevalent (38.19%) in the NEH region. Further analysis of genetic diversity parameters using Nei's measure (H value) indicated wide genetic diversity in the CLas strains of NE India (H value of 0.58-0.86). Manipur CLas strains had highest genetic variability (0.86) as compared to Eastern, Southern, Central and Western India. The R10 values (TRN≤10/TRN>10) of NE CLas population was 10.28 (72/7), higher from other regions of India.

BANANA

Characterization of endogenous and episomal banana streak viruses from local banana mats of North East India

Extensive surveys were carried out in banana groves of North East (NE) India covering all the eight sister states. A total of 216 banana mats/genotypes were collected and maintained as 'field gene bank of banana of NE India'. Selected banana germplasm was characterized for endogenous BSV sequence (eBSV) using allele specific primers. Sequencing of the eBSV indicated that banana genotypes of NE India harvours diverse eBSV alleles having similarity to endogenous banana streak OL virus (eBSOLV), banana streak IM virus (eBSIMV), banana streak GF virus (eBSGFV)

and *Musa balbisaina* PKW type activable alleles. PCR marker based analysis for eBSV indicated that the prevalence of distinct/novel alleles in the banana mats of NE India, the allelic positions of which make them activable. This indicated that activable eBSV being harboured by banana genotypes of NE India are potential blueprints of episomal BSV diversity. The episomal BSVs associated with the streak disease of banana were characterized using sequence independent rolling circle amplification (RCA). RCA-RFLP patterns of 66 isolates of BSV indicated distinct restriction profiles and infection of diverse BSV species. For the first time infection of episomal banana streak IM virus (BSIMV) was detected from Indian banana groves. In addition, sequencing of banana streak MY virus (BSMYV) was also achieved. BSMYV subpopulation from NE India showed considerable genetic diversity segregating to three distinct sub-clusters (Fig 21). Mixed infection of episomal BSMYV and BSIMV was detected for the first time.

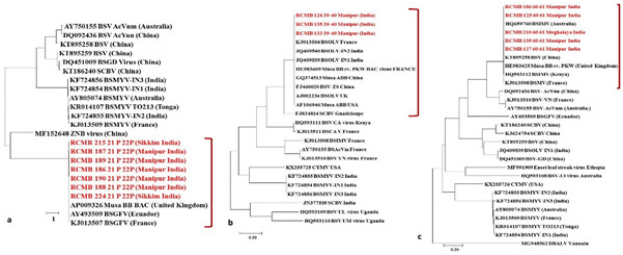


Fig 21. Phylogenetic analysis of eBSV sequences of local banana mats of NE India (a) internal markers of eBSGFV, (b) internal marker of eBSOLV and (c) internal marker of eBSIMV

TREE BEAN

Amino acid profiling of tree bean extruded products

Amino acids profiling of extruded products developed from tree bean seeds through extrusion technology was carried out (Fig 22). Tree bean dehydrated powder was found to be rich in isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine. The lysine content was increased in the ready-to-eat (RTE) extruded products with 5% tree bean which slightly decreased at 10%. Scanning electron microscopy showed better expansion at 5-10% tree bean RTE. However, RTE extruded tree bean (10%) possesses better sensory attributes as compared to RTE extruded tree bean (5%).

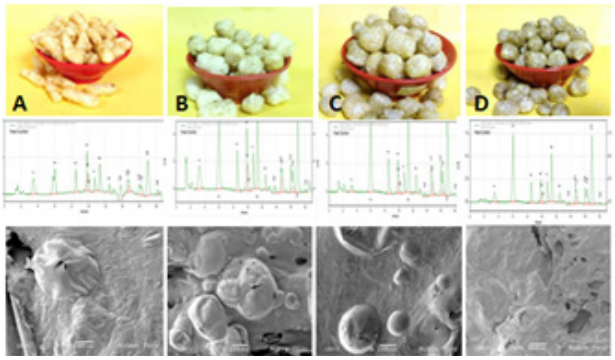


Fig 22. Amino acid profiling and SEM analyses of (A) Tree bean seed, (B) Extruded RTE 2.5%, (C) Extruded RTE 5% and (D) Extruded RTE 10%

Hydrogen peroxide pre–treatment enhances free radical scavenging activities of tree bean (*Parkia roxburghii* G. Don) seeds and pods during storage

Effective use of Hydrogen peroxide (H_2O_2) as a pre–treatment has been demonstrated to maintain the qualitative attributes in tree bean during storage, which would be an alternative against the expensive cold storage facilities for smooth marketing of this perishable legume. Treatment with H_2O_2 (10–20 mM) influenced the regulation of antioxidant properties coupled with free radical scavenging activities in tree bean resulted in extending shelf life upto thirty days, which could be used commercially to prevent the nutraceutical losses in this nutritional–rich food crop during storage (Fig 23).

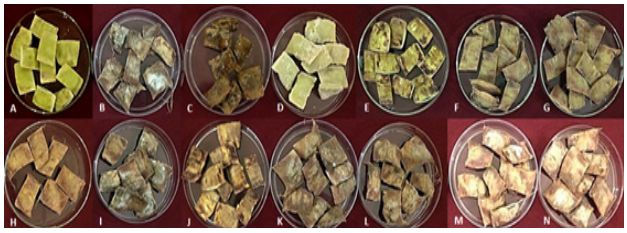


Fig 23. Effect of physical and chemical pre-treatments on tree bean pods at 30 days of storage (A) Tree bean pods prior to physical and chemical pre-treatments at 0 day, (B) Storage at RT (25°C), (C) Storage at 4°C, (D) Storage at -20°C, (E) γ-irradiation (0.25 kGy), (F)) γ-irradiation (0.5 kGy), (G)) γ-irradiation (0.75 kGy), (H)) γ-irradiation (1.0 kGy), (I) NaoCL (100 ppm), (J) NaoCl (200 ppm), (K) ClO_2 (100 ppm), (L) ClO_2 (200 ppm), (M) H_2O_2 (10 mM) and (N) H_2O_2 (20 mM)

KIWIFRUIT

Promotion of Temperate Horticulture – Launching of Organic Kiwifruit Producers' Organization in Senapati District, Manipur

Since 2012-13, ICAR Manipur Centre has undertaken area expansion activities on organic kiwifruit with an objective to promote temperate horticulture in high altitude areas in Manipur. A dedicated programme has been undertaken for establishment of Organic Kiwifruit Production Hub at Purul Sub-division in Senapati district of Manipur. Due to ICAR initiative, many growers have started cultivating kiwifruit at commercial scale. Under the programme, ICAR, Manipur Centre has launched Senapati Producers' Organization of Organic Kiwifruit (SPOOOK) at Purul Akutpa Village, Senapati district, Manipur on 2nd May, 2018 in presence of Dr. N. Prakash, Director, ICAR Research Complex for NEH Region, Meghalaya and Shri K. Debdutta Sharma, CEO, Manipur Organic Mission Agency (Fig 24). A growers-scientists interaction program was also organized after the launching ceremony. The launching of SPOOOK is an important step to create and increase opportunities for organic kiwifruit growers through promotion and support to organic kiwifruit sector in Senapati district, Manipur for ensuring a sustainable future.

Fig 24. (A) Logo of SPOOOK, (B) Unveiling of SPOOOK Logo and (C) Launching Ceremony of SPOOOK

CHILLI

First report of infection of large cardamom chirke virus from chilli crop in North East India

In April 2018, leaf deformation and severe mosaic symptoms along with green streaks (18-24% incidence) were observed in *C. annuum* (landrace Dalle Khursani) in Sikkim-Darjeeling hills region. Dark and light green elongation was detected on leaf lamina of the adult chilli plants whereas young plants exhibited puckering of leaf lamina and severe mosaic symptoms. Three representative samples collected from different fields were subjected to leaf dip transmission electron microscopy. Flexuous filamentous, 650-670 × 12.5 nm particles, similar in morphology to potyvirus virions, but smaller in size, were observed. Sap from infected chilli leaves extracted in phosphate buffer (0.2 M, pH 7.4) was mechanically transmitted to 16 healthy chilli plants (8 each of landrace Dalle Khursani and King chilli (*C. chinense*). Thirteen of the inoculated chilli plants exhibited severe mosaic symptoms and deformation of leaves, similar to original field symptoms, after 24-26 days post-inoculation (Fig 25-29). As nearby large cardamom plantations exhibited the symptoms of chirke disease caused by large cardamom chirke virus (LCCV), a macluravirus, all the symptomatic samples were tested by RT-PCR using LCCV coat protein gene specific primers. LCCV specific amplicons (~810 bp) from three field isolates were cloned and consensus sequences from two clones of each isolate were submitted to GenBank database (accession numbers: MH899147-MH899149). The LCCV specific amplification was also obtained from mechanically inoculated, symptomatic chilli plants proving the Koch's postulates. The CP sequences of the characterized virus isolates shared 98.3-98.7% nucleotide identity with LCCV available in GenBank. To the best of our knowledge, this is the first report of occurrence of a LCCV infection in any Solanaceous host, which documented the cross species transmission capability of macluraviruses.

Fig 25. Symptoms of severe mosaic and leaf deformation observed on Dalle Khursani chilli (*Capsicum annuum*) adult plants

Fig 26. Symptomatic young plants of Dalle Khursani chilli

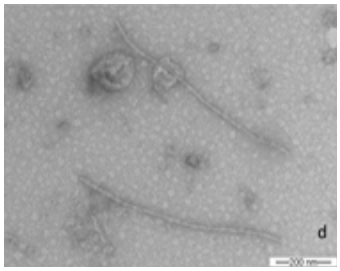


Fig 27. Electron micro-graph of infected leaf preparations

Fig 28. Inoculated king chilli plant

Fig 29. Mock inoculated king chilli plant

Detection of prevalence of viral infection in king chilli in North East India

Surveys were conducted in different king chilli growing pockets of North East India. The symptomatic and asymptomatic samples were tested for the possible infection of chilli veinal mottle virus (ChiVMV), cucumber mosaic virus (CMV), chilli leaf curl virus (ChiLCV) and capcicum chlorosis virus (CaCLV). Complex symptoms typical of those caused by virus(es) were observed under field conditions. Typical symptoms of yellow mosaic, leaf mottling, puckering, shoe-string, vein banding, and severe curling of leaves were observed on the infected king chilli plants (Fig 30). Diseased symptoms were mainly observed in the older king chilli plants. A total of 774 king chilli samples suspected to be infected with viral infection were subjected to RT-PCR based detection using specific primers for ChiVMV, CMV and CaCV and PCR for ChiCLV. Out of 774 samples tested in the present study, 72.60% were positive for ChiVMV infection and 68.47% were positive for CMV infection. 29.71% of the tested samples (230 samples) were having mixed infection of CMV and ChiVMV. This study indicated high prevalence of ChiVMV infection followed by CMV infection. The results of present study indicated widespread prevalence of ChiVMV and CMV with the viral complex symptoms of King chilli in Manipur. Interestingly, none of the tested samples was found positive for CaCV and ChiCLV.

Fig 30. Typical symptoms of viral infection in king chilli plants collected from different parts of North East India

Characterization of ChiVMV associated with the viral complex of chilli

Five representative isolates of ChiVMV isolates (Mnp1 to Mnp5) sampled from different groves of Manipur were characterized for their genetic diversity based on the conserved 432 bp fragment of CP gene. Neighbour Joining (NJ) phylogenetic analysis of these ChiVMV isolates with the earlier reported isolates from India and other parts of the world indicated genetic distinctiveness. All the five ChiVMV isolates from Manipur (Mnp1 to Mnp5) segregated to a distinct cluster (which were genetically homogenous with in the cluster), nearest to which were the isolates from Italy and China (Fig 31). The analysis indicated genetic homogeneity among ChiVMV isolates occurring in Manipur region of NE India but distinctiveness from ChiVMV isolates reported from the other parts of India.

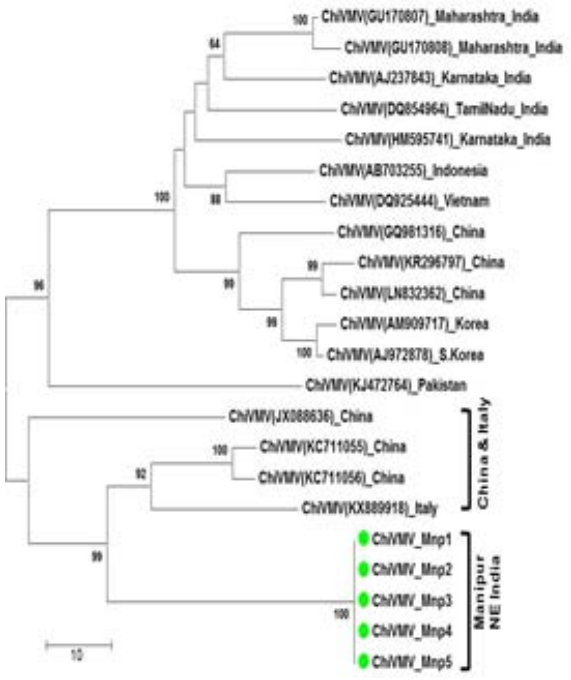


Fig 31. Genetic relationship of ChiVMV isolates from NE India (ChiVMV-Mnp1 to Mnp5: marked with green circle) with other ChiVMV isolates from India and other parts of the world based on partial nucleotide sequences of CP gene

Characterization of CMV associated with the viral complex of chilli

Thirteen representative CMV isolates from different locations of Manipur were selected for studying the genetic diversity based on their coat protein (CP) sequences (657 bp). The CP sequences of present isolates were compared with that of other isolates reported from different parts of the world. CMV isolates characterized in the present study segregated into five distinct clusters. These clusters were very distinct compared to the CMV isolates reported earlier. Isolates MKC1, MKC4 and MKC2 originated from Manipur were genetically and phylogenetically distinct as evident from their distinct segregation. This indicated that distinct genotypes of CMV infecting King chilli are prevalent under NE conditions.

BIOPROSPECTING

Free Radical Scavenging Activity of Indigenous Herbs of Manipur

The free radical scavenging activity of six wild indigenous herbs, *Eupatorium birmanicum, Alpinia galanga, Jussiaea Repens, Polygonum sagittatum, Gynrua crepidioides* and *Catharanthus roseus* were assessed using *in-vitro* antioxidant assay namely DPPH assay, ABTS assay and FRAP assay (Fig 32-34). The free radical scavenging activities of these plants were compared with L-Ascorbic Acid as positive control for their efficacy. The effectiveness of DPPH and ABTS assay in scavenging the free radical were compared using EC_{50} while FRAP assay using Ferrous Equivalents. In the entire *in-vitro* antioxidant assay performed, the *J. repens* was found to be most effective in scavenging the free radicle followed by *P. sagittatum*. The EC_{50} of L-Ascorbic acid was nearly 7 time the *J. repens* in both DPPH and and ABTS assay. This higher antioxidant activity in crude extract of *J. repens* indicates the presence of highly potent free radicle scavenging candidate compounds in this plant. The result of DPPH and ABTS assays were further supported by FRAP assay.

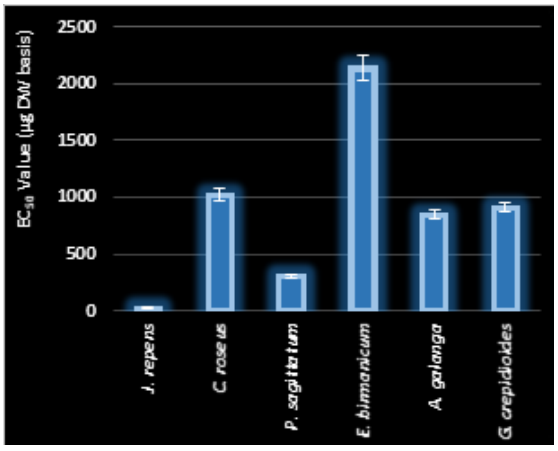


Fig 32. Antioxidant Activity of Indigenous Herbs in DPPH Assay

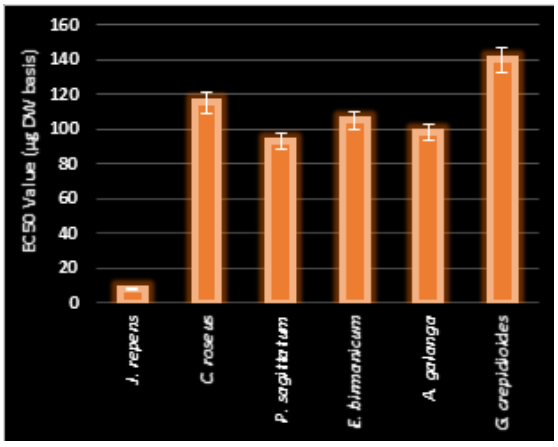


Fig 33. Antioxidant Activity of Indigenous Herbs in ABTS Assay

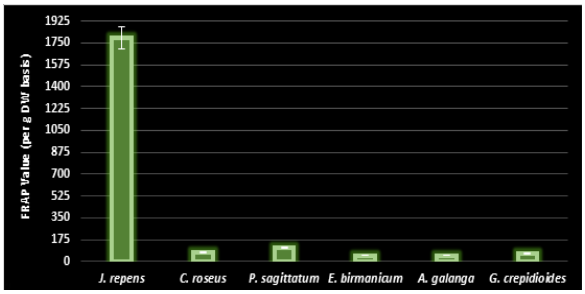


Fig 34. Antioxidant Activity of Indigenous Herbs in FRAP Assay

Screening of Edible Mushroom Species for Antioxidant Properties

All total five edible mushroom species namely, *Pleurotus oystractus*, *Pleurotus eous*, *Ramaria botrytis*, *Scleroderma citrinum* and *Termitomysis* sp. were evaluated for their antioxidant properties. The methanol and water extracts of the mushroom species were screened using different antioxidant assays namely DPPH, ABTS and FRAP assay (Fig 35-37). In DPPH assay, *Scleroderma citrinum* has shown maximum antioxidant activity for water and methanol extract (IC_{50} value 2.18 and 1.13 mg/ml, respectively). In ABTS assay, highest antioxidant activity among the water extracts was recorded with *Pleurotus eous* (IC_{50} value 0.158 mg/ml); whereas, among the methanolic extracts *Scleroderma citrinum* and *Termitomysis* sp. Showed the maximum antioxidant activity (IC_{50} value 0.091 mg/ml). In FRAP assay, among the water and methanol extract highest ferric reducing antioxidant power was observed in *Termitomysis* sp. (139.923 µg Trolox equivalent/g of sample) and *Scleroderma citrinum* (171.405 µg Trolox equivalent/g of sample), respectively. Based on the published reports, the study revealed that these mushroom species showed good antioxidant activity and their consumption is beneficial for a healthy living.

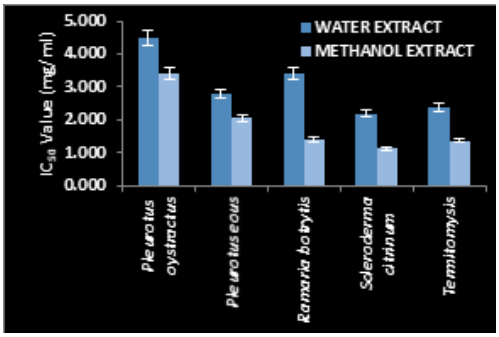


Fig 35. Antioxidant Activity of Different Mushroom Species in DPPH Assay

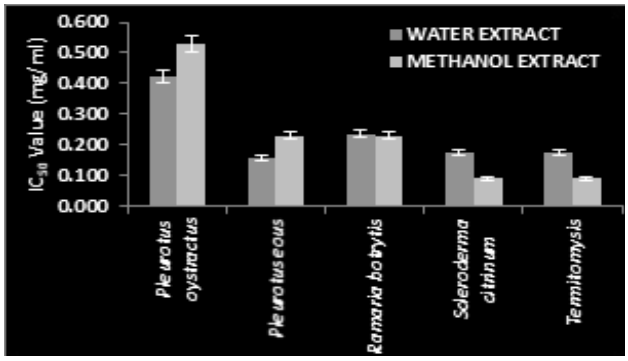


Fig 36. Antioxidant Activity of Different Mushroom Species in ABTS Assay

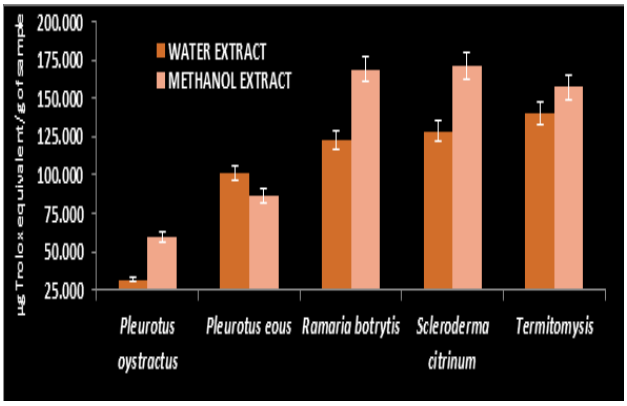


Fig 37. Antioxidant Activity of Different Mushroom Species in FRAP Assay

Nutritional Evaluation of Six Oyster Mushroom Species

All total six species of oyster mushroom were collected from AICRP Centre on Mushroom at ICAR, Manipur Centre and evaluated for their proximate composition (Table 2) and nutrient content. Maximum moisture content (90.76%) was recorded with *Pleurotus flabellatus* (PL-17-05); whereas, maximum ash content (8.40 g/100 g DW) was associated with *Pleurotus sajorcaju* (PL-17-07). *Pleurotus ostreatus* (PL-17-12) was found to be very high in crude fibre content (29.3 g/100 g DW) as compared to other species. In terms of crude protein, fat and carbohydrate content, maximum values (23.7, 2.28 and 45.89 g/100 g DW, respectively) were observed with *Pleurotus florida* (PL-17-09), *Pleurotus membranatus* (PL-17-11) and *Pleurotus sapidus* (PL-17-05), respectively. Overall, *Pleurotus flabellatus* and *Pleurotus sajorcaju* was found to be nutritionally superior over other species.

Table 2. Proximate composition of six oyster mushroom species

Mushroom species (strain)	Moisture %	Value in g/100 g dry weight				
		Ash	Crude Fibre	Crude Protein	Fat	Carbohydrate
Pleurotus sapidus (PL-17-05)	79.90	6.37	6.9	18.2	1.15	45.89
Pleurotus flabellatus (PL-17-06)	90.76	7.63	13.0	22.1	1.60	36.77
Pleurotus sajorcaju (PL-17-07)	87.50	8.40	12.8	10.7	1.50	45.77
Pleurotus florida (PL-17-09)	87.50	7.00	4.9	23.7	1.15	43.39
Pleurotus membranatus (PL-17-11)	88.97	7.30	12.5	16.5	2.28	40.83
Pleurotus ostreatus (PL-17-12)	85.47	6.00	29.3	18.0	0.82	41.27

Based on the carbohydrate, protein and fat content, the energy value of six mushroom species was also worked out (Fig 38). Maximum energy value (53.6 Kcal/100 g FW) was recorded with *Pleurotus sapidus* (PL-17-05); whereas, minimum energy value (23.08 Kcal/100 g FW) was found in *Pleurotus flabellatus* (PL-17-05).

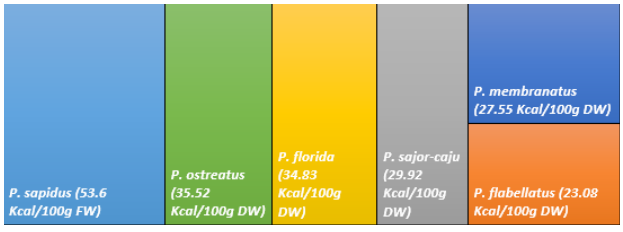


Fig 38. Energy value of Six Pleurotus Mushroom

The nutrient content of six mushroom species was also estimated (Fig 39-41). Maximum phosphorus and potassium content was recorded with *P. flabellatus* (785.11 mg/100 g DW) and *P. sajor-caju* (3155.00 mg/100 g DW). In terms of micronutrient content, maximum copper (4.02 mg/100 g DW) and manganese (0.52 mg/100 g DW) content was found in *P. flabellatus* and *P. sapidus*, respectively; whereas maximum zinc (10.34 mg/100 g DW) and iron (10.81 mg/100 g DW) content was observed in *P. ostreatus* and *P. sajorcaju*, respectively. Overall *P. flabellatus, P. ostreatus* and *P. sajorcaju* were found to be more nutritious over other species.

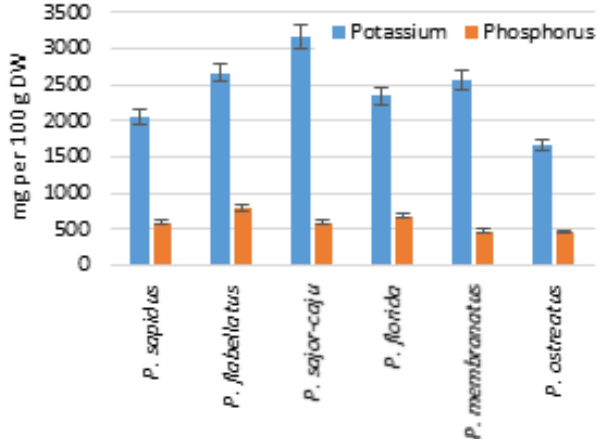


Fig 39. Potassium and Phosphorus Content in Different Mushroom Species

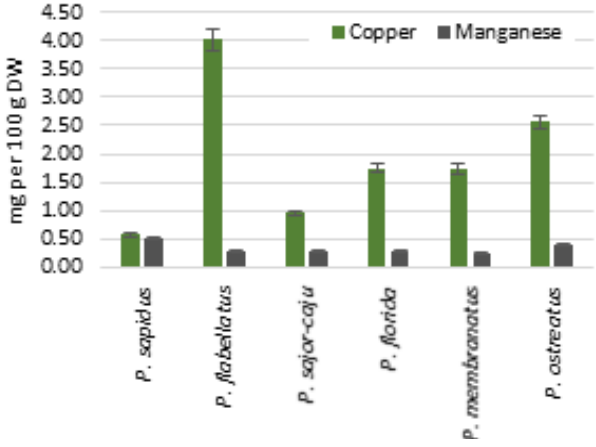


Fig 40. Copper and Manganese Content in Different Mushroom Species

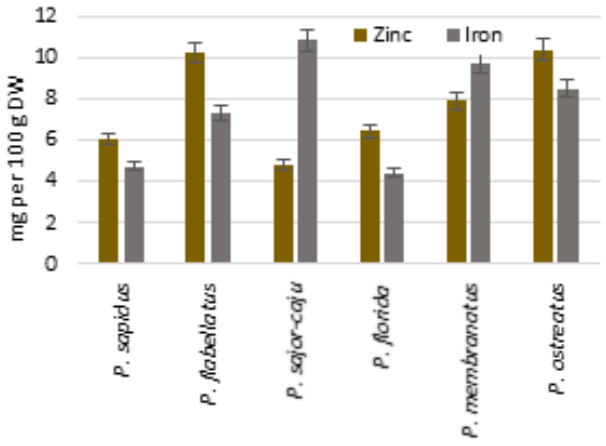


Fig 41. Zinc and Iron Content in Different Mushroom Species

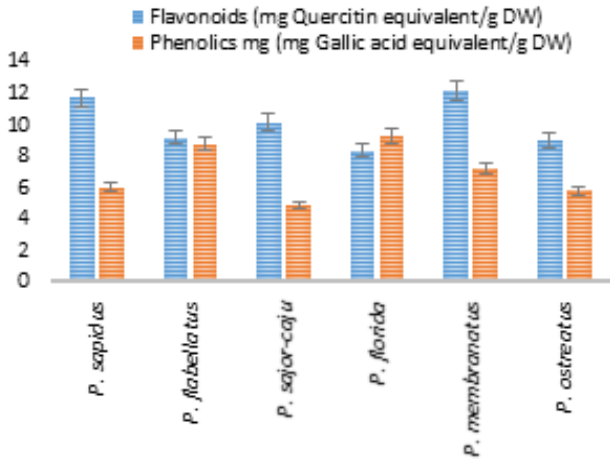


Fig 42. Phenolics and Flavonoids Content in Different Mushroom Species

These mushroom species were also screened for their phenolic and flavonoids content (Fig. 42). All the mushroom species did not show very high phenolic and flavonoid content. The phenolic content ranged from 4.84 mg gallic acid equivalent/g DW (*P. sajor-caju*) to 9.21 mg gallic acid equivalent/g DW (*P. florida*); whereas the flavons content was found in the range of 8.31 mg quercetin equivalent/g DW (*P. florida*) to 12.15 mg quercetin equivalent/g DW (*P. membranatus*).

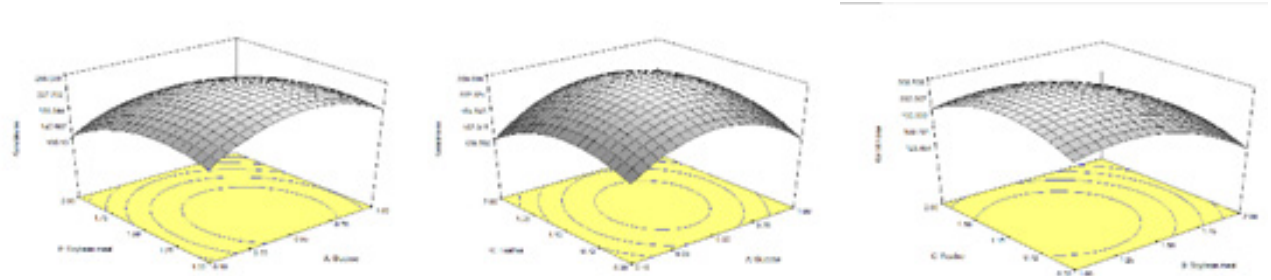
Production optimization, purification and characterization of KER102 keratinase enzyme from chicken feather waste using native bacteria *Bacillus* sp., RCM-SSR-102 and for preparation of bioactive keratin hydrolysate

Microbial or enzymatic conversion of waste into other value-added product is becoming an attractive strategy to harness wealth from the waste. With this background, the production of purified keratinase enzyme from chicken feather waste using a native bacteria *Bacillus* sp. RCM-SSR-102 was optimized. The bacterium was isolated from feather waste dumping site in Ukhrul district, Manipur, (24.9321°N, 94.4800°E). The isolate was identified by 16S rRNA gene sequencing and sequence was submitted to NCBI Gene Bank (MH997834).

Production optimization: Optimum keratinase production by strain RCM-SSR-102 was observed at 30°C and 1.5% feather concentration. Further increase in temperature as well as feather concentration decreased the keratinase production. Supplementation of carbon and nitrogen also enhanced keratinase production by strain RCM-SSR-102 and among all carbon sources addition of glucose increased the enzyme titer maximally. Based on the results of one variable at a time approach the effects of three parameters (glucose, soybean meal and feather concentrations) on keratinase production were studied using RSM. Both observed and predicted values of keratinase production were found to be comparable suggesting the authenticity of the model. The keratinase production (Y) by strain RCM-SSR-102 was expressed in terms of the following regression equation:

Y = + 259.8 + 4.41 A - 40.01 B - 5.39 C- 64.7 A2- 46.14. B2 - 45.17. C2 - 8.27. A.B + 10.39 A.C + 0.36. B.C

where A, B and C represent glucose, soybean meal and feather concentrations, respectively. The ANOVA of the experimental model was also determined. The Model's F-value of 46 and R^2 value of 0.954 is high indicating that the model is significant. The optimal concentration of each parameter for maximum keratinase production was determined from one factor, contour and 3D response surface curves (Fig 43). The keratinase yield by RCM-SSR-102 under optimized conditions (0.5% glucose, 1.1% feather and 1.2% soybean meal, w/v) was 268 U/ml which was more than threefold increase over un-optimized initial basal feather medium.



(A) Interaction between soybean meal and glucose **(B) Interaction between feather concentration and glucose** **(C) Interaction between feather concentration and glucose**

Fig 43. 3D response curves showing interactions among the variables on soluble peptide production by *Bacillus sp.* RCM-SSR-102

Purification of keratinase: The KER102 keratinase was purified using an ultrafiltration and Sephadex G 100 column chromatography. The proteolytic fraction from Sephadex G 100 gel filtration showed 7.5 folds increase in specific activity (4848 U/mg) with approximately 26.5 % protein yield (Fig 44). The homogeneity of purified keratinase was checked on SDS-PAGE where the purified keratinase showed a single protein band of approx. 30 kDa (Fig 45).

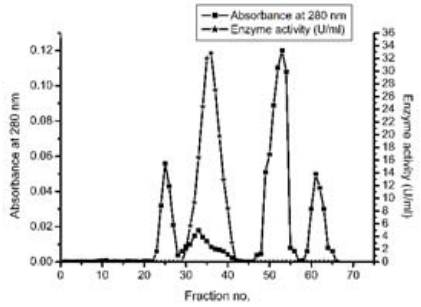


Fig 44. Elution profile of KER102 keratinase on sephadex G-100 (Elution was performed with 40 mM phosphate saline buffer pH 6.8)

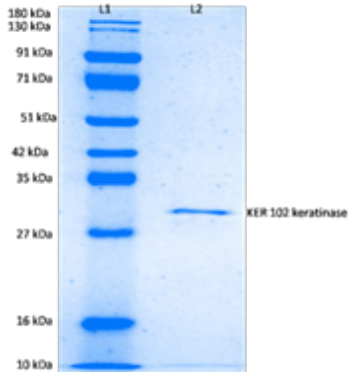


Fig 45. SDS-PAGE of the purified KER102 keratinase: Lane 1- Marker protein and Lane 2- Purified keratinase.

Characterization of keratinase: The purified KER102 keratinase was found to be quite stable at high pH (retained 98% activity at10 pH) and high salt concentrations (retained 55% activity at 3.4 M or 20% salt). In leather industry and during soaking and other related procedures of leather processing, high concentration of salt is used to achieve appropriate swelling and texturing of a hide. Hence, salt-stable KER102 has immense potential for using in leather processing. Like most other microbial keratinases KER102 was also characterized as serine metalloproteases as it was completely inhibited by PMSF, a well-known serine protease inhibitor; and the metal ion chelator EDTA. Among the bivalent metal ions Mg^{2+} and Ca^{+2} stimulated KER102 keratinase activity whereas, Fe^{2+}, Pb^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Mn^{2+} and Hg^{2+} were found to be inhibitory. The results are presented in Fig 46-49.

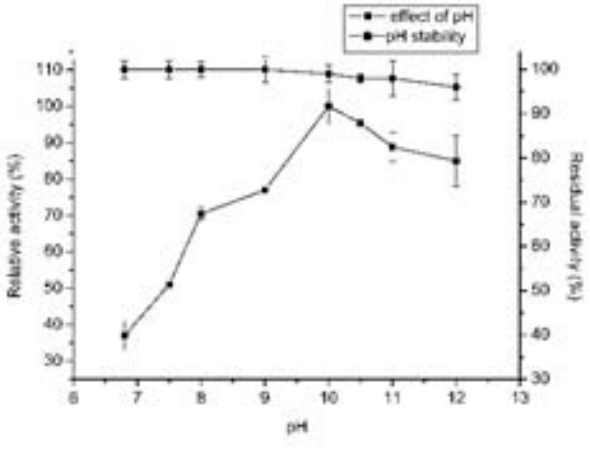


Fig 46. Effect of varying levels of pH on the activity of KER102 keratinase

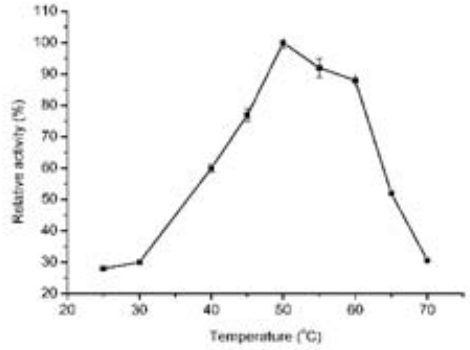


Fig 47. Effect of varying levels of Temperature on the activity of KER102 keratinase

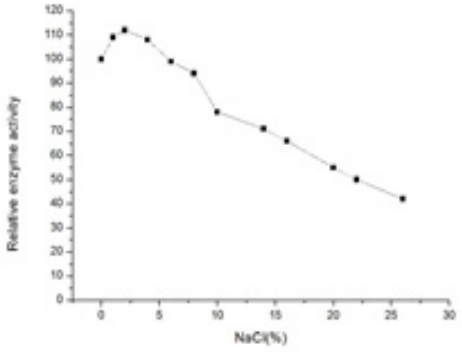


Fig 48. Effect of varying levels of Salt concentration on the activity of KER102 keratinase

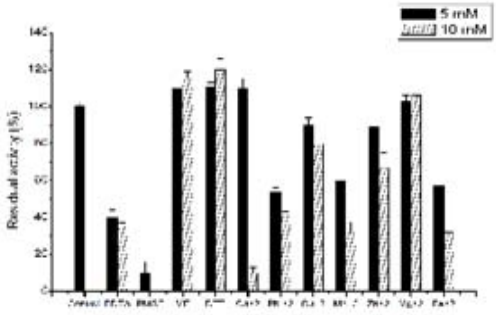


Fig 49. Effect of varying levels of enzyme inhibitors and bivalent metal ions on the activity of KER102 keratinase

KER102 keratinase was found to be highly stable in presence of oxidizing agents and surfactants (Table 3). The nonionic surfactants, Tween-20 and Tween-80, had a moderate stimulatory effect on the keratinase activity whereas Triton X100 (non-ionic surfactant) did not affect enzyme activity. H_2O_2 (oxidizing agent) also stimulates KER102 enzyme activity. This property is of biotechnological interest since there is a limited report on wild-type proteases which are stable in presence of surfactant and oxidant. Alkaline proteases are frequently used in detergent industries; it is desirable for them to be stable in presence of various oxidizing agents and surfactants.

KER102 also showed high stability in presence of organic solvents at 20% v/v concentration. There was no loss in enzyme activity at 60% concentration of organic solvents such as hexane, toluene, diethyl ether and DMSO. Keratinase activity was stimulated by hexane and DMSO. The stability of protease enzyme in presence of organic solvents may allow applicability of the enzyme for peptide synthesis reactions under a non-aqueous environment.

Table 3. Effect of oxidizing agents, surfactants and organic solvent on KER102 keratinase Activity

Additive	Concentration (% v/v)	Relative activity (%)
H_2O_2	1	130 ± 8^{b}
Tween-20	1	124 ± 6^{b}
Tween-40	1	127 ± 3^{b}
Triton X100	1	99.7 ± 2^{a}
Hexane	20 60	128 ± 2.2 98.8 ± 3^{c}
Butanol	20 60	66 ± 2.4 0
Toluene	20 60	105 ± 5^{c} 99 ± 4^{c}
Ethanol	20 60	99 ± 2^{c} 40 ± 2^{d}
Methanol	20 60	105 ± 4^{c} 39 ± 2^{d}
Acetone	20 60	78 ± 3 43 ± 3^{d}
Diethyl Ether	20 60	126 ± 1 96.5 ± 2^{c}
Chloroform	20 60	85 ± 4 62 ± 2
DMSO	20 60	142 ± 8 101 ± 6^{c}
Control	0	100 ± 2^{ac}

Values with same alphabet in a column are not statistically significant at $p<0.05$.

Keratinases are known to efficiently degrade proteinaceous substrates that are rich in keratin content such as feather, wool, nail, hair, etc. The keratinase could also hydrolyze both soluble and insoluble complex protein substrates. The KER102 keratinase can hydrolyze up to 5% (w/v) feather concentration releasing 8.58±0.5 mg protein. It showed maximum activity on casein, haemoglobin, azocasein followed by fibrin, feather and keratin azure (Table 4).

Table 4. Substrate specificity of KER102 keratinase

Substrate	Monitoring wavelength (nm)	Relative activity (%)
Casein	280	100±2[a]
BSA	280	100±4[a]
Haemoglobin	280	98±2[a]
Fibrin	280	80±6
Feather	280	70±2
Keratin azure	595	65±2
Azocasein	420	100±[a]

Values with same alphabet in a column are not statistically significant at p<0.05.

First report on bioactive feather keratin hydrolysate having antioxidant and anti-tyrosinase activity from North East India

The feather keratin hydrolysate (FKH) was prepared from defatted and autoclaved chicken feathers treated with purified KER102 keratinase. The FKH thus obtained was screened for both antioxidant and antityrosinase activity (Table 5). The maximum antioxidant activities (DPPH, ABTS and FRAP) were observed at 4-5% w/v feather concentration.

Feather concentration (%)	Feather weight loss (%)	Protein content (µg/ml)	DPPH Assay (%)	ABTS Assay (%)	FRAP Assay (A_{593})	Tyrosinase Inhibition (%)
1	80.3±2.1	463±16	8.9±0.17	32.17±3.3	0.158±.003	16.4±1.4
2	79.0±1	824±18	15.4±0.67	53.50±1.3	0.234±.003	28.5±1.4
3	63.1±0.9	1145±145	22.2±1.1	63.33±1.5	0.315±.011	37.2±0.7
4	58.0±2	1652±80[a]	26.5±0.7[a]	82.00±2[a]	0.401±.01[a]	55.0±2.6[a]
5	39.0±2.6	1716±190[a]	27.3±0.64[a]	81.33±4.2[a]	0.402±.01[a]	56.0±[2a]

Values with same alphabet in a column are not statistically significant at p<0.05.

The freeze-dried FKH was evaluated for bioactivities as a function of protein concentration. Dose-dependent responses were observed in all assays and IC_{50} values were calculated from the dose-response curves. The IC_{50} value of FKH in DPPH assay was 1.02±0.01 mg/ml and that of ascorbic acid was 8±0.02 µg/ml. The radical scavenging activity of FKH was higher in ABTS assay as compare to DPPH assay. The IC_{50} of ABTS assay was 20±0.04µg /ml and that of ascorbic acid was 5.6±0.01µg/ml. In FRAP assay the antioxidant capacity of the FKH was expressed as 230.0±12 µg ascorbic acid equivalent per mg of protein. The FKH was also able to inhibit the mushroom tyrosinase enzyme. The tyrosinase inhibition increases with increasing concentration of the feather. There was 56% tyrosinase inhibition at 5% feather concentration. The IC_{50} value of the tyrosinase inhibition was found to be 1.2 ±0.22 mg/mL and that of Kojic acid was 5±0.02 µg/ml. Antioxidant and antityrosinase compounds have potential applications in pharmaceutical and cosmetic industry.

Feather hydrolysates were reported for having antioxidant activities. However, majority of the feather hydrolysate in these studies was prepared by microbial fermentation and there are scanty reports on cell free enzymatic feather hydrolysate production. Hence, the purified keratinase can be a potential candidate for production of antioxidant and antityrosinase compounds from chicken feather waste. Hence the results of our study would to pave the way for utilization of FKH produced from chicken feather waste as a good additive in skin care products and is expected increase its commercial importance in cosmetic as well as pharmaceutical industry.

Collection of edible insects for extraction and characterization of bioactive peptides

Different edible insects were collected from different parts of Manipur. Grubs of *Rhynchophorus ferrugineus* (red palm weevil) and Stink Bug (*Bagrada* spp. roasted form) were collected from Ukhrul district. Carpenter worm (*Prionoxystus robiniae*- both early and late instars) was collected from Senapati district. Bamboo worm (*Omphisa fuscidentalis* and Grasshoppers (*Oxya* spp, *Hieroglyphus* spp.: live and roasted forms) were collected from Sekmai. House Cricket (*Acheta domestica*: live and roasted, powdered) was collected from Kadangband, Singda.

(a) Red Palm Weevil, *Rhynchophorus ferrugineus* grubs (b) Stink Bug, *Bagrada* spp. roasted (c, d) Carpenter worm, *Prionoxystus robiniae* - early and late instars (e) Bamboo worm, *Omphisa fuscidentalis* (f, g) Grasshoppers, *Oxya* spp, *Hieroglyphus* spp.- live and roasted (h) House Cricket, *Acheta domestica*- roasted, powdered and live

Fig 50. Collection of edible insects for extraction and characterization of bioactive peptides

MUSHROOM

Under AICRP-Mushroom, four strains of oyster mushroom (*Pleurotus* sp.) were evaluated under advance varietal trial-2 at temperature of <20°C (winter trial), wherein strain PL-17-01 gave the highest biological efficiency (BE) of 35.66 (based on first harvest). A total of eight high yielding strains of oyster mushroom (*Pleurotus* sp.) were evaluated at temperature of >20°C (summer trial) to identify most suitable species under Manipur conditions (Fig 51). Strain Pl-17-12 gave highest BE of 61.32 and took minimum number of days (12-14) for first harvest. Second best strain was PL-17-06 which gave the BE of 42.47%. Besides, in order to popularize mushroom cultivation among farmers of Manipur, quality spawn of different *Pleurotus* species (*P. ostreatus, P. eous, P. sapidus, P. flabellatus, P. sajorcaju, P. florida* and *P. eryngii*), and shiitake (*Lentinula edodes*) were produced and supplied to different stakeholders. Thirteen number of training programmes (347 participants) on scientific mushroom spawn production and cultivation technology and 'National Mushroom Day' (80 participants) were organized for farmers, farm women, women shelf help groups, entrepreneurs etc.

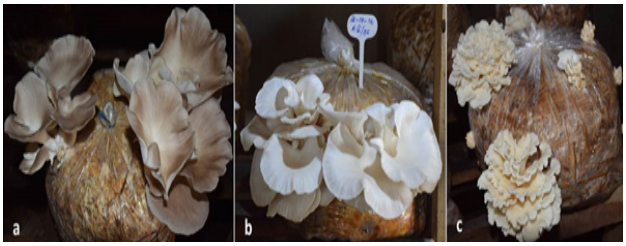


Fig 51. High yielding strains of *Pleurotus*; (a) PL-17-01, (b) PL-17-06, and (c) PL-17-12

NATIONAL MISSION ON SUSTAINING THE HIMALAYAN ECOSYSTEM (TF 6)

Fertilizer management in rice : An experiment was undertaken on fertilizer management practices (control, farmers practice and recommended dose of fertilizers) with three genotypes of rice (Thoibi, RC Maniphou-7 and -13). Significantly higher grain yield was recorded in RC Maniphou-13 (5.97 t/ha) followed by RC Maniphou-7 (5.90 t/ha), while minimum yield was recorded in Thoibi (3.21 t/ha). Similarly, RDF gave significantly high yield (5.32 t/ha) as compared to farmer practice (4.97 t/ha). Nutrient partitioning was analyzed (total N, P, K and micronutrients) in leaf, shoot and root at various growth stages of three genotypes under different fertilizer management practices. Maximum P content was found in RC Maniphou-13 in various rice plant parts (leaf, root and shoot), while higher P partitioning was recorded in RDF in various plant parts at different stages (Fig 53).

Fig 52. Experimental plot of rice under different fertilizer management

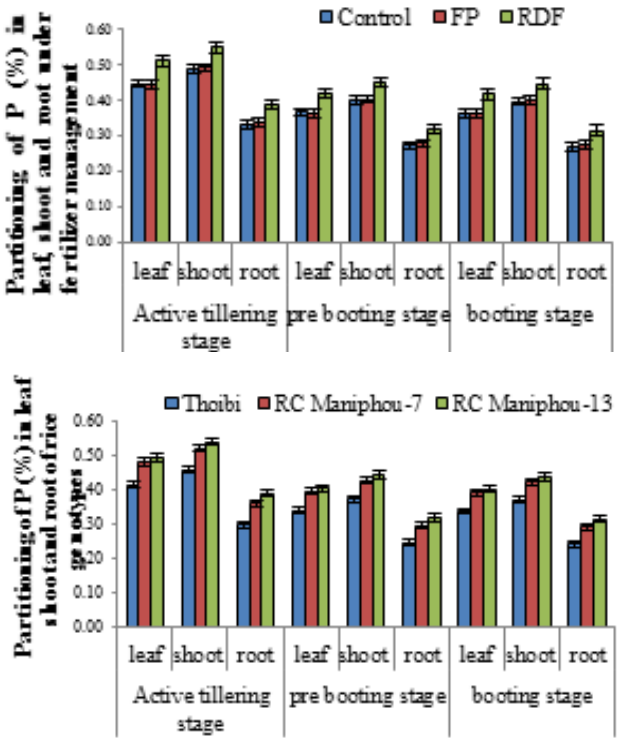


Fig 53. P partitioning in leaf, shoot and root of rice at various growth stages under genotypic variation and fertilizer management practices

Pilot studies under NMSHE (TF-6) : Under various pilot studies (Fig 54), intercropping of Maize + Ricebean: 6.45 t/ha maize equivalent yield (MEY) recorded in intercropping over 3.8 t/ha in sole cropping (Var. HQPM-1) and farmers practice of traditional maize cultivation (1.84 tonnes/ha). Introduction of lentil under Minimum till in Rice-fallow: 0.85 t/ha lentil (HUL-57) was produced under Minimum tillage after rice harvesting and performance was found better than zero cultivation (0.654 t/ha) and utera cultivation (0.342 t/ha). Besides, integrated nutrient management in maize with 50% RDF + 25% Vermicompost and 25% Compost applied enhanced 49% yield with 38% net returns over farmers practice. High yielding varieties of rice namely, RC Maniphou-9 and -13 were also introduced and farmers harvested 5.6 and 5.9 tonnes/ha rice grain from RC Maniphou-9 and -13, respectively, which is twofold higher than local cultivars. Introduction of groundnut variety ICGS-76 also resulted in 2.2 to 2.7 tonnes/ha pod yield as compared to very less harvest from traditional cultivation (maize mixed farming/rice mixed farming).

A. Maize + Rice bean intercropping

B. Lentil cultivation under minimum tillage

C. Introduction of HYVs of rice

Fig 54. Various Pilot studies under NMSHE (TF-6)

ESTIMATION OF PESTICIDE RESIDUES STATUS OF RICE AND MAJOR VEGETABLES OF MANIPUR

A rapid and reliable reverse phase high performance chromatograph (RP-HPLC) method coupled with modified QuEChERS was developed for

the instantaneous detection of insecticides residues of imidacloprid, carbofuran, chlorantraniliprole, fipronil, malathion, chloropyriphos and cypermethrin in cabbage, cauliflower and rice grains. The separation of insecticides was performed by C_{18} column with UV-VIS detector. The dual pump functions as isocratic flow of mobile phase of acetonitrile and water (90:10, v/v) with the flow rate of 0.5 mL min^{-1} at 225nm. The peaks of imidacloprid, carbofuran, chlorantraniliprole, fipronil, malathion, chloropyriphos and cypermethrin in chromatograms observed at retention times of 2.66 min, 3.25 min, 3.54 min, 4.03min, 4.17 min, 8.63 and 9.94 mins, respectively. Another method of RP-HPLC was also developed by using modified QuEChERS for simultaneous detection of residues of thiamethoxam, flubendiamide and endosulphan in cabbage, cauliflower and rice grains. Mobile phase of acetonitrile and water (90:10, v/v) @ 0.7 mL min^{-1} flow rate was operated at 230 nm. The residues of thiamethoxam, flubendiamide and α-endosulphan and β- endosulphan presented distinct peaks at retention times of 1.95 min, 2.40 min, 3.39 min and 3.90 min respectively. Constant recoveries for both the methods were observed above 80 % for all the three insecticides when samples were fortified at different levels of 0.05, 0.10, 0.25, 0.50 and 1.00 mg kg^{-1} levels.

The rice grains collected from different districts of Manipur were analyzed for estimating the residues of chemical insecticides like thiamethoxam, flubendiamide, endosulphan, imidacloprid, carbofuran, chlorantraniliprole, fipronil, malathion, chloropyriphos, cypermethrin, monocrotophos, deltamethrin, phosphamidon and dichlorvos. Out of 45 samples, the residues of malathion, cypermethrin and deltamethrin were detected above maximum residue limit (MRL) of Food Safety and Standards Authority of India from 15 rice samples collected from Imphal East, Imphal West, Bishnupur and Senapati districts. Out of 40 tomato market samples, 31 samples were found to be detected the residues of thiamethoxam, flubendiamide, chloropyriphos, fipronil, carbofuran, monocrotophos and dichlorvos above MRL (FSSAI). Out of 40 cabbage market samples, 27 samples were detected the residues of chlorantraniliprole, malathion, dichlorvos and chloropyriphos above MRL (FSSAI). Similarly, the cauliflower samples (40 nos.) collected from market, the insecticides like chlorantraniliprole, malathion, fipronil, chloropyriphos, deltamethrin and dichlorvos residues were found above MRL from 29 samples.

POULTRY SCIENCE

Evaluation of performance and lipid profile of broiler chicken through nutritional manipulation

One hundred fifty (150) day old broiler chicks of mixed sexes were used for the experiment. Feed was formulated with addition of 1% locally available herbs *viz*: *Trigonella foenum-graecum, Cinnamomum cassia, Zingiber officinale, Curcuma longa, Coriandrum sativum* and fed to broiler birds. Control group were given broiler feed recommended by BIS system without including spices. Highest overall (0-6 week) average body weight gain of 1608 gram was observed to those broiler birds that fed with *C.sativum.* Highest overall (0-6 week) feed intake of 2307 g was obtained by those broiler birds that fed by *C. longa*. Lowest overall FCR of 1.82 was observed that has been fed by *C.cassia.* Defeathered weight, Eviscerated weight, Dress yield, Breast, Back, Wings and Neck was found to be highest that fed with *C. sativum* as compared to control. Drum Stick and Thigh was found to be highest that fed with *C. longa* as compared to control. Highest Giblet was found that fed with *C.cassia* as compared to control. Thigh meat- Highest cholesterol reduction of 5.87 % and 5.58% was observed to those broiler birds that fed with *T. foenum-graecum* and *C. cassia* as compared to control group. Breast meat- Highest cholesterol reduction of 6.41 % was observed to those broiler birds that fed with *C. cassia.*

ICAR-Poultry Seed Project

The total number of parent stock of Vanaraja, Srinidhi and Gramapriya poultry birds maintained in the poultry farm was 1872 birds (including poultry chicks). During the reporting year, a total of 72729 numbers of day old chicks was produced and were supplied to the beneficiaries in various districts of Manipur. Altogether, 2036 numbers of farmer's were benefitted under TSP component of this project. Besides, two numbers of three days training programme on scientific poultry rearing was conducted and 50 farmers were benefitted from this training programme.

Performance of Vanaraja and Srinidhi birds under Backyard conditions

Data from field were randomly collected from each beneficiary farmer. The body weight of Vanaraja at 4th , 8th , 12th ,16th and 20th weeks are 210.42g, 751.31g, 961.23g 1307.56g and 1943.47g and the body weight of the Srinidhi at 4th , 8th , 12th ,16th and 20th weeks are 198.11g, 491.32g, 703.18g, 1041.17gms and 1275.35g, respectively. The main reason of mortality of the birds in the farmer's field was found due to coccidiosis, chronic respiratory diseases, cannibalism, parasitic infestation and poor electricity.

VETERINARY PUBLIC HEALTH

Development of Recombinase Polymerase Amplification (RPA) based assay for rapid detection of *Salmonella typhimurium* from Poultry and Food Samples

An oligonucleotide primer targeting the serotype-specific "*typh*" gene of *Salmonella typhimurium* was designed for Recombinase Polymerase Amplification (RPA) based assay for rapid detection of *Typhimurium* from poultry and food samples. The minimum volume, shortest time and optimal temperature of the RPA reaction were 15µl, 20 minute and 40-42°C respectively. The RPA assay for detection of *S. typhimurium* was successfully standardized in raw milk samples.

Dairy, Piggery and Hydroponic Fodder Demonstration Unit

In dairy demonstration unit, a total of 12 animals (Milch cow = 5, Bull = 2, Heifer = 3 female and 2 calves) were maintained to impart knowledge on exotic cross-bred dairy cattle (Local x Jersey and Local x HF) and farm management to the farmers.

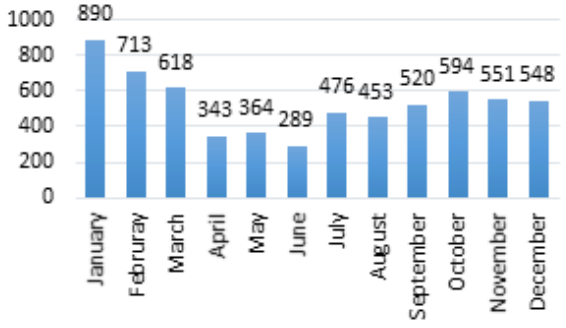


Fig 55. Milk Production (in liters) 2018

Fig 56. Hydroponic green fodder unit

During 2018, all total 6359 litres of milk (17.42 litres/day) was produced (Fig 55). In Piggery unit, nine pigs are maintained (White Yorkshire boar=1, Adult Hampshire female=6, Large Black=1, Adult White Yorkshire female=1). During 2018, a total of 52 numbers of piglets are produced. Besides, Hydroponic Green Fodder Unit is also maintained to produce green and fresh maize fodder throughout the year for the farm animals, and to impart training and demonstrations to farmer's, NGOs, SHG etc. (Fig 56).

FISHERY SCIENCE

Brood stock development for early breeding and seed productions

A preliminary survey was conducted in 16 private hatcheries in the valley districts of Manipur to map out pre-monsoon breeding incidence and prevalence. Fish breeding operation were mainly found in unorganized state. No proper brooder management was found in most of the farms. Major problem in most of carps species were late maturation of male brooders in Manipur. Fish brooders IMC carp, indigenous carps and exotic carps were collected and maintain in ponds of ICAR-Manipur Centre. The highest ovulation rate (91.8 %) of Amur was found in 1st week of March at water temperature of 12°C-26°C and lowest (85.29%) in 4th week of March at the temperature range of 18-28°C. Breeding of *Ompok bimaculatus* was also done successfully in captivity using ovasis @ 0.7ml/kg (Fig 57). Uniform size rectangular 3 earthen ponds (10m × 10m × 1.5m) were used for rearing of fingerlings. These ponds were further divide into three sections (7m × 10m × 1.5m) with the help of small mesh size mosquito net and bamboo poles.

Fig 57. Development of Seed production protocols of *Ompok bimaculatus*

Studies on molecular taxonomy, genetic diversity and phylogeny study of selected indigenous fish species of found in Manipur

Molecular analysis was conducted for partial and complete mitochondrial DNA analysis of indigenous fish species of Manipur. The first completed mitochondrial genome of *Bangana dero* was successfully assembled and deposited in NCBI Genebank (Table 6).

S.N.	Name of Genes	NCBI Genbank Accession No.
1.	Mitochondrial 16SrRNA gene	MH973621
2.	Mitochondrial NADH dehydroge-nase subunit1	MK091816
3.	Mitochondrial Atpase 6 gene	MK091817
4.	Mitochondrial complete genome	MK461139

SOCIAL SCIENCE

Analysis of Fish Consumption Behaviour of Imphal West District of Manipur

For the study primary household level data were collected from 50 numbers of fish consumers, randomly selected from Imphal West district of Manipur. Of the total respondents, 25 belong to urban area and another 25 consumers belong to rural area. It was found that the average age of the fish consumers were 50 and 45 years for urban and rural areas, respectively. All the households were non-vegetarian and consuming fish as part of edible food. The average consumption of fish ranges from 3.0 to 4.5 kg per week per household with a frequency ranging from 3 times a week in rural areas to 4 times a week in urban areas. The average household income was Rs. 24,000 for rural areas and Rs. 35,000 for urban areas. The average monthly expenditure on fish items per household accounts for Rs. 3700 for urban and Rs. 3000 for rural consumers which constitute 14% and 17% of the total expenditure on food items. For urban areas, the monthly expenditure on dry fish and fermented fish were Rs. 1170 and Rs. 450, respectively and for rural areas they were Rs. 970 and Rs 430, respectively.

The three most preferred fishes for urban consumers were Rohu, Grass Carp and Common Carp while Rohu, Small fishes and Grass Carp were the preferred fishes for rural areas. Urban consumers selected fish on three important criteria viz. fish type, freshness and size whereas rural consumers selected fish based on fish type, freshness and taste. Five major problems faced by both urban and rural fish consumers with regard to purchase and consumption are sub-standard weighting scales and measures used by the sellers, wide fluctuations in fish price within the same market and other selling places, mixing of fresh and old and damaged fish stock, non-availability of desired fish as and when required and high retail price. The findings indicate that effort should be made to make quality fish available in sufficient quantities to meet the demand of the people of the state.

Socio-economic analysis of fish traders of Imphal West District of Manipur

For the present study, primary data was collected through interview schedule from 25 numbers of fish vendors (traders) randomly selected from Imphal West district of Manipur. It has been found that maximum i.e. 56 % of the traders were in the age group of 45 to 60 years of age and 88 percent of them were women. The average years of experience in fish trading was 13 years, traders travel an average 11.5 km for selling the fishes and handle about 63 kg of fish per trading. They have a poor education as maximum of them were illiterate or only primary standard. The important variables cost involved in marketing of fishes were loading and unloading, ice, transport, plastic bag

for packaging and electricity charges and average variable cost expenses accounts for Rs. 606 per trader. Fixed cost involved were knife, weighting balance, basket and plastic sheet. Average expense on fixed cost was Rs 7.95 per trader and average investment was Rs 16,216.84. Total cost in fish marketing was worked out to be Rs 16,830.79 per trader and total return from sale of fishes was Rs 19,954.76. The fish traders incurred a profit of Rs.3123.21.

The three major types of fishes handled by the traders were Grass Carp, Common carp and Silver carp along with this Rohu and Mirgal were also sold by the traders. Farm gate prices of fish according to types are Rs 180/kg for Grass Carp, Rohu and Mirgal, Rs.150 for Common Carp, Rs 80 for Silver Carp, respectively. The fishes were sold at various markets with an additional amount of Rs 20 over and above the farm gate price. Four major problems faced by the fish traders are lack of government support, shortage of fund to invest in the business, spoilage and wastage of fish and lack of cold storage facilities. In order to make fish marketing more efficient, infrastructures need to be developed for scientific storage of fishes and regulation put in place to control price of fishes and maintenance of quality standard.

TECHNOLOGY COMMERCIALIZATION

ICAR Research Complex for NEH Region signed memorandum of understanding (MoU) with M/S Divine Enterprise, Imphal, Manipur on 27.11.2018 (Fig 58) for popularization and commercialization of 'Bay leaf Beverage' technology developed at Manipur Centre in collaboration with PJTSAU, Hyderabad under DBT twinning project on "Nutraceutical properties of underutilized fruits and vegetables of NEH region of India". The beverage with indigenous raw materials would be beneficial for consumers across the country.

Fig 58. Ceremonial Signing of MoU for Bay Leaf Beverage Technology

AGRI-BUSINESS INCUBATION (ABI) CENTRE

The Agri-business Incubation Centre at Manipur Centre has provided incubation support to more than 40 budding agripreneurs. Of these, 17 incubates have graduated successfully and started their own business venture. Under ABI, one state level sensitization workshop on "Agripreneurship Development for Increasing Farm Income and Promotion of Agri-business in Manipur" was organized on 21 August, 2018. Besides, ABI organized two hands-on training programmes (Fig 59-60) on fruit processing and mushroom cultivation benefitting 35 participants and also co-sponsored the National Mushroom Day 2018 organized at Manipur Centre. In addition, 10 ABI members were sent for advance training on various agro-ventures and 8 ABI members have participated in North East Regional Agri Fair during 6-9 January, 2018 at ICAR Research Complex for NEH Region, Meghalaya.

Fig 59. ABI training on fruit processing

Fig 60. ABI training on mushroom production

MIZORAM

WEATHER REPORT

Daily weather parameters were recorded at the agro-meteorological observatory of ICAR Research Complex for NEH region, Mizoram Centre during 2018. The total annual rainfall was 2655.40 mm with 121 rainy days and 2 extreme rainy days (more than 100 mm rain per day). The highest one-day rainfall of 117.4 mm occurred on 9th August 2018. Maximum rainfall received during the monsoon months (1720.30 mm) followed by pre monsoon (710.40 mm), post monsoon (201.80 mm) and winter months (22.90 mm). The considerable variation in mean monthly maximum temperature (Mean T_{max}) and mean monthly minimum temperature (Mean T_{min}) was evident (Fig 1). The mean T_{Max} varied from 27.7^{0}C (April) to 29.1^{0}C (October) and the mean T_{min} varied between 11.4^{0}C (January) to 14.8^{0}C (February). Highest maximum temperature was observed on 19th July, 2018 (32.5°C) and lowest minimum temperature on 8th January, 2018 (8.0°C). The variation in RH-morning was less than the RH-evening. While, the RH-morning varied from 81% (April) to 95.7% (September), the RH-evening varied between 48.4% (February) to 84.1% (July). Southerly to South-Easterly wind was the most prevalent throughout the year. The average Bright Sunshine Hours (BSS) varied from 3.4 to 5.8 hours during monsoon months (June to September) and 5.4 to 7.4 hours during post monsoon months (October to December, 2018).

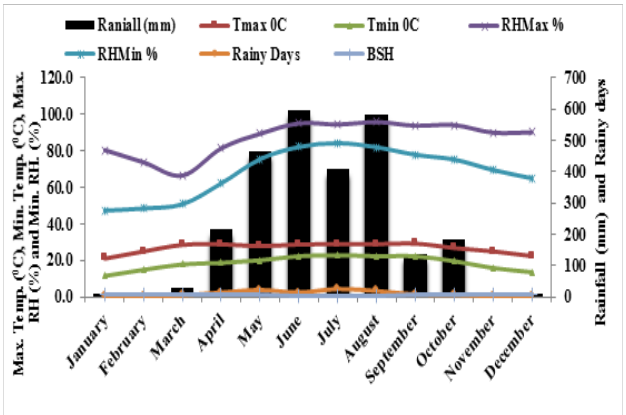


Fig 1. Graph Depicting the mean monthly weather condition recorded at ICAR Research Complex for NEH region, Mizoram during 2018

RICE

Evaluation of Different Lowland Rice Germplasm

Rice (*Oryza Sativa* L.) is the principal food crop of north eastern region occupying an area of about 3.5 m ha with an average productivity of 1.72 t/ha which is less than the national average. The yield trial was conducted to evaluate the yield potential of 26 released lowland rice varieties against the potential good yield performer of local rice landraces (8 nos.). The accessions were collected from different parts of north-east India under RCRT trial. Local low yielding rice varieties took more time for maturity (160-170 DAT) which provides very less time for second and third crops in succession. Moreover, lodging effect was experienced in all local varieties due to more plant height. *Gomati* (Fig 2 & 3), a medium maturing (~136.25 days) variety performed (Table 1) satisfactory (avg. yield of 4.92 t/ha) followed by Pusa Sugandhi (avg. 130.5 days; yield of 4.83 t/ha) and Tripura Hakuchuk 1 (Avg. 130.50 days; yield 4.72 t/ha). Incidence of rice neck blast (*Magnaporthe grisea*), rice sheath blight (*Rhizoctonia solani*) diseases along with rice stem borer (*Scirpophaga incertulus*) and rice leaf folder (*Cnaphalocrocis medinalis*) was commonly observed in majority of the varieties. Disease scoring unveiled least incidence of insect pests in Gomati rice.

Fig 2. Evaluation of different rice varieties at Mizoram Centre

Fig 3. *Gomati* rice variety

Table 1. Yield attributes of different lowland rice varieties in Mizoram.

Name of the Variety	Plant height (cm)	Tillers/ m^2	Panicle/ m^2	Grain yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)	Test weight (g)	Avg. No of days (DAT)	Lodging Effect
Gomati Dhan	115.4	290.8	255.3	4.92	10.58	46.5	27.4	136.3	Non Lodging
TRC 2013 11	120.4	252.3	225.5	4.25	10.05	42.3	28.1	120.5	Non lodging
TRC 2015 7	125.1	243.5	219.2	4.48	10.94	41.0	28.6	130.5	Non lodging
TRC 2013 11	122.4	225.4	204.4	3.97	8.68	45.7	27.6	120.5	Non lodging
TRC 2014 8	125.9	220.3	185.4	4.16	8.94	46.5	28.6	130.5	Non lodging
Tripura Hakuchuk1	130.5	270.1	240.4	4.72	9.21	51.3	29.6	130.5	Non lodging
Tripura Nirogi Dhan	138.9	240.4	184.2	4.16	8.51	48.9	28.7	115.2	Non lodging
Tripura Chikan Dhan	131.2	190.5	156.4	3.47	7.26	47.8	22.4	130.5	Non lodging
Tripura Sarat Dhan	132.8	210.4	194.3	3.82	7.38	51.8	26.7	130.5	Non lodging
Naveen	110.3	230.5	185.2	3.81	7.28	52.3	28.9	121.9	Non Lodging
Nagaland Rice 1	131.9	180.2	152.3	3.61	7.65	47.2	28.3	135.5	Non lodging
Nagaland Rice 2	126.5	220.4	185.5	4.15	8.15	50.9	30.4	130.5	Non lodging
Nagaland Rice 3	120.4	220.3	185.2	3.94	7.15	55.1	26.3	130.5	Non lodging
Nagaland Rice 4	130.7	240.2	202.4	4.32	8.34	51.8	29.5	120.5	Non lodging
Nagaland Rice 5	134.0	195.2	164.3	4.21	8.19	51.4	27.6	130.5	Non lodging
Nagaland Rice 6	120.4	210.4	185.4	4.25	8.28	51.3	26.3	130.5	Non lodging
Nagaland Rice 8	128.7	180.5	152.2	4.27	8.59	49.7	30.4	160.8	Non lodging
RCM 9	131.2	120.7	65.2	2.95	6.85	43.1	23.8	125.6	Non Lodging
RCM 10	126.8	160.6	145.8	3.05	6.84	44.6	21.9	130.8	Non Lodging
RCM 11	129.8	230.4	185.1	2.96	6.08	48.7	26.1	135.0	Lodging
RCM 13	132.7	190.6	162.3	3.87	7.83	49.4	27.1	120.5	Lodging

CAU R1	120.6	210.7	152.1	2.68	6.24	43.0	23.4	123.1	Non Lodging
CAU R4	115.7	190.4	142.5	2.48	6.49	38.2	24.5	122.5	Non Lodging
Tapashi	112.7	220.3	195.4	3.89	7.41	52.5	26.8	132.5	Non Lodging
PB 1121	115.6	215.4	185.6	4.29	8.61	49.8	32.5	135.5	Non Lodging
PB 1509	110.5	160.6	135.4	3.84	7.95	48.3	30.1	110.5	Non Lodging
PD 13	105.4	160.9	126.4	2.94	6.74	43.6	26.4	100.0	Non Lodging
P44	102.5	220.5	174.5	3.89	7.18	54.2	25.9	140.5	Non Lodging
Pusa Sugandhi	110.5	284.3	235.3	4.83	8.95	54.0	29.9	130.5	Non Lodging
Shahsarang 1	120.4	210.4	196.5	3.89	8.34	46.6	24.4	153.1	Non Lodging
Gandhi Biron	145.8	170.3	150.3	3.51	7.06	49.7	29.6	180.3	Lodging
BhadshaBhog	140.2	180.6	156.4	2.81	6.84	41.1	21.0	171.3	Lodging
Mizoram Local	135.6	160.2	125.8	1.38	4.34	31.8	24.8	175.6	Lodging
SE(m)±	0.15	0.17	0.18	0.17	0.18	0.18	0.15	0.14	
CD (*p*=0.05)	0.44	0.49	0.49	0.49	0.50	0.51	0.42	0.41	

Evaluation of Different Upland Rice Germplasm

The yield potential of 22 upland rice germplasms along with one check variety IURON 514 was evaluated at Mizoram Centre research farm. Significantly higher grain (3.84 t/ha) and straw (8.91 t/ha) yield was recorded in IURON 514 followed by MZ UP Rice 6 which recorded 3.31 t/ ha grain yield and 6.82 t/ ha straw yield and MZ UP Rice 4 (3.01 t/ha and 6.61 t/ha, as grain and biomass yield, respectively); while the lowest grain yield was recorded in 2.05 t/ha with 5.28 t/ha straw yield for MZ UP Rice 3 (Table 2 and Fig.4). IURON 514 matured within 125 days after sowing (DAS) followed by MZ UP Rice 4 (142 DAS) and MZ UP Rice 6 (155 DAS). Rice neck blast (*Magnaporthe grisea*) and rice sheath blight (*Rhizoctonia solani*) diseases were prevalent for majority of the landraces. Rice stem borer (*Scirpophaga incertulus*) and rice leaf folder (*Cnaphalocrocis medinalis*) were the major insect infestation recorded during the trial.

Fig 4. Evaluation different upland local rice germplasms under RCRT trial

Table 2.Yield and yield attributes of different rice germplasms of Mizoram

VARIETY	Plant Height(cm)	No of Tillers/ plant	No of panicle/ plant	Panicle length (cm)	Grain yield (t/ha)	Biomass (t/ha)	Harvest Index (%)	Test Weight (g)	Avg. no. of day
MZ UP Rice 1	158.6	12.3	7.2	20.5	2.51	6.21	40.4	22.3	175
MZ UP Rice 2	162.8	14.6	8.7	25.4	2.79	6.05	46.1	25.4	162
MZ UP Rice 3	145.6	10.5	6.3	21.3	2.05	5.28	38.8	20.7	175
MZ UP Rice 4	168.9	12.6	8.0	26.7	3.01	6.61	44.1	28.6	142
MZ UP Rice 5	158.0	14.5	8.2	18.4	2.94	6.67	44.1	26.5	165
MZ UP Rice 6	162.7	16.4	12.6	20.4	3.31	6.82	50.1	30.4	155
MZ UP Rice 7	162.7	12.6	7.3	17.2	2.51	5.85	42.9	26.4	168
MZ UP Rice 8	164.5	14.3	8.1	20.7	2.31	6.64	34.8	28.6	168
MZ UP Rice 9	175.9	12.9	7.2	22.4	2.45	6.74	36.4	24.6	158
MZ UP Rice 10	168.9	14.4	8.8	16.8	2.08	6.13	33.9	22.7	155
MZ UP Rice 12	159.4	15.1	9.3	18.3	2.14	6.51	32.9	20.8	182
MZ UP Rice 13	157.9	11.8	6.3	18.7	3.02	5.84	51.7	23.9	152
MZ UP Rice 14	167.4	12.5	6.2	24.3	2.37	6.72	35.3	27.8	175
MZ UP Rice 15	146.8	10.8	6.4	22.7	2.54	6.34	40.1	22.6	145
MZ UP Rice 16	159.8	14.8	9.2	20.1	2.15	6.37	33.8	23.8	160
MZ UP Rice 17	168.4	16.8	12.1	26.1	2.18	6.34	34.4	26.8	160
MZ UP Rice 20	171.2	14.8	10.2	23.7	2.37	6.31	37.6	20.7	165
IURON 514	125.9	17.8	14.3	22.1	3.84	8.91	43.1	25.7	125
SEm±	0.16	0.18	0.17	0.21	0.16	0.15	0.13	0.18	0.14
CD (p = 0.05)	0.47	0.52	0.49	0.61	0.47	0.44	0.38	0.53	0.39

Zero Tillage – A Viable Option for Residual Soil Moisture Utilization in Lowland Rice Fallows and Increase of Pulse and Oil Seed Production in Mizoram

Conventionally, the fields remained fallow in the low lying areas in Mizoram after *kharif* rice. Excess moisture owing to seepage from surrounding hillocks limited the suitability of growing vegetables in those areas. Favorable condition for cultivation of successful *rabi* crops like pea, soybean, French bean, mustard etc. can be created with provision of suitable drainage facility at physiological maturity. To study the performance of pulses like pea, soybean, French bean and oilseed mustard varieties/germplasms were procured from IARI and were grown under zero tillage in lowland rice fallow using recommended dose of NPK (20:60:40 kg/ha) followed by one manually weeding cum hoeing at 30 DAS. The MZFB 48 recorded maximum pea equivalent yield (4.24 t/ha) followed by soybean (2.55 t/ha) and pea (2.33 t/ha) among various available cropping options (Table 3). Pusa Mustard recorded maximum seed yield (1.31 t/ha) followed by Pusa Sag 1 (1.05 t/ha) as leaf harvest. Zero tillage cropping options with pulse and oilseed cultivation with appropriate agronomic interventions in the rice fallows can be popularized for optimum residual soil moisture utilization and additional income to the small and marginal farmers in Mizoram.

Table 3. Yield attributes of different pulses and oilseed crops in rice fallow under zero tillage practice

Name of the variety	No of pods / plant	No of seeds / pod	Grain yield (t/ha)	Biomass yield (t/ha)	Test weight (g)	Pea equivalent yield (t/ha)
Pea (Arkel)	28.68	6.14	2.23	8.85	248.1	2.23
Soybean (JS 335)	238.34	2.24	1.91	5.94	119	2.55
Frenchbean (Contender)	35.61	5.02	2.59	9.38	193.9	1.73
Frenchbean (MZFB 48)	52.91	6.01	4.24	10.75	285.5	4.24
Name of the variety	**No of siliqua / plant**	**No of seed / siliqua**	**Grain yield (t/ha)**	**Biomass yield (t/ha)**	**Test weight (g)**	**Pea equivalent yield (t/ha)**
Pusa Mustard 28	61.5	9.47	0.98	4.05	4.2	1.31
Pusa Sag 1	46.16	6.81	0.79	3.51	3.4	1.05
SEm+	**0.3**	**0.02**	**0.05**	**0.07**	**2.3**	**0.24**
CD (P=0.05)	**0.85**	**0.08**	**0.14**	**0.21**	**6.7**	**0.84**

Fig 5. Different pulses and oilseed crop cultivation in rice fallow land of Mizoram

SOIL SCIENCE

Seasonal Variation of Soil under Different Land Uses in Mizoram

Different land uses were selected in Tuichhuahen area of Kolasib district to ascertain the variation of soil as affected by seasons. Teak, rubber and areca nut land uses were selected and surface soil (0-15 cm depth) samples were collected. Soil organic carbon (SOC) has been considered one of the most important indicators for soil quality irrespective of the season. SOC values exhibited in Areca nut (1.57%) > Rubber (1.37%) > Teak (1.12%). SOC was significantly higher during April and October (1.57% and 1.39 %) than January and July (1.22% and 1.21%), respectively, irrespectively of the land uses. Acid phosphates enzyme (ACP) active represents an indicator of soil quality and is responsible for the mineralization of P in organic forms. It has been observed that the ACP activity was significantly higher during July (770.42 µg/mg pNP) as compared to January, April and October (443.26, 396.26, 388.27 µg/mg pNP, respectively). Areca nut soil has the highest ACP activity (629.63µg/ mg pNP) compared to rubber and teak (475.55 and 393.48 µg /mg pNP, respectively). The increase in ACP activity during the month of July may be due to the increase in soil moisture which in turn increases the microbial mineralization of phosphorus. Variation of SOC and ACP activity as affected by land use and seasons is depicted in Fig 6.

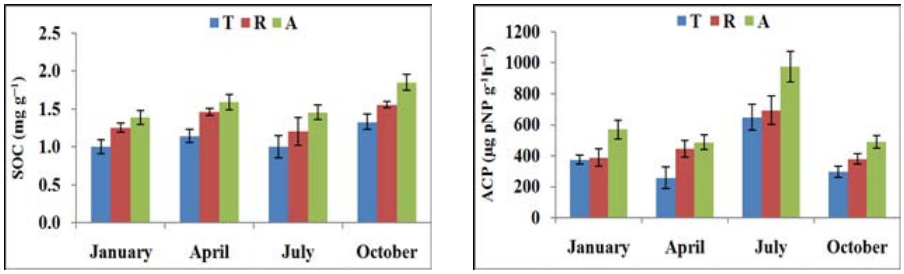


Fig 6. Variation of SOC and ACP activity as affected by land use and seasons

NB: Bars represent standard error (SE)

Effect of Integrated Nutrient Management on Growth and Yield of Maize

An experiment was conducted in the terraces of ICAR RC NEH Region, Mizoram Centre during 2018 to explore the combined effect of fertilization and lime on growth and yield of maize (RCM 76) and its residual effect on pea. The study was laid out in a randomized complete block design (RCBD) consisting of 7 treatments combination. The fertilization treatments include T_1-Absolute control, T_2-Half RD (NPK @ 40:30:20 kg/ha), T_3-Full RD (NPK @ 80:60:40 kg/ ha), T_4-Half RD and Lime @ 400 kg/ha, T_5-Half RD and Lime @ 800 kg/ha, T_6- Full RD and Lime @ 400 kg/ ha, T_7-Full RD and Lime @ 800 kg/ha. The data presented here is from one year experiment. There is no significant difference among the treatments (Table 4) from one year data but the full dose and lime exerted relatively higher yields.

Table 4. Effect of nutrient management on growth and yield attributes of maize

Treatments	Cob length (cm)	Cob girth (cm)	No of rows	Seeds per row	Grain yield (t/ha)
T_1	7.70^{b}	9.02^{b}	11.30^{a}	22.77^{a}	3.14^{b}
T_2	11.94^{a}	10.41^{ab}	12.00^{a}	26.33^{a}	3.65^{ab}
T_3	11.41^{a}	10.58^{a}	11.56^{a}	25.22^{a}	3.80^{ab}
T_4	11.47^{a}	11.50^{a}	11.67^{a}	26.33^{a}	3.95^{a}
T_5	12.97^{a}	$10.32a^{b}$	11.22^{a}	26.22^{a}	3.68^{ab}
T_6	12.71^{a}	10.93^{a}	12.56^{a}	26.89^{a}	3.89^{a}
T_7	13.10^{a}	11.57^{a}	12.33^{a}	26.89^{a}	4.28^{a}

PH: Plant height; GY: Grain yield. Different letters signify significant difference by DMRT test

Evaluation of Resources Conserving Option on Productivity and Water Use Efficiency (WUE) of Maize – Pulse/Oilseed Cropping System under Terrace Condition

The maize based cropping system was evaluated at the research farm of ICAR-NEH-Mizoram under NMSHE-TF 6 project. Treatments comprised of conventional tillage (CT) and zero tillage (ZT) in main plot and intercropping options like maize sole, maize + soybean (Fig 7), maize + ground nut, maize + black gram (Fig 8), maize + green gram and maize + sesamum. Results revealed that higher gain yield was recorded under zero till as compared to conventional tillage (Table 5). Maize + soybean recorded maximum maize equivalent wield (6281 kg/ha) followed by maize + groundnut (5121 kg/ha) and maize + black gram (4987 kg/ha) system. The maximum water use efficiency (WUE of 42.9 kg/ha-mm) was observed under maize + soybean intercropping with zero till followed by maize+ groundnut (36.8 kg/ha/mm).

Table 5. Maize equivalent yield and water-use efficiency

Treatments	Tillage Treatments					
	ZT	CT	Mean	ZT	CT	Mean
	Seed yield (kg/ha)			Water use efficiency (kg/ha-mm)		
M1-Maize	4200	3821	4010	30.9	33.1	32.0
M2-Maize + soybean	6281	5684	5982	42.9	40.3	41.6
M3-Maize + groundnut	5721	5219	5470	36.8	33.2	35.0
M4-Maize + black gram	4987	4533	4760	29.2	31.2	30.2
M5-Maize + green gram	4568	4316	4442	28.9	36.2	32.6
M5-Maize + sesamum	4530	4260	4395	27.6	31.5	29.6

Fig 7. Sweet corn maize intercrops with soybean

Fig 8. Sweet corn maize intercrops with black gram

HORTICULTURE

Collection and Physico-chemical Characterization of Local mango (*Mangifera Indica l.*) Germplasm of Mizoram

Twenty local mango fruit germplasms were collected from different places of Kolasib and Mamit districts of Mizoram based on fruits shape, fruits size and fruits color. Collected fruits were analyzed for physico-chemical parameters. Small size, medium and big size mangoes were observed and data were recorded from different colour of fruits and fruits pulp which varied from green orange to yellowish orange. The fruit weight ranged from 19g to 305g and the maximum fruit weight, fruit length, fruit width were observed at Darlak area of Mamit district. The fruit TSS content ranged from 7 to 16^0 Brix with maximum fruit TSS content (16.33^0 Brix) recorded from Darlak area of Mamit district. The acid content ranged from 0.24 to 3.76% and ascorbic acid content was from 3.2 to 16 mg/100g of pulp. The total carotenoids content in collected mango germplasm ranged from 0.0036 to 0.033 mg/100g of mango pulp.

Rengtikawn

Vengthar 2

Dampui

Venghar 1

Fig 9. Mango samples from Kolasib of Mamit district of Mizoram

Standardization of Package and Practices of Dragon Fruit under Mizoram Condition

Dragon fruit (*Hylocereus undatus*.) variety commercial red was planted at ICAR- Research farm, Kolasib at different spacing of 2×2 m, 2×3 m and 2×3.5 m. Three plants were planted in one pit around the cement pole. The growth of dragon fruit was observed at different distance and different manures treatments comprising of T1: Control, T2: NPK fertilizer @ 25: 75:75g/plant. T3: NPK @ 25:75:75g/plant + FYM @ 2 kg/plant, T4: NPK @ 25:75:75 g/plant + Vermicompost @ 1 kg/plant, T5: NPK @ 25:75:75 g/plant + FYM 2 kg/plant + Vermicompost @ 1 kg/plant. Result revealed that T5 treatment showed significantly higher growth and number of branches and higher number of fruit (7 no.) as compared to other treatments.

ANIMAL SCIENCE

Molecular and Serological Characterization of Important Viral and Bacterial Diseases of Pigs in Mizoram

Important viral diseases of pigs were investigated in four districts (Aizawl, Champhai, Kolasib and Serchhip) of Mizoram. Serum samples (n=246) were collected randomly from pigs irrespective of their age, sex and breed from organized and unorganized farm during February to November, 2018. The serum samples were analyzed at ICAR, Umiam by commercially available enzyme-linked immunosorbent assays (ELISA) (OIE approved) according to the manufacturer's instructions. Clinical tissues samples from 16 animals were analyzed by conventional PCR method using previously published primer set based on ORF 6 gene segment of PRRSV (Table 6 and Fig 10).

Table 6. Detection of important viral diseases of pigs by ELISA

Sl. No.	Place	Source	No. of samples	Viral diseases			
				PRRSV	CSFV	PCV2	PPV
1	Aizawl	Serum	20	5	9	-	-
2	Champhai	Serum	74	12	8	56	21
3	Serchhip	Serum	110	38	47	70	46
4	Kolasib	Serum	42	34	25	38	8
Total			**246**	**89**	**89**	**164**	**75**

Out of 246 samples, 89 samples were found positive for PRRSV, 89 samples for CSFV, 164 samples for PCV2 and 75 samples for PPV indicating a mean positivity of 36.18% (89/246), 36.18% (89/246), 66.67% (164/246) and 30.49% (75/246) respectively. Presence of mixed infection was observed in many cases. Total of 12.60% (31/246) showed the presence of PPV and PCV2 whereas 8.94% (22/246) showed the presence of PRRS, CSFV and PCV2; 8.13% (20/246) showed the presence of CSFV, PPV and PCV2; 6.50% (16/246) showed the presence of PCV2 and CSFV; 5.28% (13/246) showed the presence of PRRSV, CSFV, PCV2 and PPV; 2.85% (7/246) showed the presence of PRRSV, PPV and PCV2 . The hidden threats of PCV2 can be recognized from co-infection point of view.

Faecal samples (n=144) were collected randomly from pigs irrespective of their age, sex and breed with or without the history of diarrhoea from 3 districts (Champhai, Kolasib and Serchhip) of Mizoram to study the prevalence of porcine bacterial diseases. Total of 154 *E. coli* was isolated out of which 82 isolates was shown positive to *E. coli* by 16S rRNA detection by PCR. Based upon the PCR assay, a total of 4, 1, 1, 12, 1 isolates were recorded as positive for *stx2*, *hly*, *eaeA*, *astA*, *papC* virulence genes of *E. coli* and 20 isolates were recorded as positive for *blaCMY*. A total of 12 *Pseudomonas*, 6 *Salmonella* and 59 *Staphylococcus* were isolated from 144 samples collected from 3 districts of Mizoram.

Fig 10. PM Examination (Porcine Reproductive & Respiratory Syndrome)

FISHERIES

Fish Diversity Assessment from Different Rivers of Mizoram

The fish diversity in three major rivers of Mizoram at Chhimtuipui, Tut and Teirei river were assessed. Sampling locations were selected considering the physical habitat differences existing in the river and sampling was carried out with the help of local fisherman. Fishes were collected using cast net and other available fishing gears including fishing trap and hook (Fig 11). The collected fishes were fixed in 10% formalin followed by preservation in 70% alcohol for further examination. A total of 35 fish species belonging to 14 families were observed from Chhimtuipui river with 6 species identified to have a potential for culture while 18 species possesses high ornamental value. Out of the various fish species collected, 2 species including *Tor tor* and *Glyptothorax striatus* falls under "Near Threatened" category while 30 species falls under "Least Concern" category with other 3 species were "Not Evaluated" category under International Union for Conservation of Natural (IUCN) resources red list indicating the need for conservation of the indigenous fishes. Fishes belonging to Cyprinidae family was found to be dominating where as fish species belonging to *Amblycipitidae* family was least in the river.

Fig. 11. *Notopterusnotopterus* and *Schisturakoladynensis* from Chhimtuipui river

A total of 20 fish species belonging to 9 families were observed including freshwater prawn, *Macrobrachium birmanicum* in Tut river. 5 species were identified to have potential for culture while 10 species were found to possess high ornamental value. Fishes belonging to *cyprinidae* family was observed to dominate while fishes belonging to *Botidae* family was observed to be the least dominating in the river. 2 fish species including *Tor tor* and *Glyptothorax striatus* falls under "Near Threatened" category while 15 species were categorized as "Least concern" and 3 species falls under "Not evaluated" in IUCN red list was also recorded from the river. Similarly, fishes belonging to *Cyprinidae* family dominated Teirei river followed by fishes belonging to *Bagridae* family. A total of 22 fish species belonging 12 families were recorded.

Morphometric Analysis of Important Fishes with Hydrological Parameters of Rivers

Morphometric and meristic assessment has been undertaken which is not only vital for precise identification of species but help in stock assessment and growth studies. 23 morphometric parameters and 9 meristic characters were recorded from prioritized fishes for identification and growth studies. The length and weight relationship was also established for *Neolissocheilus hexagonolepis* and *Esomus danricus* revealed that a slope of 3.26 and 2.19 with an r^2 of 0.97 was obtained in *N. hexagonolepis* and *E. danricus* respectively (Table 7). The study indicated the growth of *N. hexagonolepis* follows positive isometric growth pattern while it is negative allometry in *E. danricus*.

Table 7. Descriptive statistics on morphometry of some indigenous fishes of Mizoram

Name of species	Total length (cm)			Body weight (g)		
	Mean±SD	Max	Min	Mean±SD	Max	Min
Neolissocheilus hexagonolepis	16.76±4.11	28.5	11.2	56.90±56.17	243.81	12.92
Devario aequipinnatus	8.32±1.35	11.3	5.4	6.53±3.39	18.36	1.28
Garra lissosynchus	9.75±0.94	11.1	8.3	13.12± 3.442	18.86	7.58
Garra gotyla	11.52±2.92	18.5	7.1	17.67±13.77	61.71	4.28
Garza natusa	16.87±1.85	19.3	14.2	45.50±12.91	62.48	25.81
Puntius ticto	6.42 ±0.44	7.4	5.7	3.87±0.96	6.36	2.58
Mastacembalus armatus	26.55±13.67	46.6	16.1	56.99±74.70	168.4	9.08
Schistura reticulata	7.71±2.11	10.3	3.6	5.73±1.90	9.42	3.87
Esomus danrichus	6.32±0.35	7.1	5.2	2.46±0.34	3.61	1.6

Chhimtuipui, Tut and Teirei were surveyed during the year for examination of physico-chemical parameters in the post monsoon season during November to December 2018. (Table8). The physico-chemical parameters are found to be in acceptable ranges for fishes..

Table 8. Physico-chemical parameters of water from major river of Mizoram

Parameters	Chhimtuipui	Tut	Teirei
Temperature (°C)	18	18	19
pH	7.5	7.5	7.3
Total Hardness (mg/l)	90	120	90
Iron (mg/l)	0.3	0.3	0.3
Nitrate (mg/l)	0.2	0.5	0.3
DO (mg/l)	8	12.8	9.6
Total Alkalinity (mg/l)	125	100	75 mg/l
Phosphate (mg/l)	0.27	0.45	0.35
Nitrite (mg/l)	0.05	0.05	0.05
CO_2 (mg/l)	3.0	4	5.0

AGRICULTURAL CHEMISTRY

Removal of Pesticide Mixture of Thiamethoxam, Carbofuran, Fipronil and chlopyriphos from Brinjal Fruits by Different Decontamination Processing Techniques

A study was undertaken to evaluate various decontamination processing techniques for removal of pesticide mixture of thiamethoxam, carbofuran, fipronil, chlopyriphos from brinjal. Damage- free brinjal fruits sample were collected from net house where no pesticides were applied in the last two seasons. The insecticide mixture of thiamethoxam, carbofuran, fipronil and chlopyriphos was sprayed on the fruits with 0.001% active ingredient up to drenching level. The treatments were performed in three replications. Therandomly selected fruits were analyzed for initial deposit of pesticides and each lot of pesticide treated sample was subjected to different decontamination processing techniques *i.e.*, washing with different solutions such as tap water, 5% Citric acid, 10% Citric acid, 5% Acetic acid, 10% Acetic acid, 2% brine solution, 0.1% baking soda solution; boiling with water and 2% brine solution; washing and boiling in water and washing and boiling in 2% brine solution. The residues were extracted and clean up and finally estimated with HPLC. The residues of thiamethoxam, carbofuran, fipronil, chlopyriphos in brinjal sample were found substantially reduction by different decontamination processing techniques. Among these techniques, washing and boiling in 2% brine solution was the most effective with more than 95% reduction of pesticide residue of all four pesticides followed by washing and boiling in water (Fig 12).

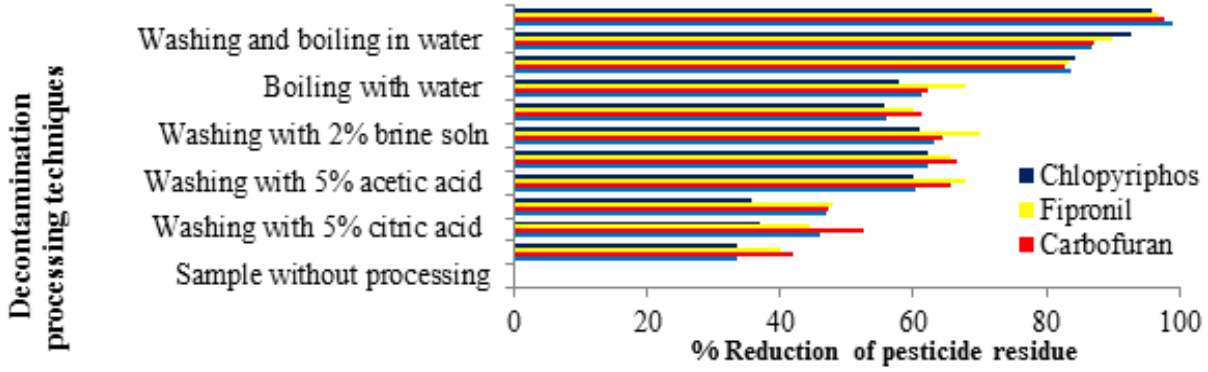


Fig 12. Percent reduction of thiamethoxam, carbofuran, fipronil, chlopyriphos residues by different decontamination processing techniques.

NAGALAND

WEATHER REPORT

The total rainfall received during 2018 was 1408.4 mm with 82 rainy days. It was observed that 2018 received about 9.41 % less rainfall than the normal (1554.8 mm). The total rainfall received during Pre- Monsoon (March –May) and Monsoon (June- September) were 238.7 mm and 1012.7 mm respectively, which were respectively 24.38 % and 3.88 % less than the normal. The post-monsoon (October- December) received rainfall of about 127 mm, about 18 % less than normal. The highest amount of rainfall in a single day was recorded on 4th June (129.0mm) which was followed by 28th June (63.6mm). The total evaporation was about 1043 mm, with the highest evaporation in the month of April (116.1 mm) and lowest in January (50.4 mm). 2018 recorded an increase in temperature with higher maximum temperature and decrease in minimum temperature over the months compare to normal. The highest recorded maximum temperature was 36.2^{0}C (20th June) whereas the lowest recorded minimum temperature was 5.7^{0}C (29th January). The maximum and minimum relative humidity were also observed higher than the normal over the months, with an average increase of 13.40 % and 13.1 % respectively. The lowest and highest wind speeds were observed in the month of January (0.613 kmph) and April (1.609 kmph) respectively. The highest wind speed in a single day was recorded on 17th March with 2.767 kmph. The average soil temperature recorded at 5cm, 10cm, 15cm and 20cm depth showed a decreasing trend along with the depth.

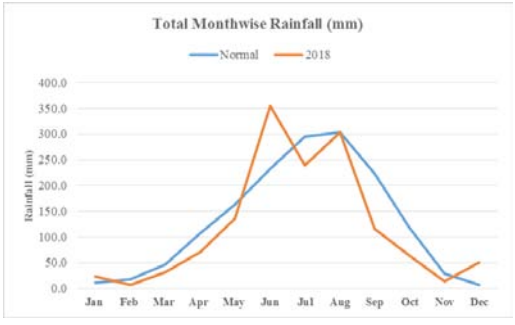


Fig 1. Monthwise total rainfall

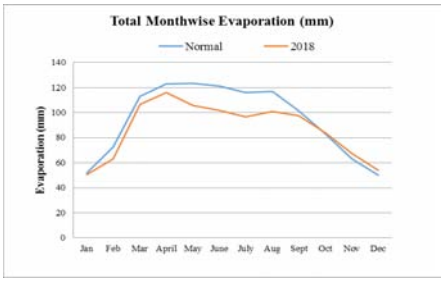


Fig 2. Monthwise total evaporation

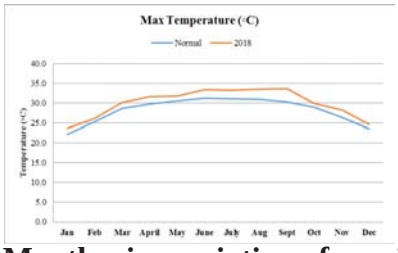


Fig 3. Month wise variation of maximum temperature

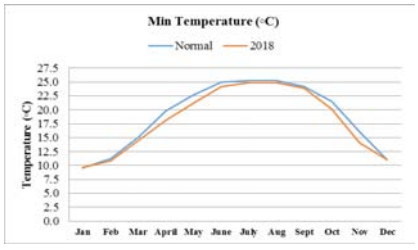


Fig 4. Month wise variation of minimum temperature

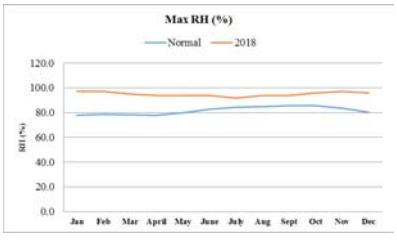


Fig 5. Month wise variation of maximum Relative Humidity (%)

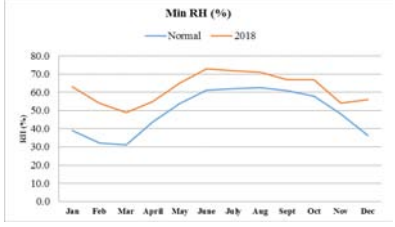


Fig 6. Month wise variation of minimum Relative Humidity (%)

AGRONOMY

Development of low cost, low volume and ecofriendly nutrient management practices for Jhum farming

The experiment conducted in existing *Jhum* cultivation practices (Mix cropping system) revealed that the crop receiving of Organic manures (2.5 t/ha) + Spraying of 2% DAP + Bio fertilizers (Azospiriium /Rhizobium) recorded the highest yield of Rice (2550 kg/ha), Maize (1800 kg/ha), soybean (1631 kg/ha) which was closely followed by the application of Organic manures (2.5 t/ha) + Micro dosing of NPK (17-17-17), 20 kg/ha + Bio fertilizers, Rice (2050 kg/ha), Maize (1840 kg/ha), soybean (1352 kg/ha). However, the highest yield of ground nut (1510 kg/ha) was recorded in the crop receiving Lime (250 kg/ha) + Bio fertilizers + Micro dosing of NPK (17-17-17) which was followed by application of lime Lime (250 kg/ha) + Bio fertilizers 20 kg/ha (1185 kg/ha).

The experiment conducted in improved *Jhum* cultivation practices (Strip cropping with line sowing system) revealed that the crop receiving of lime + Bio fertilizers (Azospiriium /Rhizobium) + micro-dosing of NPK (17-17-17) recorded the highest yield of Rice (3150 kg/ha), Maize (2350 kg/ha), soybean (2370 kg/ha) and groundnut (1790 kg/ha) which was closely followed by the application of Organic manures (2.5 t/ha) + Micro dosing of NPK (17-17-17), 20 kg/ha + Bio fertilizers in Rice (2500 kg/ha) and Maize (1950 kg/ha), However the batter yield of soybean (1700 kg/ha) groundnut (1650 kg/ha) were recorded in the crop receiving lime (250 kg/ha) + Bio fertilizers (*Azospiriium* /*Rhizobium*)

The effect of Improved *Jhum* management practices was found to be influenced positively on the yield of soybean (45%), Groundnut (18.5%), Maize (30.5%) and rice (40%) irrespective of other nutrient management practices under the study.

AICRP on Oilseed

Varietal Evaluation trials of Sesame

Six varieties of Sesame *viz*. Saviti, Amrit, Prachi, TKG-3018, GT-10 and TRC TIL 1-8 were evaluated for their performance in Yield. The result reveals that among all the varieties of sesame variety, TRC TIL 1-8 recorded the highest yield with 1.3 t/ha followed by Savitri (1.1 t/ha).

Varietal Evaluation trials on Sunflower

Four varieties of Sunflower were evaluated for their yield performance in foot hill of Nagaland. The result reveals that among all the varieties the Sunflower variety KBHS (1430 kg/ha) recorded highest yield which was followed by sunflower variety, LSFH-171 (1347 kg /ha).

Network Project on Organic Farming

Evaluation of maize varieties under organically managed nutrient management practices:

Six varieties of Maize *viz*., VMH-45, VMH-46, VMH-53, VMV-76, RCM-76 and RCM-1-2 were evaluated under Organic nutrient management practices. The result reveals that among all the varieties, the maize variety VMH-53 (6.40 t/ha) recorded highest yield followed by VMH-45 (6.10 t/ha). However, among organic nutrient management practices the crop receiving 7.5 tonne organic manure (50% FYM + 50% poultry manure) recorded highest yield of maize (5.30 t/ha) irrespective of varieties.

Evaluation of Rice varieties under organically managed nutrient management practices

Ten varieties of upland varieties of Rice, SARS-1, SARS-2, SARS-3, SARS-5, SARS-7, SARS-8, SARS-9, SARS-10 and Bhalum-3 were evaluated under organic nutrient management practices. Among all the varieties, the paddy variety, Bhalum-3 (3.25 t/ha) recorded the highest yield followed by SARS-8 (2.30 t/ha). However, application of 5 t/ha of organic manure recorded highest yield irrespective of all varieties under the study.

Fig 7. Nutrient management in Maize

Fig 8. Nutrient management in Rice

Integrated Nutrient management on Maize

Different sources of organic manures and doses of inorganic nutrient management practices were evaluated for development of nutrient management practices of Maize variety, All-rounder). The result reveals that application of 5t/ha (FYM) along with 50% of RDF (80-60-40 N, P_20_5 and K_2O kg/ha) was found to economically viable and recorded the higher yield of maize (4.6t/ha).

Planting geometry and its effect on growth and yield of Maize+ green gram intercropping system

Experiment conducted to study the planting geometry in Maize+ green gram cropping system reveals that growing of maize with green gram in 1:1 additive series recorded the highest maize equivalent yield (6.40t/ha), total income (Rs.143300) and income from cropping system which was closely followed by growing of maize with green gram in 1:1 replacement series. Inclusion of green gram with maize was found to increase in soil organic carbon content from 0.5-1% in the first year experiment

Effect of different sources of organic manures and fertilizers of growth and yield of groundnut

Experiment result reveals that among different sources of organic manure, the crop receiving poultry manure (2.5t/ha) recorded the highest yield of groundnut (2750 kg/ha). However, the application of poultry manures (2.5t/ha) + recommended dose of fertilizers (RDF= 20-60-40 kg/ha Nitrogen, Phosphorous and Potash) recorded the highest yield (3640 kg/ha) of groundnut.

SOIL SCIENCE

Management of Citrus Rhizosphere using multifaceted microbial consortium against Citrus Decline in Acidic Soils of NEH Region

Two orchards located in Ngwalwa, Peren District and ICAR Nagaland Centre, Dimapur District was selected for the microbial consortium treatments. Two types of microbial consortiums were used (1) Native type (CAU Microbial Consortium, CPGS, CAU) and (2) Non-Native (Arka Consortium, IIHR, Bangalore). The treatment combinations were T1: Control (Rhizosphere application of Vermicompost); T2: Rhizosphere Soil Application of Arka Microbial Consortium; T3: Rhizosphere Soil + Foliar application of Arka Microbial Consortium; T4: Rhizosphere Soil Application of CAU Microbial Consortium; and T5: Rhizosphere Soil + Foliar application of CAU Microbial Consortium and the treatments were replicated 4 times.

Fig 9. Rhizospheric application of Microbial consortium

Fig 10. Foliar application of microbial consortium

The result of the microbial consortium treatments showed that the performance of treatments T3 and T5 were found to be better with the visual observation from zero fruiting to the initiation of fruiting after the application of the microbial consortiums. The significant ($P \leq 0.05$) increase in soil organic carbon and available nitrogen were observed in T2, T3, T4 and T5 treatments. From this experiment it can be concluded that the timely application of microbial consortiums and at regular intervals can significantly improved the nutrient content in the soil in addition to plant health improvement and yield of the citrus. It can also be concluded that for the first time in this research in NEH region the microbial consortiums have been used for the nutrient management by two methods i.e. foliar and the rhizosphere application in the Citrus plants.

Soil health analysis of IFS models

Soil samples have been collected from the 5 types of IFS models located in ICAR Nagaland centre farm at 3 different depths. Some of the soil nutrient content parameters are presented in Table 1.

Table 1. Soil nutrient content in different IFS models

Models	Depths	pH	EC mS/m	SOC (%)	DOC µg g^{-1} (dw) soil	Avail. N (kg/ha)	Avail. K (kg/ha)
Model 1	0-15	5.95	0.069	0.72	1058.63	161.0	548.8
	15-30	5.17	0.039	0.58	958.40	130.0	521.9
	30-45	4.96	0.033	0.50	676.07	111.5	470.4
Model 2	0-15	5.07	0.046	0.91	687.71	204.8	182.6
	15-30	5.01	0.038	0.80	667.54	179.6	128.8
	30-45	4.97	0.055	0.77	353.76	173.4	121.0
Model 3	0-15	5.31	0.300	2.09	1100.29	470.6	593.6
	15-30	5.20	0.117	0.83	890.37	185.8	560.0
	30-45	5.22	0.112	0.74	872.92	167.2	504.0
Model 4	0-15	5.10	0.046	0.99	1173.98	222.9	566.7
	15-30	5.06	0.038	0.88	411.63	198.2	312.5
	30-45	5.04	0.030	0.55	771.82	123.9	237.4
Model 5	0-15	5.39	0.031	0.83	1053.44	185.8	303.5
	15-30	5.15	0.018	0.52	987.32	117.7	149.0
	30-45	5.06	0.016	0.17	931.38	37.2	153.4

CROP IMPROVEMENT

Evaluation of Upland rice germplasms

During cropping season 2018, 210 rice germplasms were grown under upland condition for study of yield and yield attributes and grain quality tests. The plants were harvested during Oct-Dec depending on the duration of the respective germplasm. Data taken includes plant height at harvest, panicle length, and straw yield. Number of filled grains per panicle, filled grain percentage, test weight and grain yield, grain length and width (decorticated and un-decorticated), GT, GC, amylose content and aroma tests have started. Seed germination for DNA extraction and subsequent genotyping of Nagaland rice germplasm has been initiated.

Fig 11. Evaluation of upland rice germplasm

PPV & FRA

Under this project DUS characterization of 22 varieties consisting of 10 farmers' varieties and 12 check varieties was conducted. All total 63 characteristics were studied during 2018 kharif season. A number of 85 Farmers' varieties were collected (freshly) from different districts of Nagaland and are in the process of registration and seed packaging.

Fig 12. DUS Testing of Farmers variety

PLANT PATHOLOGY

All India Coordinated Research Project on Mushroom, Nagaland Centre

Collection, identification and conservation of wild edible mushrooms

During the3 period, around 33 naturally growing seasonal mushrooms were collected and documented from Nagaland. Out of which, 16 mushroom were categorized under edible mushroom. The passport data of edible mushroom was recorded and submitted to the DMR, Solan along with culture for preservation. The photographs of edible mushrooms collected mentioned in Fig 13.

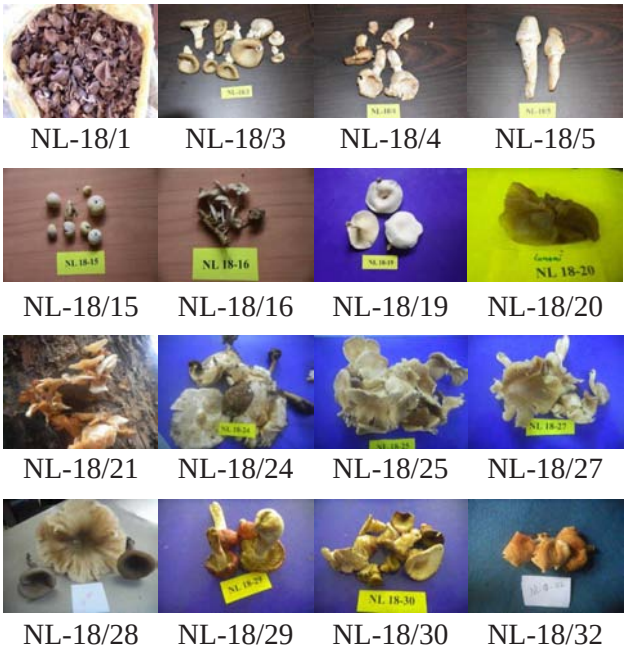


Fig 13. Wild edible/non-edible mushroom collected during the period

The mushroom specimen collected from Nagaland were cultured and submitted to DMR, Solan and accession number has been issued for the 9 culturable mushrooms.

Yield trials for identification of *Pleurotus* species suitable for Nagaland

The *Pleurotus* species were evaluated for yield/100kg of dry substrate of paddy straw. The maximum yield of 49.55 kg of mushroom recorded in PL-17-12 and it was on par with PL-17-09 (46.17 kg) strain. The significant different was observed in other strains of *Pleurotus* species. The lease yield of 30.79 kg was reported in PL-17-06. The minimum time taken for first harvest of 25 days was recorded in PL-17-12 which was highly significantly different with other strains. The maximum pileus size of 7.67 cm was recorded in PL-17-09. The stipe length of 2.64 cm and stipe thickness of 1.33 cm was recorded in PL-17-07.

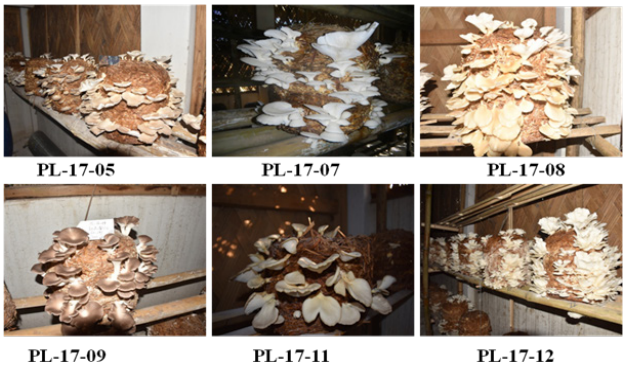


Fig 14. Identification and evaluation of *Pleurotus* species for higher yield in Nagaland

Screening of upland land rice lines against Rice blast under field condition

In the present study a set of 46 upland rice lines were evaluated for the blast resistance using uniform blast nursery method following 0-9 standard evaluation scale for rice blast (SES IRRI, 1996) under field condition during 2018. Based on the disease reaction, all the lines were all categorized into different categories. Among all the 46 lines, 3 lines (Manipur-Rü, Mekrü-Rü and Lokhomu) showed Highly Resistance, 13 lines were resistance, 23 lines were Moderate resistance, 5 lines were Moderately Susceptible and 2 lines (Temesüng Tsük and SARS 14) were susceptible to rice blast. However, none of the lines were reported under Highly Susceptible category.

HORTICULTURE

Nutritional characterization of underutilized vegetable crops

Underutilized crops have been found to contained phenols ranging between 0.30mg/g (*Elatosterma sp*) to 6.00mg/g (*Herpertospermum operculatum*). Antioxidant activity (CUPRAC) value ranged between 1.10mg/g – 8.40mg/g with

Plukenetia corniculata recorded highest (8.40mg/g), followed by *Herpertospermum operculatum* (8.40mg/g) and lowest in *Diplanzium esculentum* (1.10mg/g). Ferric reducing antioxidant power (FRAP) assay values ranged from 0.10mg/g – 1.90/g with *Herpertospermum operculatum* recorded highest (1.90mg/g) and lowest in *Elatosterma sp* (0.10mg/g). The edible parts of all plants contain minerals like iron, zinc, magnesium and copper in varying concentration. The highest concentration of Iron (Fe) was present in *Cynoglossumsp* (9.40/100g) and in *Diplanzium esculentum*(1.86mg/100g). Zinc (Zn) concentration ranged between 0.27g/100g (*Litsea citrata*) to 3.36g/100g (*Plukenetia corniculata*). A sufficient amount of Cu was present in the plants ranged between 0.07g/100g – 0.40g/100g and among them, *Diplanzium esculentum* contained the highest (0.40g/100g) followed by *Clerodendrum glandulosum* (0.38g/100g) and *Piper pedicellatum* (0.37g/100g).The Magnesium (Mg) concentrations of the plants studied ranged between 1.34/100g –50.50/100g. The highest amount of Mg was found in *Herpertospermum operculatum* (50.50/100g). A very good quantity of Mg was also present in *Piper pedicellatum* (23.70g/100g) and *Zanthoxyllum rehetsa* (15.88g/100g). Consumption of these plants locally available therefore can help in better growth and health issues of the indigenous people.

Table 2. Total antioxidant activity and mineral composition of underutiulized crops of North Eastern Region, India

Crops	Phenol (mg/g)	Cuprac (mg/g)	Frap (mg/g)	Fe (mg/100g)	Zn (mg/100g)	Cu (mg/100g)	Mg (mg/100g)
Gynura cusumbua	1.00	1.90	0.30	2.84	0.59	0.34	10.19
Centella asiatica	1.70	3.40	0.60	5.30	1.25	0.19	4.26
Diplanzium esculentum	0.80	1.10	0.30	1.86	1.49	0.40	3.86
Garcinia cowa	1.60	2.10	0.30	4.03	1.58	0.08	3.86
Eryngium foetidum	1.30	2.50	0.50	7.51	1.60	0.20	4.65
Zanthoxyllum rehetsa	2.90	3.70	0.90	4.44	1.21	0.26	15.88
Hauttinia cordata	2.10	3.50	0.80	2.51	0.58	0.12	4.99
Clerodendrumgla ndulosum	3.50	4.90	1.50	3.31	1.04	0.38	12.83
Herpertospermum operculatum	6.00	8.00	1.90	7.19	2.39	0.34	50.5
Plukenetiacornicu lata	3.00	8.40	1.10	7.98	3.36	0.19	5.49
Cynoglossum sp	3.40	3.60	1.20	9.40	0.52	0.17	1.73
Piper pedicellatum	3.70	6.20	1.10	3.70	1.09	0.37	23.7
Litsea citrata	4.10	5.30	1.40	2.87	0.27	0.07	2.13
Elatosterma sp	0.30	1.50	0.10	2.31	1.99	0.09	1.34

Standardization of Naga King Chilli cultivation for out of season production

The performance of Naga king chilli was evaluated under different protective structures at different sowing time during September and October with different nutrient doses. The plants grown under polyhouse treated with Poultry manure @2.5 t/ ha+ RDF (25%) and FYM @ 10t/ha+ RDF (50%) showed significantly higher results with respect to various growth and yield attributes.

Effect of different growing media on germination and vegetative growth for nursery production in Naga king chilli

The effect of different mixture of growing media *viz*. sand, soil, FYM, vermicompost, cocopeat, Poultry manure, wood ash, pig manure, perlite and

vermiculite was studied on germination, seedling growth and vigour of local Naga king chilli seedlings. The study revealed a significantly higher germination percentage of seeds (19.53 %, 93.94% and 90 % at 15, 30 and 45 DAS) and uniform seedling production in a mixture of cocopeat + vermiculite + perlite (3:1:1). Treatment comprising of mixture of soil + vermicompost + sand (1:1:1) showed significantly higher seedling growth and vigour at 30 and 45 DAS respectively.

Value-addition and entrepreneurship development through Naga king chilli pickles and sauces

Value added products such as king chilli sauces and pickles is a remunerative option during peak season in order to tackle the post harvest losses and enhance shelf life of the produce. Naga King chilli pickles and sauces with a cost benefit ratio of 1:1.43 and 1:1.28 respectively, were developed and various hands training were imparted to rural/ unemployed youths, farmers and SHG's for entrepreneurial activities in this sector.

ANIMAL SCIENCE

Effect of feeding linseed oil on fertility of pig under sub-tropical condition of Nagaland

The present experiment was conducted to study the effect of feeding of omega-3 fatty acid supplementation on reproductive efficiency of boar in summer season. Boars (Group-I) were fed breeder's ration with supplementation of 90 ml of linseed oil containing 53% omega-3 fatty acid for 16 weeks from May to August months. Control animals (Group-II) were fed with same diet except canola oil in place of linseed oil for making the diet isocaloric. Semen was collected twice a week by glove hand technique. Semen quality parameters of boars that received supplementation of omega-3 fatty acid shows significant ($p<0.05$) improvement over the control group from third week onwards. Total semen volume varied from 350±4.74 ml to 360±5.82 ml in group-I compared to 225±4.57 ml to 275±4.96 ml in group-II. Total sperm per ejaculate were significantly ($p<0.05$) higher in group-I compared to group-II (136.25±1.74 to 146.12±3.56 versus 121.71±2.15 to 135.24±2.15 million per ml). Other semen parameters were also showed the same trend. Farrowing percentage of 84% was obtained after artificial insemination with semen of group-I compared to 74% with semen of group-II. Boar semen is generally diluted so that one AI dose contains 2-3 billion spermatozoa. Feeding of omega-3 fatty acid significantly increased the volume and numbers of spermatozoa available for AI, thereby, increased the number of potential AI dose.

Poultry Seed Project, ICAR Nagaland Centre

The Parent stock of Vanaraja and Srinidhi variety of chicken were maintained at ICAR, Nagaland Centre. During the year 2018, a total of numbers of 196379 eggs were produced out of which 112549 chicks were hatched at the hatchery unit of the Centre. Altogether 111321 chicks were distributed to the 1187 beneficiaries belonging to various parts of Nagaland state as well as Arunachal Pradesh, Meghalaya, Assam at a subsidized rate. The production performance of Vanaraja and Srinidhi parent line for the year 2018 were also recorded which is shown in table No.3. The performance of Srinidhi was better in terms of egg production compared to Vanaraja. However, both line showed survivability of 85 to 95% in different climate of Nagaland. Hatchability on fertile egg was recorded highest (76.29%) in Vanaraja.

Table 3. Production performance of different parent stock during the year 2018.

Breed	Egg produced	Total Egg set	Fertile Egg set	Chicks hatched	Fertility %	Hatchability on TES %	Hatchability on FES %
Srinidhi (Batch IV)	6922	8598	6856	4967	79.73	57.76	72.44
Srinidhi (Batch V)	27029	22692	18703	12857	82.42	56.65	68.74
Vanaraja (Batch X)	51583	55786	45256	34530	81.12	61.69	76.29
Vanaraja (Batch XI)	110845	99984	81504	60195	81.51	60.20	73.85
TOTAL	**196379**	**187060**	**152319**	**112549**	**81.19%**	**59 %**	**72.83%**

Table 4. Body weight record of Vanaraja and Srinidhi Parent line

Age	Vanaraja Male	Vanaraja female	Srinidhi Male	Srinidhi Female
Initial	37.65	36.83	39.45	33.3
1st week	86.85	80.16	114.6	53.96
2nd	194.85	144.63	246.7	106.63
4rd	382.6	280.56	401.4	214.56
6th	576.35	435.7	836.9	371.1
8th	845.9	635.63	1097.45	570.33
10th	1141.5	859.46	1234.3	615.66
12th	1087.4	929.26	1648.25	866.23
14th	1449.6	1070.2	1981.25	924.3
16th	1875.35	1375.86	2061.65	1055.26
18th	2193.7	1604.26	2264.65	1181.33
20th	2294.8	1715.46	2550.8	1127.06

Mega Seed Project on Pig, ICAR Nagaland Centre

Parent stock of Ghungroo and crosses of Ghungroo and Hampshire breeds of pigs were maintained under the project. A total of 581 piglets were farrowed, of which 418 piglets were distributed to the beneficiaries, NGOs, KVKs, and GOI sponsored programs in all the districts of Nagaland and neighboring districts of Assam, Arunachal and Meghalaya. The coverage area for artificial insemination (AI) was also expanded. The excellent result of AI at field level was maintained in the reporting year. At the farm level the farrowing rate and average litter size were 53.9% and 8.42 piglets, respectively following double insemination. At the farmers' level, the conception rate was 81.99% with an average litter size of 9.03 piglets. Around 4500 piglets of improved breed were produced in the farmer's field through artificial insemination. In many villages of Nagaland, especially in southern Angami areas of Kohima and in Phek district, Artificial insemination has been initiated for the first time with successful results and many farmers are availing this technology through MSP-Pig, ICAR Nagaland Centre Medziphema.

FISHERIES

Breeding and larval rearing of selected indigenous ornamental fishes of Nagaland.

Three species, *Botia, Schistura and Garra* were collected and acclimatized in aquarium and FRP tank for their survival ability and adaptability in captive condition prior to undertaking breeding trial.

Growth Performance trial of carps in polythene lined Rain water harvesting structure:

Culture method of Indian Major carps and Exotic carps in polythene lined rain water harvesting structure was standardized. Five species *viz*. Rohu, Catla, Mrigal, Common carp and silver carp were stocked in the ratio 30:20:20:10:20 respectively maintaining a stocking density of 5000 nos./ha. The fish were stocked after the onset of monsoon and once the pond was filled with water and was reared for 6 months. The fish were fed with supplementary diet @ 2-3 % of total body weight. The highest average gain in weight was observed in Mrigal (700 g) followed by common carp (650 g), silver carp (400 g), Rohu (350 g) and catla (225 g).

Study on the Ichthyo-diversity of River Chathe

Documentation of the ichthyo-diversity of River Chathe was undertaken and so far 12 species belonging 9 genera *viz*. *Badis* (2), *Schistura* (2), *Garra* (1), *Barilius* (2), *Lepido cephalichthys* (2), *Rasbora* (1), *Pethia* (1) and *Danio* (1) has been documented.

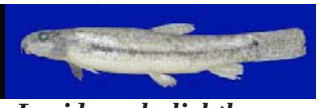
Badis sp.

Badis sp.

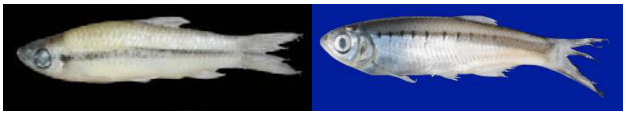
Schistura sp.

Barilius bendelisis

Paracanthocobitis botia

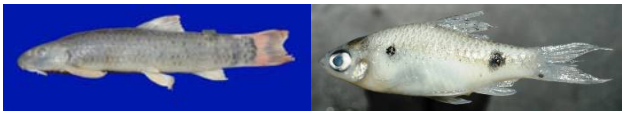


Lepidocephalichthys sp.



Rasbora rasbora *Barilius barila*

Danio dangila *Schistura sp.*



Garra abhoyi *Pethia sp.*

National Mission for Sustaining Himalayan Ecosystem (NMSHE)

Compilation and synthesis of soil fertility status

A total of 37 nos. of soil samples were collected from farmer's field and tested through mini soil testing lab and distributed soil health card to the farmers during the "World Soil Day" on 5th December, 2018. An average of pd, EC and SOC of 3.94, 0.06 and 1.57 was recorded from the Longleng respectively. The major nutrients *viz*., N, P, K and S were analyzed and reported an average of 387.44, 17.46, 190.76 and 11.03 kg/ha was reported from 37 samples collected from Longleng district respectively.

Integrated farming system for increasing the farm income

The Integrated Farming Systems (IFS) models was developed at Hukphang village (Area: 2.5 ha) The steady increase of income over a period of year was noticed and an income of Rs. 73440 and Rs. 69945 was earned from the animal based IFS model, respectively in Longleng district.

Development of fruit block and large cardamom based forestry system

A total of 9.5 ha of land were brought under cultivation of Large cardamom (var. Ramsay Sawney and Serenna) in adopted (Hukphang and Mongtikang) village. In the year 2016, 2017 and 2018 total no. of suckers distributed were 11000, 9000 and 22000 respectively comprising 44 nos of farmers from adopted (Hukphang and Mongtikang) village. So far, under the project site, a total of 42000 nos. of planting suckers were planted in the adopted villages. The production of large cardamom capsule is continuing.

Fig 15. Large cardamom in at Hukphang and Mongtikang village

Demonstration on protected cultivation of flowers and vegetables

A poly house structure measuring size of 11m x 6.2m has been constructed at IFS model site under Protective cultivation of Flowers and Vegetables. Gerbera variety (*Brilliance*, *Stanza*, *Rosalin*, and *Silvester*) has been planted under Poly house structure at IFS model, Hukphang village. The demonstration of drip irrigation and powdery mildew management was demonstrated in gerbera. A total of 765 nos. of flowers sold @Rs. 15/flower. The total of Rs. 11475 has been generated as a total income from that protecting structure.

Artificial Rain Water Harvesting Structure (*Jalkund*)

Three nos. of low cost scientific rainwater harvesting structure were established at Hukphang and Mongtikang village with the storage capacity of 92000 litres of water for irrigation purpose during the lean period of the year. The assessment of the water productivity [WP=Total production (kg)/Water used (m^3)] of *Jalkund* was conducted. Before intervention of the technology the water productivity of garden pea and chilli was 0.15 and 0.14 kg/m^3 respectively in the farmers practice whereas after intervention of the technology the water productivity become 0.37 and 0.33 kg/m^3 respectively.

Fig 16a. Construction of *Jalkund* at Mongtikang village

Fig 16b. Construction of *Jalkund* at Hukphang village

Effect of Different Nutrient Management practices in Jhum rice

A trial on rice (Local variety) is conducting at KVK, farm with an area of 309 sqm with the treatments (Lime @ 250 kg/ha), Lime + Bio-fertilizer, Lime + Bio-fertilizer + NPK (17-17-17), Bio-fertilizer + NPK (17-17-17) + Organic manure@ 2.5 t/ha) and Farmers practice on rice to find out the most suitable treatments for higher production and productivity. Rice was sown in the month of April and harvested in the month of September, 2018. The sowing of rice was done traditionally by broadcasting method. Result found that, out that the maximum yield was recorded 2.05 t/ha with Bio-fertilizer + NPK (17-17-17) + Organic manure@ 2.5 t/ha) followed by Lime + Bio-fertilizer + NPK (17-17-17) (1.9 t/ha) and Lime + Bio-fertilizer (1.3 t/ha).

RECYCLING OF FARM WASTE

Waste Utilization through Low Cost Vermicomposting Technology

Introduced 1 no. of low cost polythene sheet Vermicomposting structure at Mongtikang village in the month of November, 2018 for production of organic manure and recycling of farm waste materials.

Fig 17. Low cost Vermicomposting unit at Mongtikang village

Demonstration and popularization of oyster mushroom cultivation technology

Hand on demonstration on mushroom production technology unit was conducted on Oyster mushroom cultivation was established at Hukphang village under NMSHE project. Input (spawn, poly bag, plastic tank, sprayer etc.) was provided to the beneficiaries. Yield after 2nd harvest was recorded 20 kg of mushroom per unit at 1.2 kg per bag have been harvested. Net benefit of 3000/- was received with the benefit cost ratio of 3.2:1.

Fig 18. Mushroom production unit at Hukphang village

Farmers participatory seed production:

The centre has taken up initiatives for promoting quality seed production through farmers' participatory seed production under ICAR Seed Project. The centre is promoting location specific improved varieties of rice, toria, soybean, green gram, linseed, groundnut and sesame to minimize yield gap.

Gramin Krishi Mausam Sewa (GKMS)

ICAR Research Complex for NEH Region, Nagaland Centre has a well maintained Agromet Observatory, Automatic Weather Station and an Agro-Automatic Weather Station where observations are being recorded daily at 0613, 0830, 1313 and 17:30 hrs for different weather parameters *viz.* rainfall, temperature, dry bulb, wet bulb, relative humidity, cloud cover, wind speed, wind direction, vapour pressure, evaporation, sunshine hrs, soil temperature and water temperature.

104 biweekly Integrated Agro Advisory Bulletin has been issued for the farmers of all the eleven districts of Nagaland based on the medium range weather forecast to plan agricultural operation so as to take advantage of the favorable weather and mitigate the effects of adverse weather. 19939 registered farmers are benefiting through SMSs service which are provided twice a week in local language "*Nagamese*" covering all aspect on crops and livestock, fisheries etc for the farmers in remote location. During the year 2018, 6823 farmers have been registered for the service and SMSs have been disseminated 91 times during the said year. Farmers are encouraged to utilize the service for contingency planning and betterment of their livelihood. Monthly weather based integrated agro advisory have been published 12 times in the local dailies "*The Morung Express*" in addition to articles on agriculture and allied topics contributed by expert from different institutions. Four Farmer Awareness Programmes had been conducted under GKMS in different villages of Dimapur and Peren district where 146 farmers have been benefitted through the programme. Farmers were also apprised about the importance of Agromet Advisory services during different training programmes organised by ICAR Nagaland Centre and KVK, Dimapur at ICAR Complex, Medziphema.

SIKKIM

WEATHER REPORT

The total rainfall received during the year 2018 (January to December) was 2939.2 mm with August being the wettest (562.8 mm) and January being the driest months (Fig 1). The maximum average temperature (29.1°C) was recorded in August and the minimum temperature (7.2°C) was in January. The maximum relative humidity of 94.5% was observed during September and the minimum was observed in January (38.8%) (Fig 1).

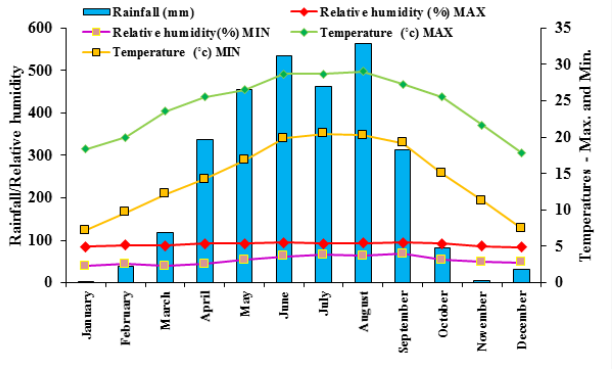


Fig 1. Monthly variation in weather parameters at Gangtok (January -December 2018)

AGRONOMY

Effect of cropping system on system productivity and production efficiency

The productivity of rice is very low due to imbalance organic nutrition in the state of Sikkim. Hence, diversification of rice through inclusion of leguminous crops was undertaken in a Completely Randomized Block Design (CRBD) with seven rice based cropping systems *viz*., rice-maize, rice-fenugreek (leafy vegetable)-maize (green cobs), rice-broccoli-*Sesbania* (green manuring), rice-vegetable pea-maize (green cobs), rice-coriander (green leaf)-cowpea (vegetable), rice-fenugreek (leafy vegetable)-baby corn and rice-buckwheat. The results of the study revealed that inclusion of legumes in the rice based cropping system significantly increased the yield attributing characters and yield of rice under organic management at Sikkim Himalayas. Among the different cropping systems, significantly higher (18.4% over traditional practice) grain yield of rice (4.6 t/ha) was recorded with rice-fenugreek (leafy vegetable)-baby corn followed by rice- broccoli-*Sesbania* (4.45 t/ha) cropping systems.

Diversification of maize-based cropping system through *in-situ* moisture conservation practices for improving water and crop productivity

In Sikkim, very scanty or marginal rainfall is received during winter season, hence, farmers do not grow second crop after late harvest of maize. This results in low cropping intensity (118%). *In-situ* moisture conservation practices during winter season through residue retention can play vital role for improving the crop productivity and enhancing the cropping intensity in the state. Keeping this in view, an attempt was made to diversify the maize-based cropping system by incorporating the legumes and *in-situ* moisture conservation practices. The results of the study revealed that among the cropping sequences, maize+cowpea-vegetable pea recorded the higher maize equivalent yield (12.42 t/ha) followed by maize + cowpea - rajmash (10.27 t/ha). Similarly, net return was also higher in the same system with B: C ratio of 2.86 compared to farmers practice (B: C of 1.76). With respect to the moisture conservation practices, *in-situ* retention of maize stalks + weeds biomass recorded higher maize equivalent yield (8.76 t/ha) compared to control (without mulch) (8.34 t/ha).

Resource conservation techniques for improving productivity and resource-use efficiency of maize-pea cropping system

Organic conservation agriculture practices not only enhance the productivity but also overcome the problem of declining factor productivity especially in the hilly terrain. An experiment with three tillage practices (*viz*., conventional, reduced and zero) with four organic sources of nutrients (*viz*., farmers' practice, recommended dose of N (RDN) through organic sources, 75% of RDN of organic source+maize stalk/pea stover, 50% RDN of organic sources+maize stalk/pea stover)was conducted. Zero tillage (ZT) recorded significantly higher maize equivalent yield (MEY: 11.33 t/ha) over conventional tillage (10.15 t/ha) but comparable to reduced tillage (RT) sown maize (11.14 t/ha).Significantly higher B:C ratio was observed with ZT (3.13) followed

by RT (2.93) while lowest was with CT (2.47). The organic sources of nutrients also showed significant effect on MEY and recommended dose of N recorded the maximum MEY (12.19 t/ha) followed by 75% ofRDN of organic source+pea stover (11.72 t/ha) and the lowest RYE was with farmers' practice (9.24 t/ha).

Development of climate resilient maize-based cropping system for mountain ecosystem under organic management

Mono cropping of maize is prevalent in the state and non-availability of irrigation water during *Rabi* season is one of the reasons for this. Hence, double cropping is negligible. As a result, cropping intensity in the state of Sikkim is very low (118%) compared to national average (140%). An attempt was made to increase the cropping intensity up to 300% through intensification of maize-based cropping sequences with the inclusion of leguminous crop. Three cropping sequences *viz*., CS_1-maize-fallow (FP), CS_2-maize-urd bean (*pahenlo dal*)-buckwheat and CS_3-maize-urd bean (*pahenlo dal*)-toria were tested under three different organic nutrient management practices (T1: 50%FYM + 25%VC + 25%MC + biofertilizers; T2: 50%MC + 25%FYM + 25%VC + biofertilizers and T3: 25%FYM + 25%MC + 25%VC + 25%PM+biofertilizers) and the performance was compared with farmers practices. The results revealed that among the organic sources of nutrients, grain yield of maize (3.53 t/ha) was higher under T3 treatment over other treatments.Similarly, grain yield of maize was significantly higher in CS_3(2.53 t/ha) followed by CS_2 (2.19 t/ha). The yield of black gram was higher in CS_3 (0.82 t/ha) followed by CS_2 (0.71 t/ha).

Varietal response of rice (*Oryza sativa* L.) under different planting methods in mid hills of Sikkim Himalayas

Farmers in Sikkim grow improved scented varieties in traditional methods. This results in sub-optimal productivity but at higher input cost. An experiment was conducted using three rice cultivars namely Pusa Sugandha-5, Pusa Sugandha-6 and local *cv. Attey* were grown in two methods of planting *viz.*, system of rice intensification (SRI) and conventional planting (CP). The results revealed that SRI recorded 5.79 per cent higher grain yield over CP. Among the varieties,Pusa Sugandha-5 (3.71 t/ha) recorded significantly higher grain yield than Pusa Sugandha-6 (3.67 t/ha) and local *cv. Attey* (3.08 t/ha).

Effect of tillage practices on productivity of black gram and rajmash under maize-based cropping system in mid hills of Sikkim

Black gram and rajmash are being grown by the farmers' during *Kharif* season after harvesting of maize without due consideration of field moisture status. Moreover, tillage operations for sowing of black gram may not be feasible for early sowing after harvest of maize. An experiment was conducted at ICAR-NOFRI Research Farm in which rajmash and black gram (*Pahenlo dal*) were grown under different tillage practices *viz*., conventional tillage (CT), zero tillage (ZT) and reduce tillage (RT) in FRBD with three replications. The results showed that rajmash recorded higher grain yield in RT (1.30 t/ha) over conventional tillage (0.94 t/ha) and ZT (0.86 t/ha) while black gram produced higher grain yield in MT (0.94 t/ha) compared to other tillage practices.

Screening of sunflower and sesame varieties under organic management condition in mid hills of Sikkim

Sunflower and sesame are the two potential oil seed crops which can reduce the deficit (-64%) in oilseed production in the state. We evaluated six varieties of sunflower and sesamum under organic management conditions in the mid-hills of Sikkim. Among the sunflower varieties, KBSH-41 produced higher yield (2.48 t/ha) followed by LFSH-171 (2.19 t/ha). The oil content was highest in DRSH-1 (36.2%) followed by DRSF-113 (35.6%) and KBSH-41 (34.9%). In sesamum, we identified two early maturing varieties namely Amrit and TKG -308 with growth duration of 142 days each. The maximum number of pods per plant (35.4) as well as seed yield (6.2 q/ha) was observed in GT10 (35.4) followed by TKG -308 (5.7 q/ha).

Evaluation and standardization of vertical farming in large cardamom under organic management practices

Large cardamom is an important cash crop of Sikkim and is generally grown under shade condition as a component crop in different agro-forestry systems in the state. Present days, farmers' grow it in rice field under open conditions. Since it is a shade loving crop, vertical farming (trailing plant above the large cardamom) likely to benefit the large cardamom. We evaluated one such experiment and compared with farmers practice of growing in open

paddy field. We found lower lux (15.0 to 31.7) of large cardamom when grown in vertical farming compared to open condition (36.2-40.0). Among the trailing vegetables, chow-chow provided shades for longer duration. Maximum yield of large cardamom was recorded with GI wire planted bottle gourd (12.52 t/ha) followed by cucumber (8.64 t/ha) as trailing vegetables.

PLANT BREEDING

Development of high yielding rice varieties resistance to biotic and abiotic stress under organic agriculture of Sikkim

Sixty three (63) rice entries collected from various sources namely VPKAS Almora (19 entries), CSKHPKV Palampur (24 entries) and other HYVs & local collections (20 entries) of Sikkim were evaluated for yield and its contributing traits. Highest grain yield was recorded in VL DHAN 81 (5459 kg/ha) followed by HPR2795 (5431 kg/ha) and HPR1156 (5328 kg/ha). Similarly, 103 entries of rice were evaluated for their response to low temperature under late transplanting conditions. These include 79 entries from Tripura and 24 from different sources including local cultivars and improved varieties. No seed setting was recorded in 35 entries. Only few of them produced higher grain yield namely Tripura Sharat Dhan (4434 kg/ha), TRC 20166 (3889 kg/ha), HPR 1068 (3314.6 kg/ha), Chirakey (3310.3 kg/ha) and Kalami (3235 kg/ha). Of these 103 entries screened, 47 were found resistant to sheath rot. Few of the prominent resistant to sheath rot entries were: Gomati red, Tripura Aush Dhan, Khowai, TRCBN102142BB1, TRCPSM353170 B B7, Jala Dhan, TRC series, Zornalli, Himalayaii, Khimti, VL Dhan65, VL Dhan82, Pusa5, China 988, HPR 1068, Sijali, Sano Attey, Kalami, Chirakey etc.

SOIL SCIENCE

Soil organic carbon stocks and fractions in different orchards of Sikkim

Carbon stock in soil depends largely on land use management, crop types, aerial extent of the soils, carbon content, soil depth, bulk density etc. Experiment was conducted to estimate soil organic carbon stocks and fractions in different orchards at ICAR-Sikkim Centre. Initial soil properties along with SOC of all the orchards were estimated. Oxidizable organic carbon stock (Mg C/ha) in surface soil (0-15 cm) was highest in peach (17.29) followed by kiwi (17.29), citrus (16.87), guava (16.81), pear (16.42), plum (16.37) and lowest in mandarin (16.32) orchards. The similar trend was observed in the sub-soils (15-30, 30-45, and 45-60 cm). Active carbon pools (Mg C/ha) of the same surface soil was significantly higher in citrus (13.29) followed by kiwi (13.26), peach (12.89), guava (12.23), mandarin (11.37), pear (11.21) and lowest in plum (10.38). In sub-soils, similar trend with oxidizable carbon was observed. Passive carbon pools (Mg C/ha) in surface soil was highest in peach (10.79) followed by guava (10.61), kiwi (10.56), pear (10.23), mandarin (9.37), citrus (9.27) and plum (9.07).

Effect of organic nutrient management practices on carbon sequestration and soil carbon pools in different cropping systems in Sikkim

An experiment was undertaken to study the influence of different management options including cropping systems on soil organic carbon (SOC), labile carbon pool (LCP), soil organic carbon pool (SOCP), carbon sequestration and sequestration rate in the pre-humid mid hill acidic soils of Sikkim. The experiment consisting of three main plot organic treatments *viz.*, FYM @ 10 t/ha (NM_1), VC @ 5.0 t/ha (NM_2) and poultry manure 5.0 t/ha (NM_3); and six sub-plot cropping systems *viz.*, maize-black gram (CS_1), maize-rice (CS_2), maize-soybean (CS_3), maize-mustard (CS_4), maize-buckwheat (CS_5) and maize-vegetable pea (CS_6). The initial SOC and bulk density of the experimental soil was 9.50 g/kg and 1.30 Mg/m^3, respectively. The bulk density in the surface soil (0-20 cm) varied from 1.25 to 1.27 $Mg/m^3$and increased consistently along the depth in sub-soil. The SOC content in surface soil varied significantly among different cropping systems: 12.21 to 15.74 g/kg and decreased with the increase in depth of soil. The highest SOC content was measured with organic management in maize-soybean (CS_3) system. The LCP in surface soil ranged from 2332.4 to 2571.3 mg/kg and decreased with increase in depth of soil. The LCP was higher in maize-rice (CS_2) system over other cropping systems. The SOCP was significantly higher in maize-soybean (CS_3) system (39.35 Mg/ha) compared to other systems. This resulted in both higher carbon sequestration (14.65 Mg/ha) and carbon sequestration rate (2.93 Mg/ha/year) in the same system. The carbon sequestration rate in the cropping systems followed the order as $CS_3>CS_4>CS_1>CS_2>CS_6>CS_5$. The carbon sequestration rate of maize-soybean (CS_3) was

almost at par with maize-mustard (CS_4). Therefore, either maize-soybean (CS_3) or maize-mustard (CS_4) cropping system under organic management is better for sequestering higher C in the soil than the maize-black gram (CS_1), maize-rice (CS_2), maize-vegetable pea (CS_6) and maize-buckwheat (CS_5) systems.

Co-composting of organic manure amended with low cost biochar for soil acidity management

Laboratory incubation study was conducted to assess the efficacy of different organic manures amended with biochar on soil acidity management. Poultry manure, pig manure, goat manure, FYM and vermicompost were used to prepare biochar co-compost. Both the biochar and organic manures were mixed at 1:2 ratios and kept for 15 days. This mixture called biochar manure co-compost was analyzed for soil pH. In all the combinations, soil pH was alkaline, ranged from 8.86 (vermicompost biochar co-compost) to 9.35 (poultry manure biochar co-compost). We also studied liming potential of these combinations. For this, acidic soil (clay loam with pH 5.2) was incubated with biochar co-compost. The co-compost prepared was applied at three rates (0, 2.5, and 5.0 t/ha) in the soil and incubated for two months. At 5.0 t/ha application rate, poultry manure biochar co-compost increased pH by 1.6 units from the initial pH of 5.2 followed by 1.4 unit increase by pig manure biochar co-compost (pH 6.6). Co-compost type, application rate, and their interaction had significant effects ($p<0.05$) on soil pH. Thus, these manure biochar co-composts can be effectively used for management of acid soils of Sikkim and other parts of Northeast India.

HORTICULTURE

Flagship Program on Temperate Fruits

Kiwi fruit

Organic package of practices were standardized for maximization of 'A' grade kiwifruit production under partial protection (PP) with 50% agro-shade net. Third year trial was undertaken on hand pollination (HP) and its effect on the percent fruit set, average fruit weight, fruit length and fruit width, fruit yield and fruit quality under partial protection and compared with control (C). Results revealed that the time of hand pollination and partial protection of kiwi fruit significantly increased the per cent fruit set (from 69.72% to 95.56%), fruit weight (from 63.7 g to 100.2 g), fruit volume (from 62.2 ml to 95.7 ml), fruit length (65.6 mm to 77 mm), fruit width (from 39 mm to 45.2 mm) and fruit yield (from 10.7 kg/plant to 41.7 kg/plant). It also significantly influenced the TSS (15.47% to 22.94%) and no. of seeds/fruit (500 to 1121).

Regional trial on advance breeding lines of horticultural crops – Guava

Five guava varieties *viz*., RCGH1 (Sour type X Red fleshed local), RCGH4 (Red fleshed X Allahabad Safeda), RCGH7 (Lucknow-49 X Pear shaped), Allahabad Safeda and Lucknow 49 (Sardar) were planted in ultra-high density system of planting at 2 m x 1.5 m spacing during 2014-15. During fourth year, all the guava varieties entered in to reproductive phase and observations on biometrics and yield attributing parameters were recorded. The maximum plant height was observed in var. RCGH 1 (208.4 cm) followed by RCGH4 (199.7 cm) and the minimum plant height was recorded in RCGH7 (182.8 cm). The maximum plant canopy was recorded in var. L 49 (190.7 cm^2) and the minimum was recorded in var. RCGH4 (147.2 cm^2). The maximum trunk diameter was recorded in var. RCGH1 (24.2 cm) and the minimum was in Allahabad Safeda (19.3 cm). The fruit weight (166 g) was highest in RCGH 1 and minimum (110.2 g) was recorded in Allahabad Safeda. The number of fruits/plant was highest in RCGH7 (144) and minimum in L 49 (52). The yield (17.2 kg/plant) was highest in RCGH 7 followed by RCGH 1 (14 kg/plant). Standardization of organic nutrient management and scheduling of bio-pesticide and bio-fungicide spray were done. Application of well-decomposed and dried cattle manure @ 20 t/ha in two split doses (December and June), neem cake @ 2 t/ha, dolomite @ 2 t/ha, and vermicompost @ 2 kg/plant showed better growth response in all the guava varieties. Spray of petroleum-oil based spray mixed with neem oil in equal concentration @ 5 ml/l during April-May and July-August was effective for control of aphids and spray of copper oxychloride @ 0.25% during April-May and July-August at 15 days interval was effective for the management of anthracnose disease. Spinosad (45 EC) when applied @ 0.3 ml/l at 15 days interval was also effective in control of nettle grubs, Bihar hairy caterpillars, aphids and other insects in all the guava cultivars.

Flower and fruit drop studies in Sikkim mandarin under organic management practices

Flower and fruit drop of citrus was observed in

spatio-temporal dimensions. For Sikkim mandarin, at Tadong (ICAR-NOFRI) condition, we recorded 63.88 ± 2.36 % of fruit set. Maximum drop was during the final stages of fruit development. Similarly, in South Sikkim (Village: Lingee Payong) condition, 52.1 ± 1.28 % fruit set was recorded and the maximum drop happened during final stages of fruit development. In Mosambi, at Tadong condition, majority of the drop was during post anthesis and subsequent drops were in a smooth wave. In Rough lemon, majority of the drop was at maturity stage (57.39 ± 1.14 % fruit set) at Tadong condition. Majority of fruit drop at all the locations was due to fruit fly infestation followed by *Fusarium* spp.

AGROFORESTRY

Carbon sequestration potential and bio-economic appraisal of large cardamom based agroforestry systems (AFS) in mountain region

An experiment was conducted at ICAR-NOFRI, Tadong in large cardamom based AFS. Large Cardamom cultivar Sawney was planted in combination with multi-purpose tree species as well as mixed forest systems. Growth performance of four year old plants had recorded more number of average plant height and bearing tillers/clump under *Alnus nepalensis* based AFS followed by mixed forest system while minimum was recorded under *Ficus hookerii*. Dry yield (gm)/clump were higher in *Alnus nepalensis* based AFS followed by mixed forest system and *Leuceana leucocephela* and minimum with *Ficus hookerii* based AFS.

Effect of large cardamom-based different agroforestry systems on soil properties

This experiment was initiated to evaluate nutrient dynamics in large cardamom under different agroforestry systems. Pooled data showed that plant available nitrogen, phosphorus and potassium were significantly higher in *Alnus* followed by mixed forestry and *Leuceana leucocephela* based AFS. However, accumulation of soil organic carbon content was higher in mixed forestry system followed by *Ficus* based agroforestry system.

Sikkim mandarin and Assam lemon based AFS

A field experiment was conducted to assess the growth performance of Sikkim mandarin and yield of intercrop. As intercrops Pahenlo dal (Urd bean) and maize were sown in kharif season, whereas buckwheat and mustard were sown in Rabi season in association with Assam Lemon. The average yield of buckwheat, mustard, maize, soybean and pahenlo dal was recorded as intercrop and as sole crop to know the suitability of crop for intercropping in Sikkim mandarin based AFS. All crops yielded less as intercrop compared to sole crop. Leguminous crops (Soybean and Pahenlo dal) showed higher reduction in yield (45.53% and 35.96%, respectively) than other crops. Mustard also exhibited low yield (5.92 q/ha as an intercrop) in comparison to sole crop (8.88 q/ha). However, yield penalty of Buckwheat crop (10.31%) was less when grown as intercrop than sole crop followed by Maize (15.22%). Therefore, Buckwheat was found suitable crop as intercropping in Sikkim Mandarin based AFS.

As intercrops, Pahenlo dal (*Urd bean*) and maize were sown in *kharif* season, whereas buckwheat and mustard were sown in Rabi season in association with Assam lemon. In this study, all crops yielded lesser as intercrop compared to sole crop. Pahenlo dal (urd bean) showed higher reduction in yield (33.69%) than other crops. Mustard also exhibited low yield (6.50 q/ha as an intercrop) in comparison to sole crop yield (8.92 q/ha). The present study recorded less yield penalty of Buckwheat crop (24.96 %) when grown as intercrop than sole crop followed by maize (25.90%). The average height of Assam lemon was recorded at 1.19 m and diameter 11.16 cm with intercrop compared to 1.27 m and 13.69 cm in control, respectively.

PLANT PATHOLOGY

Studies on epidemiology of blight of large cardamom and its management under organic conditions

A survey on blight disease of large cardamom was conducted and blight infected samples were collected to know the causal organism of the disease. A total of eight different leaf blights; two pseudo stems blights and one capsule rot symptom were collected and associated fungi were isolated. The different blight symptoms and difference of cultures on media indicated towards the complex nature of the disease. The isolated cultures were sent for identification of associated fungi.

Evaluation of maize germplasm of hilly areas against natural population of Turcicum leaf blight pathogen

An experiment was conducted to evaluate the

performance of 11 lines of commonly cultivated maize varieties of hills against the Turcicum leaf blight pathogen during March-July 2018. A disease score of 1.0 was considered as highly resistant, 2.0 as resistant, 3.0 as moderately resistant and the scores of 4.0 and 5.0 are considered as susceptible and highly susceptible, respectively. Percent Disease Index (PDI) was calculated with following formula:

Percent Disease Index (PDI)

$$= \frac{\text{Sum of individual disease ratings}}{\text{Total No.of plants/leaves observed}} \times \frac{100}{\text{Maximum disease rating value}}$$

Among the 11 lines, Rato Makai, Baiguney Makai and Kalo Makai exhibited resistance reaction (score 2.0); Setimakai, Satheya, RCM1 1, RCM 1 3; Pahenlomakai showed moderately resistant (score 3.0) reaction and Vivek Sankul 35, RCM 76 and Vivek Sankul 31 expressed susceptible (score 4.0) reaction towards Turcicum blight pathogen in organic condition of Sikkim.

Screening and characterization of resistance germplasm for development of high yielding rice (*Oryza sativa* L.) varieties against blast and sheath rot disease in organic conditions of Sikkim

An experiment was carried out to ascertain the resistance source in rice germplasm against blast and sheath rot diseases in organic cultivation. A total of 166 rice germplasm from NEH region were screened to natural populations of pathogens - Blast and Sheath rot. The screening results revealed that five germplasm (Sano Attey, Sijali, Tabrey, Phudungey, Thulo Attey) were susceptible; 159 germplasm were either resistant or moderately resistant to blast pathogen. Out of 165 germplasm, 130 germplasm showed resistance or moderately resistant and 35 germplasm (HPR 2656, Hasan Sarai, HPU 2216, China 988, RR 2421,Nagar Dhan, Phudungey, Pusa-6, HPU 741, Varun Dhan, HPU 779, HPR 288, HPR 2720, HPU 741, Takmaru, VL DHAN 208, VL Dhan 61, VL DHAN 154,VL DHAN 157, VL DHAN 85, VL DHAN 221, VL Dhan 86, Tripura Hakuchuk Dhan1, TRC-BN-29-35-B-B-B-3, TRC-BN-188-145-B-B-18, TRC BN-803-372-B-B-18, TRC-2017-13, TRC-2017-49, TRC2015-13, TRC2015-12, Joymati, Himalaya II, Kasturi, Tabrey and VL DHAN 82) were found susceptible to sheath rot pathogen under organic agriculture of Sikkim.

ANIMAL SCIENCE

Productive and reproductive performance of Singharey Goats inorganized and conventional farms of Sikkim

With the synchronization of estrous cycle in female goats using melatonin @20 mg through subcutaneous route, reproduction rate was improved (pregnancy rate 100% and kidding rate 166% with 50% of the treated animals gave twins and triplets). Melatonin treatment @ 20 mg per doe was beneficial for augmenting reproductive performance in Singharey goats. Buck exposure to the breedable female goats for 15 minutes, twice daily induced estrous in 94.1% goats against 66.7% in exposed female goats. Pregnancy rate was 100% for buck exposed group against 75% in unexposed group. Higher birth weight in kids was recorded using buck exposure than melatonin for inducing estrous in goats.

Three kiddings were accomplished in less than two years, which was the minimum possible period to decrease the kidding interval. The kiddings were spaced by one melatonin treatment and two time natural interventions with buck exposures. The placement of all the kiddings within a period of 15-20 days with both the protocol helped in the management of the kids for better growth and reduced mortality in kids. Thus, Singharey goats in Sikkim can be bred round the year and buck exposure to breedable females can be used effectively to synchronize estrous in goats. This method is natural, economic and simple to be adopted by the farmers of Sikkim.

Reproductive disorders of dairy cattle in relation to mineral deficiency in different agro-climatic zones of Sikkim

Progesterone level was examined in the post partum dairy cattle of East, North, South and West districts of Sikkim. The progesterone concentration in cows at more than 60 days post-partum did not differ significantly ($P>0.05$) among the districts. The progesterone concentration (ng/ml) in the post partum cows were 2.46±0.5, 1.40±0.53, 1.89±0.49 and 2.56±0.52 in East, North, South and West districts, respectively.

True anoestrus condition was more prevalent in winter season than other seasons of the year. Irrespective of districts, number of animal bearing cyclic corpus luteum (CL) was more during rainy season. Availability of green grasses during rainy

season might be attributed to more cows in estrous cycle. In contrast, during winter and autumn seasons, the cows are heavily dependent on the leaves and tender twigs of the tree fodders. During the winter period, the livestock are fed with paddy straw, maize stover, bamboo leaves, broom grass and tree fodders.

Network Project on Organic Farming (NPOF)

Evaluation of maize composite under organic management condition

An experiment was conducted to study the evaluation of maize varieties under organic management condition. The experiment was laid out in RBD with 3 replications having 12 entries *viz.*, T_1-Seti makkai; T_2-Pahenlo makkai; T_3-Rato makkai, T_4-Baiguni makkai; T_5-Kalo makkai; T_6-Satheya; T_7- RCM 11; T_8-RCM 1 3; T_9-RCM 75 ; T_{10}-Vivek Sankul31; T_{11}-Vivek Sankul37; T_{12}-Vivek Sankul35. Results revealed that the maximum yield was recorded for variety Vivek Sankul35 (2.89 t/ha) and the lowest was recorded for *cv* Kalomakkai (1.42 t/ha). The lowest percent leaf feeding of army worm was observed in Pahenlo Makkai (10%) followed by RCM 13 (12.2%) and RCM 11 (14%). The leaf feeding rating for Pahenlo Makkai, RCM 13 and RCM 11 were 1, 1.2 and 1.2, respectively. Also the lowest percent plant infestation by stem borer was observed in Pahenlo Makkai (8.53%) followed by RCM 13 (26 %) and RCM 11 (32.2%).

Evaluation of Buckwheat composite under organic management condition

Experiment was conducted to study the evaluation of buckwheat varieties under organic management condition. The experiment was laid out in RBD with 3 replication having 12 treatments viz., T_1- Local Meethey; T_2- Local Teethey; T_3- IC 109728 from NPBGR, HP; T_4- IC 26600 from NPBGR, HP; T_5- IC 109729 from NPBGR, HP; T_6- IC 15393 from NPBGR, HP; T_7- IC 109433 from NPBGR, HP; T_8:- IC 49671 from NPBGR, HP; T_9- EC 2018742 from NPBGR, HP; T_{10}: PRB – 1; T_{11}- VL Ugal 7; T_{12}- Sangla B-1. Results revealed that the maximum yield was recorded on IC 109433 (2.61 t/ha) which was followed by Local Meethey (2.51 t/ha) and lowest yield was recorded on PRB-1 (1.44 t/ha).

National Mission for Sustaining Himalayan Ecosystem (NMSHE)

Under the programme three sites *viz.*,Timpyem (mid altitude), Thanka–Martam, East Sikkim (mid altitude) and Lachen, North Sikkim (high altitude) are included for the project. Following interventions were made in 2018 in the pilot site *at Timpyem village, East Sikkim*

- During the month of July transplanting of rice was done in various farmers field from the nursery site.
- After a month of rice transplant (August) bunds were cleaned for sowing of soybean seed in order to utilize the bunds to generate extra income. Soybean being a leguminous crop helps to restore soil fertility as well as suppresses the weed growth.
- Timely monitoring of crops was done to check the incidence of disease and pests, thinning, weed management *etc*.
- Various cropping systems under different land use have been implemented in farmers field such as rice-vegetable pea, maize-*Pahenlo dal*-buckwheat, large cardamom-turmeric, large cardamom-ginger, maize-soybean, mandarin-vegetable, *Alnus nepalensis*-turmeric, guava-cowpea. This has been monitored at regular intervals to check its proper growth and development and also to combat against disease and pest through proper management practices.
- Integrated farming system was emphasized upon to generate higher income and self-employment.
- The programme also stressed on the importance of poultry manure in organic agriculture and advantages of rural poultry farming with Vanaraja birds, scientific housing, brooding management of chicks and treatment of poultry diseases.

AICRIP on Rice-2018

IVT-M(H) Irrigated: Total of 22 entries were evaluated in RBD design with 2 replications. Highest grain yield per ha was recorded in entry No. 2909 (4337.59 kg/ha) followed by 2911 (4220.17 kg/ha) and 2921(4059.75 kg/ha). AVT1-M(H) Irrigated: Total of 19 entries were evaluated in RBD design with 3 replications. Highest grain yield per ha recorded in entry No. 2818 (5729.0 kg/ha), followed by 2816 (5685.66 kg/ha) and 2802 (5538.33 kg/ha).

All India Network Research Project on Onion and Garlic (AINRPOG-Garlic Trials)

All India Network Research Project on Onion and Garlic (Garlic Trials) was allotted to ICAR-NOFRI Tadong, Sikkim with the objectives to evaluate, characterize and maintain garlic germplasm supplied by DOGR, Pune. As per recommendations, available germplasm were evaluated at our Institute for various traits during the Rabi season. A total 19 lines were evaluated during Rabi season of 2018 with Sikkim Garlic (SG01) as local check for both IET trials and AVTI. Under IET, the nine entries along with Local Check SG 01 were evaluated and the highest yield was recorded in SG 01 (128.6 q/ha) with maximum marketable yield (107.7 q/ha). The SG01 also exhibited second higher values for average bulb weight (22.9 g). Among the ten entries stored for storage trials, the percent loss in total weight was minimum in SG 01 (17.5%) followed by GN 17 12 (19%), while GN 17 14 had the highest percent (30.9%) of loss of total weight.

Effect of zinc and boron application on yield and storage quality of Garlic

An experiment on garlic was conducted with different micro nutrient combinations - namely T_1: soil application of zinc sulphate @ 10 kg/ha, T_2: foliar application of zinc sulphate @ 0.5% at 45 and 60 DAT, T_3: soil application of borax @ 10 kg/ha, T_4: foliar application of borax @ 0.25 % at 45 and 60 DAT, T_5: foliar application of micronutrient mixture @ 0.5% at 45 and 60 DAT and T_6: control without micronutrient. Recommended dose of organic manure FYM @ 15t/ha along with *Trichoderma viride* @ 5 kg/ha mixed with *Azotobacter* @ 10 kg/ha was applied as basal for all treatment. Marketable bulb yield (MBY) and total bulb yield (TBY) were significantly higher in treatment T_5, while field sprouting was higher in T_3. Macronutrient uptake of N, P, K and S were significantly higher in T_5. Similarly, micronutrient uptake of Zn, Fe, Cu, Mn and B was significantly higher in Treatment T_5.

Development of intensive high value organic vegetable production techniques in Sikkim

Production technology of cole crops, leafy vegetables and root vegetables has been standardized under various vegetable cropping sequences for low cost plastic tunnels in the last 5 years. After five years of research, the average percent yield difference of 267.07% for broccoli, 288.9% for cabbage, 245.8% for cauliflower, 130.32% for fenugreek, 252.54% for spinach, 203.84% for coriander, 161.56% for radish, 199.41% for carrot, 137.75% for beetroot, 163.72% for garlic and 187.69% for leafy mustard was observed. Similarly, after four years of research, the average percent yield difference of 364% for tomato, 326.92% for capsicum, 660% for bitter gourd, 669.56% for bottle gourd, 395.50% and sponge gourd during rainy season, 385.92% for Zucchini during off season and 194.24% for pea in main season was observed.

AICRP on Spices

Observation trial on the performance of bold and vegetable ginger at different locations

Observation trial on the performance of bold and vegetable ginger varieties of different locations were conducted at ICAR-NOFRI as per guidelines of AICRP on Spices main Center. The trial was conducted in Randomized Block Design (RBD) with three replications of each treatment. Among all the varieties, Pottangi PGS 121 performed better with 17 t/ha followed by local cultivar *Bhaise* with 12.5 t/ha.

Management of Bacterial wilt of ginger through chemicals and bio-agent

The experiment was initiated to evaluate the effect of soil solarization along with organically permitted chemical (calcium salt) and bio-control agents (*Bacillus* sp. GAP107 MTCC 12725) against bacterial wilt of ginger. The trial was conducted with local cultivar (Bhaise) in factorial RBD with three replication of each treatment in a field having inoculums of bacterial wilt pathogen. Among all, treatment (*Bacillus*+Solarization) showed higher yield (7.40 t/ha) than others despite of high infection of bacterial wilt 4.08%.

Studies on evaluation of organic treatments against major soil borne diseases of large cardamom

An experiment was carried out to evaluate the different organic treatments against major soil born diseases of large cardamom in field conditions at ICAR-NOFRI, Tadong. The trial was conducted with different combinations of *Trichoderma* and COC at Randomized BlockDesign (RBD) and replicated thrice. Among the treatment combinations, sapling treatment with COC @ 2 g/l during sowing + soil application of *Trichoderma* (4 ml/l) 10 days after planting followed by COC @ 2 g/l near clump

followed by *Trichoderma* (4 ml/l) at 10 days after COC application in each month showed less incidence of diseases (9.52%).

Network Project on integrated management of rhizome rot complex of Ginger *(Zingiber officinale)*

Ginger *cv*. *Bhaise* was evaluated against soft rot complex of ginger under different treatments comprising of bio-control agents and ethno-botanicals during kharif season of 2018. During the first year of the experiment, it was found that the when Ginger rhizome was treated in hot water (47^0 for 30 minutes) along with *Schimawallichii* (rhizome treatment with plant extract), *Artemisia vulgaris* (rhizome treatment with plant extract @50%) and *Trichoderma viride* + *Pseudomonas fluorescens*, the disease incidence was least (40.48%) compared to other combinations and control (93.3% disease incidence). The diseased ginger rhizomes and the collar regions of infected plants were also utilized to isolate the pathogens associated with the disease. The infected parts were cultured in laboratory following the standardized protocols, and pathogens of bacterial and fungal origin were isolated in pure culture.

AICRP on Mushroom

Four strains of oyster mushroom PL1701, PL 1702, PL 17 03 and PL 1704 were evaluated for yield performance. Among them, the best performance was exhibited by PL1703 with a yield of 56.1 kg/100 kg dry substrate followed by PL1701 (yield of 43.7 kg/100 kg). The lowest yield of 28.2 kg/100 kg was reported in PL17 02. The PL1703 and PL1704 took maximum time of 30 and 29 days, respectively for first harvest.

Poultry Seed Project (PSP)

Under the Tribal Sub Plan (TSP) component of the Project, the Centre has been distributing 25 day old chicks (DOC) of Vanaraja to each tribal family of Sikkim. During 2018 (January to December), total 94,457 numbers of Vanaraja chicks have been distributed to 3285 farmers of Sikkim. Out of this, a total of 85,645 chicks were distributed free of cost under tribal sub plan (TSP) to the 3217 tribal farmers of Sikkim.

A total of 1,61,215 numbers of eggs produced from Vanaraja parent layers maintained at Farm during 2018 with the highest production of eggs in the month of August (19180 nos). During the period, the distribution of the birds reached a peak in the month of September, 2018 with the supply of 12,375 numbers of chicks in the month. During the year, three batches of Vanaraja parent stock birds were reared, out of which one batch has been introduced to the farm in the month of September 2018. A peak fertility (92.69%) and hatchability (85.95%) was achieved in the month of December, 2018, which was consistent with the previous year. A total of 35 brief training sessions have been conducted on poultry.

Technology Transfer to the farmers field

Maize-*pahenlo dal*- buckwheat a climate resilient cropping system

Maize-*pahenlo dal*-buckwheat a climate resilient cropping system was demonstrated through ICAR-Krishi Vigyan Kendra, East Sikkim to the progressive farmers of the East District of Sikkim. The technology was extended as front line demonstration to 160 nos. progressive farmers covering an area of 40 ha in Bhasme, Loosing, Tshlamthang, Sirwani, Ralap, Thanka-Martam and Amba village of East Sikkim and Mangle and Sripatam in South Sikkim.

Front Line Demonstration of oilseeds and pulses in East Sikkim

Complete package of practices of black gram (var. SKPD-3) was demonstrated on 20.0 ha land to the 82 nos. of farmers in East District of Sikkim. Overall, the grain yield of black gram (var. SKPD-3) was 61.90 percent higher than farmers practice. Similarly, soybean var. JS-9560 was also promoted with complete organic package of practices in 20 ha area with 80 nos. of farmers in East Sikkim. The yield enhancement was 38.8 percent higher over *Seto Bhatmas* (local cv. of soybean).

No-till vegetable pea in rice-fallow

In order to enhance the cropping intensity of the state by exploring the best possible resource conserving technologies (RCTs) like zero tillage by retaining some part of rice stubble (30-40 per cent) and utilizing the residual soil moisture of *kharif* rice; a zero tillage vegetable pea technology in puddled rice-fallows was demonstrated to the progressive farmers of the East District of Sikkim. The technology has been disseminated as front line demonstration to 72 nos. progressive farmers covering an area of 22.5 ha in Timpyem, Nandok, Thanka, Upper Sirwani village of East Sikkim.

TRIPURA

WEATHER REPORT

Overall the year 2018 was a normal monsoon year with 2253.8 mm rainfall in 98 days, and it was accompanied with total pan evaporation losses of 1152.3 mm at an average rate of 3.15 mm/day (Fig 1). The rain during monsoon (June to September) was 26% less than normal seasonal rain (1992-2017). Again post monsoon rain (October to December) recorded 40% deficit over normal. Deficit rain (58% less than normal) during August and September hamper cultivation of late Aman in few places of Dhalai, North and Unokuti district of the state. Available bright sunshine hour during entire year was 17.7% less than normal. In May 18, more than 190 mm rainfall recorded in a single day, which is second highest rainfall in a single day during August and 9th highest in a year during last 27 years. There were 6 extreme event of rainfall (>60 mm in a day) during 2018 compare to 8 normal event. Throughout the year, the mean monthly temperature ranged from 9.8°C (January) to 33.2°C (March and June) and the mean monthly maximum temperature of 24.9 (January) to 33.2°C with absolute maximum value of 40.2°C on May 29, 2018. The coolest day of the year recorded 3.5°C on January 9.

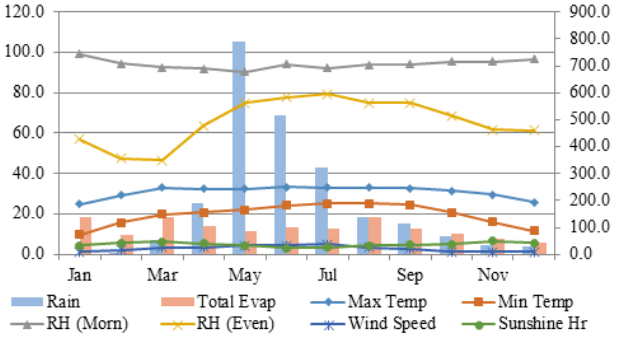


Fig 1. Mean monthly meteorological data recorded at Lembucherra Observatory during 2018

RICE

Rice Improvement / All India Coordinated Rice Improvement Project:

During the year, 2436 promising single plant selections from 34 crosses were characterized for yield and other attributes, 293 entries were evaluated in replicated station trials. In AICRIP, 5 entries qualified for VIC proposal on completion of 3 years of testing (IVT, AVT1 & AVT2) in AICRIP. The entries completed 3 years testing were TRC 2013-11/ IET 24195 and TRC 2014-8/ IET 24197 in AVT2 E (H), TRC 2015-7/ IET 25355 in AVT2 IM and TRC 2015-12 / IET 25662 & TRC 2015-15 / IET 25636 in AVT2 Aerobic. CVRC release proposals were submitted for 2 entries: TRC 2014-8/ IET 24197 and TRC 2015-12 / IET 25662; out of which TRC 2014-8/ IET 24197 was identified by CVRC for release. On the basis of AICRIP trials 5 entries were promoted to 3rd year of testing – AVT2; these are: TRC 2015-5/IET 26178 in AVT2-Aerobic, TRC 2016-9/ IET 25818 & TRC 2016-2/IET 25826 in AVT2 E(H) and TRC 2016-4 / IET 25833 & TRC 2016-3/ IET 25836 in AVT2 M(H). The following entries were promoted to AVT1 on the basis of superior performance in IVT: TRC 2017-12/26690 promoted in Z-7 to AVT1 RSL, TRC 2017-11/ IET 26763 promoted to AVT1 E-TP on overall mean basis, TRC 2017-20 / IET 27191 promoted in Z-3 of AVT1 Aerobic, TRC 2016-14 / IET 26435 on overall basis and TRC 2016-18 / IET 26440 in Z-4 promoted to AVT1 boro.

In AICRIP Hill trials – IET 26573 / TRC 2017-1, IET 26564 / TRC 2017-9 & IET 26585 / TRC 2017-4 promoted to AVT-2M(H); IET 26002 / TRC 2017-3 promoted to AVT-2 U(H); IET 27468 / TRC BN-83-372-B-B-18), IET 27466 / TRC KS -20-114-B-B-37 & IET 27461 / TRC BN-102-142-B-B-1) promoted to AVT-1E(H); IET 27478 / TRC BN-29-35-B-B-B-3), IET 27493 / TRC FS -146-100--B-B-27) & IET 27488 / TRC PSM-353-170-B-B-7) promoted to AVT-1M(H); IET 27506 / TRC BN-188-145-B-B18), IET 27498 / TRC SMCT-23-202-B-29) & IET 27500 / TRC SMCT-152-190-B-46 promoted to AVT-1 U(H).

TRC 2014-8 (IR 83928-B-B-9-1) / IET 24197 was identified for release by VIC CVRC in 2018.

The entry was tested in Early Hills during 2014-17. The entry IET 24197 / TRC 2014-8 (IR 83928-B-B-9-1) showed 23.03% and 5.31% yield superiority in 2015 in Himachal Pradesh and Karnataka,

respectively. Similarly, in 2017, the entry IET 24197 / TRC 2014-8 (IR 83928-B-B-9-1) showed 19.0% and 5.6% yield superiority over the best check in Himachal Pradesh and Karnataka, respectively. The entry (Fig. 2) also has good quality parameters like 68.45% milling, 60.85% head rice recovery, long slender grains (kernel length: 6.63 mm and kernel breadth: 2.1 mm). Disease and insect reactions of the variety is on par with the check varieties.

Fig 2. Field view, grain view and milled rice of TRC 2014-8 (IR 83928-B-B-9-1) / IET 24197

TRC 2015-12 / IET 25662 (Naveen x Kataktara) has qualified for CVRC VIC proposal in Aerobic trials in 2018.

Proposal for its release was submitted to VIC-CVRC, however, the variety was not identified. The variety will be proposed to SVRC, Tripura for release. The variety performed very good (4464, 4922 and 4360 kg/ha) in IVT, AVT-1 and AVT-2, respectively (Fig. 3).

Fig 3. TRC 2015-12 / IET 25662 – field view, paddy and milled rice

Special AICRIP Multi-location Late Sown Trial – Early 2017:

The trial was initiated to identify early duration varieties under late sown condition for delayed monsoon. Overall, variety Tripura Khara Dhan 1 consecutively for 3rd year stood highest yielding (6450 kg/ha) entry among 17 entries in the trial. Tripura Khara Dhan 1 produced 30.36% higher yield than the experimental mean. Such high yield under late sown condition, even when temperature during maturity dropped below normal temperature for flowering in rice (Minimum and maximum temperature during flowering were 15.4 and 28.7 degrees C, respectively), clearly indicated that the variety is truly climate resilient.

Notification of Crop Varieties by Govt. of India

Gazette Notification No. 5077, dated: 26 December, 2018, has notified 16 crop varieties developed and released by Tripura Centre in recent years. Notified varieties include 11 varieties of rice (Gomati Dhan, Khowai, Tripura Chikan Dhan, Tripura Sarat, Tripura Nirog, Tripura Hakuchuk 1, Tripura Hakuchuk 2, Tripura Jala 1, Tripura Khara 1, Tripura Khara 2 and Tripura Aush); 1 variety of fieldpea (TRCP-9), 1 variety of greengram (Tripura Mung 1), 1 variety of blackgram (Tripura Maskalai), 1 variety of sesamum (Tripura Siping) and 1 variety of toria (Tripura Toria -1). Notified varieties are already being taken in the State Seed Chain by the Department of Agriculture, Govt. of Tripura.

Stress Tolerant Rice for Africa and South Asia (STRASA) - Foreign aided project funded by BMGF & IRRI

During the period, 343 entries were evaluated in 7 trials to identify promising entries against drought stress. Trials conducted and the highest yielding entries in each trial are listed in the below given Table 1.

Table 1. Trials conducted under BMGF-STRASA and the most promising entries, wet season 2018.

Sl. No.	Trial	No. of Entries	Highest yielding entry	Yield (kg/ha)	Yield of best check (kg/ha)	% over best check
1	AYT 100-120 (Non Stress)	40 entries + 7 std. checks + 1 local check	IR 106312-50-1-1-1	6893	5929	16.25
2	AYT 100-120 (REPST)	40 entries + 7 std. checks + 1 local check	IR 107891-B-B-785-2-1	5549	5173	7.26
3	DONORS (Re-productive Stage Drought)	11 entries + 4 std. checks +1 local check	IR 80310-12-B-1-3-B	5589	5071	10.21

4	DONORS (Vegetative Stage Drought)	11 entries + 4 std. checks + 1local check	Genit	6767	5464	23.84
5	OYT (Non Stress)	95 entries + 7 Std. Ck + 1 LC (checks multiplied 5 times)	IR 106178-163-6-7-2-1	5893	5267	11.88
6	OYT (REPST)	95 entries + 7 Std. Ck + 1 LC (checks multiplied 5 times)	IR16L1632	4578	3064	49.41
7	PVS	6 entries + 3 std. checks	IR 93329:61-B-21-12-21	7285	6482	12.38

Front Line Demonstration on Rice under NFSM

During 2018-19, FLDs on rice under NFSM were conducted at 4 clusters (Batapura, Beltoli, Madancher and Lamapara in Khowai district of Tripura and 2 clusters (Ramnagar and Kalikapur) of South Tripura. FLD plots included recently notified varieties from ICAR, Tripura Centre, Gomati Dhan and Tripura Nirog along with ICM. Farmers plots with Swarna + traditional practices were taken as check plots. Yield advantages ranged from 38.29% at Ramnagar (highest) to 9.56% at Kalikapur (lowest). However, in 5 out 6 clusters yield advantages were higher than 24%. Economic Gains were much more prominent in all the clusters, ranging from 75.76% in Lamapara cluster (highest) to 25.27% at Kalikapur (lowest). Clusters with Gomati Dhan has recorded higher economic gain, which was due to the fact that the variety fetches higher sale price due to fine grain and good cooking quality.

Fig 4. FLD cluster at East Ramchandraghat, Khowai

Fig 5. AICRIP Monitoring Team members visiting FLDs

PULSES

Pulses Improvement "Breeding Superior Pulses for NEH region

In total 244 promising single plant selections were made from F10 advanced progenies of the cross SPS 5 x IPM 99-125. In addition, 54 promising lines were evaluated in replicated station trial; while 3 entries were nominated to AICRP MULLaRP. F5 bulk and single plant selections of LGG 450 x IPM 02, LGG 460 x IPM 409-4 and single plant selections from IPM 02-19 x EC 496841. Selections were also continued in F5 of LBG 20 x KUG 216 and LBG 752 x Mash 114. Selections were also carried out in F6 bulk of IPM 03-1 x SPS 5 (Mungbean x Urdbean). Selections were also made in F10 bulk of VRM(Gg) 1 x *Vigna umbellata*, F10 bulk of VBN3 (blackgram) x *V. silvestris* and F4 of VBN(Gg)3 x IPM 205-7.

Fig 6. A promising mung line given for testing at State Agriculture Research Station farm, Department of Agriculture, Tripura

Fig 7. A mungbean segregant with very different leaf shape

MAIZE

Promoting Improved Technology of Maize Production in NEH Region

Improved maize production technology was introduced to the farmers of North Pulinpur ADC Village, Khowai Tripura. A total of 69 farmers have been targeted covering a total area 10 ha. High yielding maize variety DA61A and vegetable pea variety Arkel were provided, with other inputs. Maize (spaced at 60 cm X 20 cm) was intercropped with bitter gourd and vegetable pea. Performance of crop was good with intercropping of garden pea (Fig. 8) and bitter gourd. The demonstration of maize based intercropping creates new enthusiasm among the famers.

Fig 8. Maize+ vegetable pea intercropping at farmers field

Fig 9. Field performance of sunflower hybrid KBSH-78

SUNFLOWER

Evaluation of short duration sunflower varieties and hybrids for their performance in NEH regions

A total of nine short duration sunflower varieties and hybrids were evaluated in rice fallow land of Tripura under ICAR-Indian Institute of Oilseed Research, Hyderabad. All the hybrids were sown on 3rd November 2018 at 60 x 30 cm spacing and harvested between 5th to 15th Feb, 2019. Among the tested hybrids, KBSH-78 (Fig. 9) produced maximum seed yield (1951 kg/ha) along with other yield attributing character without logging as compared to other hybrids.

SEED PRODUCTION

In total 393.9q breeder seed of released varieties under ICAR Breeder Seed Project (BSP); 4093 q TL seed under ICAR Seed Project (ISP) and 1055 q pulses seed were produced under Pulses Seed Hub during the year in participatory mode.

Table 2. Details of quality seed produced during 2018-19 under ICAR Seed Project

Crop	Variety	Breeder seed (q)	Truthfully labeled seed (q)
Cereals			
Rice	Gomati Dhan (TRC 2005-1 / IET 21512), Tripura Khara 1 (IET 22837), Tripura Khara 2 (IET 22835), Tripura Jala 1 (IET 22167), Tripura Chikan Dhan (IET 22112), Tripura Sarat (IET 22113), Tripura Nirog (IET 22580), Tripura Hakuchuk 1 (TRC 2013-4), Tripura Hakuchuk 2 (TRC 2013-5), Tripura Aush (TRC 2013-12)	338.8	3749.5
Pulses			
Fieldpea	TRCP-8	22 (expected)	30 (expected)
Blackgram	Tripura Maskolai 1	23	30
Greengram	Tripura Mung 1	7.6	20

Lentil	Tripura Lentil Sel 1	--	60
Rajmash	Tripura Rajmash 1	--	200 (expected)
Oilseeds			
Sesamum	Tripura Siping	1.2	1.1
Toria	TRC Toria 1 (TRCT -1-1-5-1)	1.3	2.4
Total		**393.90**	**4093.00**

Table 3. Seed production under pulses Seed Hub "Seed Hubs for increasing indigenous production of Pulses in India" during 2018-19

Crop	Target (q)	Variety	Seed production Achieved / Expected (q)	Class of seed produced (F/S, C/S, or T/L)	Surplus or deficit (q)
Kharif					
Mungbea	400	Tripura Mung 1	417	TL	+17.0
Urdbean	650	Tripura Maskolai	723	TL	+73.0
Rabi					
Fieldpea	50	TRCP 8	20 (expected)	TL	-30.0
Lentil	70	Tripura Lentil Sel 1	85 (expected)	TL	+15.0
Rajmash	200	Tripura Rajmash 1	260 (expected)	TL	+60.0

FARMING SYSTEM

Resilient farming systems for efficient factor productivity and livelihood security in Tripura:

To study the initial status of physico-chemical properties, soil sample was collected at 0-10 cm, 10-20 cm and 20-40 cm during October, 2018. Available nitrogen ranged from 250-257 kg/ha under soils of integrated seed-based farming system (ISFS) and 244-252 kg/ha under integrated intensive farming system (IIFS) from 0-40 cm depth. Initial soils of ISFS had available potassium 256-348 kg/ha, organic carbon 3.3-5.3 g/kg and bulk density 1.48-1.50 Mg/m^3, and soils of IIFS available potassium 176-162 kg/ha, organic carbon 3.0-4.85 g/kg and bulk density 1.43-1.46 Mg/m^3.

Optimization of Nitrogen fertilizer requirement of mustard cultivation on a newly developed Farming system model: To increase the productivity of mustard, a study was conducted to identify the optimum dose of nitrogen for a newly introduced mustard variety NRCHB-101. Seven levels of nitrogen i.e., 0, 30, 60, 90, 120, 150 and 180 kg N/ha were applied as respective treatment. The crop was sown on 26th October 2017 and harvested 26th February 2018. Application of nitrogen increased the mustard seed yield (16.9 to 131.8%) and biomass yield (56.3 to 299.0%) over those under control (Fig. 10).

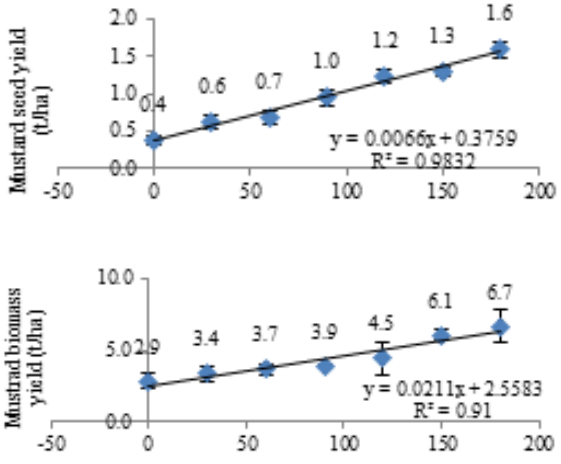


Fig 10. Effect of different levels of nitrogen on mustard yields

Optimization of top dressing of Nitrogen fertilizer for rajmash cultivation on a newly developed Farming system model : An experiment was conducted to optimize the top dressing requirement of nitrogen for rajmash. Result revealed that top dressing application of nitrogen from 15 to 90 kg/

ha through urea increased the rajmash seed (115-335.6%) and biomass (169.6-476%) yield over without top dressing (Fig. 11).

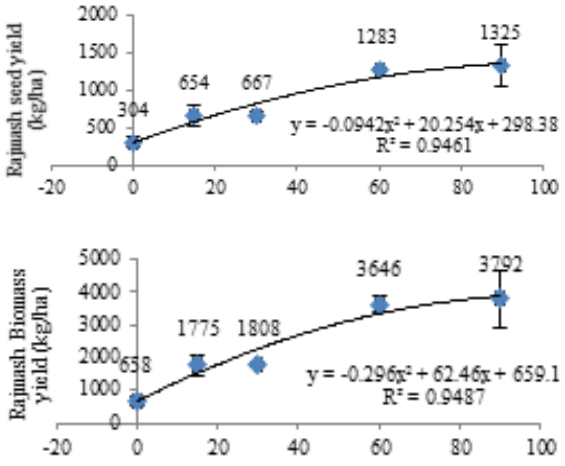


Fig 11. Effect of nitrogen top dressings on rajmash yields

Effects of foliar spray of urea and potassium chloride on mustard yield grown under a newly developed Farming system model : Mustard is an emerging oilseed crop to rice fallow lands of Tripura but the productivity is often low due to moisture stress during reproductive phase. To addressing this issue, a field experiment was conducted to assess the efficacy of two agro-chemicals (urea and potassium chloride) on the performance of the crop. As per treatment, foliar application of 2% chemical was done at 50% flowering stage of the crop. In general, application of either chemical improves seed yield by 12.5 to 15%. The performance of both the agro-chemicals was found statistically at par. However, combined application of both chemicals (2% urea + 2% KCl) further improved the seed yield by 21.1% over control.

Integrated resource conservation technologies for improving crop productivity and soil health under sub-tropical hill ecosystem

Effect of conservation tillage practices on productivity and soil health of rice based cropping systems:

A field experiment was conducted to assess the effect of conservation tillage practices on productivity and soil health of rice based cropping systems to augment productivity and soil health. The experiment consisted of four tillage systems i.e., no-till (NT), minimum tillage (MT), conventional tillage (CT), and permanent broad bed and furrow system (PBBF) and four type of cropping systems i.e., rice-fallow, vegetable cowpea-rice-maize, vegetable cowpea-rice-mustard and vegetable cowpea-rice-lentil. Experiment was started in June 2018, rice crop was direct sown on 6th July 2018 under different tillage as per treatment by following standard practices of management and harvested on 15th October 2018. Result revealed that rice crop sown under CT produced maximum number of tillers (Fig. 12) and biomass yield (Fig. 13) followed by NT than those under MT and PBBF.

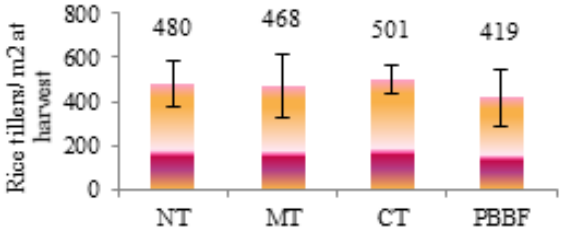


Fig 12. Effect of conservation tillage practices on rice tillers production at harvest

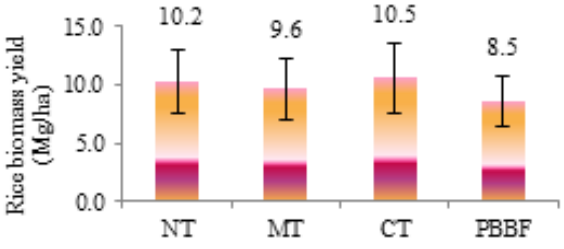


Fig 13. Effect of conservation tillage practices on rice biomass production

Effects of foliar spray of urea and potassium chloride on leaf relative water content, excised leaf water loss and lentil yield:

An experiment on foliar spray of urea and potassium chloride on leaf relative water content (LRWC) and excised leaf water loss (ELWL) in lentil was conducted with four treatments viz. control (no foliar spray), 2% foliar spray of urea, 2% foliar spray of KCl and a combine foliar spray of 2% urea and 2% KCl. The combined foliar spray of 2% urea and 2% KCl increased the LRWC (74.6±3.1%) than those under other treatment. However, the ELWL was low when plant treated with combine foliar spray of 2%

urea and 2% KCl as compared to those under other treatments. Foliar application of either 2% urea or 2% KCl and a combined foliar spray of 2% urea and 2% KCl at both flowering and pod filling stage increased the lentil seed yield from 646 to 1275 kg/ha (Fig. 14) as compared to those under control (396 kg/ha).

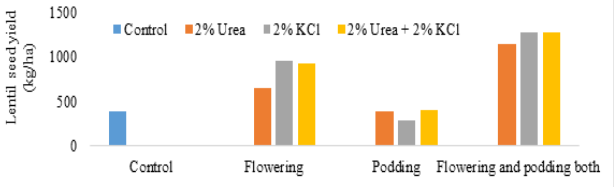


Fig 14. Effect of foliar spray of urea and potassium chloride on seed yield of lentil

SOIL SCIENCE

Chemical weed management in kharif maize

A field experiment was conducted during kharif 2018 to test the efficacy of herbicides for managing weeds in maize under Tripura condition. Maize var. INDAM 1202 (12C002) was sown under no till condition and the crop was mainly infested with grassy weeds. The weed control treatments consisted of Tembotrione @ 100 g a.i./ha Post, Topramezone @ 25 g a.i./ha Post, Tembotrione @ 100 g a.i./ha + Atrazine 250 g a.i./ha Post, Topramezone @ 25 g a.i./ha + Atrazine 250 g a.i./ha Post, Hand weeding at 20 & 40 DAS, Control (no weeding). Application of Tembotrione @ 100 g a.i./ha or Topramezone @ 25 g a.i./ha at 20 DAS satisfactorily controlled weeds (Fig. 15). The different weeding treatments increased maize grain yield by 2.2-2.7 t/ha over control treatment. The data showed that the existing weed populations had the potentiality to reduce maize grain yield by 36-40% under the different treatments. In terms of maize grain yield, there were no significant differences among Tembotrione (6.68 t/ha), Topramezone (6.25 t/ha) and manual weeding (6.72 t/ha) treatments.

A. Control **B. Tembotrione**

C. Tynzer **D. Hand weeding**

Fig 15. Effect of Tembotrione and Tynzer on weeds in maize field.

Weed management in upland kharif rice

Rice var. Hakuchuk-2 was dry seeded in upland field during kharif 2018. The field was highly infested with sedges, grassy and broad-leaved weeds. The highest grain yield of 4.8 t/ha as recorded in the weed free treatment (weeding was done as and when weed growth was noticed till 60 DAS) was statistically similar to the yields recorded in pre-emergence application of pendimethalin @ 1000 g a.i./ha plus hand weeding at 30 DAS (4.67 t/ha), Pendimethalin @ 1000 g a.i./ha (PE) with application of bispyribac sodium @ 25 g a.i./ha Post at 25 DAS (4.33 t/ha) and two hand weeding at 20 & 40 DAS (4.47 t/ha). Control (no weeding) yielded the significantly lowest grain yield (0.56 t/ha) among the given treatments. The data showed that in absence of any control measure, weed reduced the upland DSR yield by 88.3%. The growth of rice was fully suppressed by weeds (Fig. 16) in the plots where no weeding was done.

Fig 16. Complete suppression of growth of upland DSR in absence of weed control measure.

National Mission for Sustaining Himalayan Ecosystem (NMSHE-TF 6)

Monitoring of soil organic carbon pool under different land use system in Tripura

Soil Organic Carbon under different pineapple based agro-forestry systems : To assess the effect of major land use systems, SOC in different soil horizons in different agro-forestry systems were monitored e.g., neem - pineapple, teak - pineapple, eucalyptus - pineapple, sisso- pineapple established in 1989 at Cocotilla farm in comparison to adjacent cultivated land. Soil cores were obtained from four depth profiles of 0 - 15 cm, 15 - 30 cm, 30 - 60 cm and 60 - 100 cm and composite soils samples were also obtained from respective depths. Results showed that carbon concentration was higher in the sisso-pineapple based system followed by Teak-pineapple system; whereas cultivated land has the lowest SOC concentration. SOC contents in soils of all the agroforestry systems were significantly higher over adjacent cultivated field. Among the agroforestry systems, sisso-pineapple and teak-pineapple had higher SOC pool (22.1±1.4, 11.6±1.2, 18.0±4.3, 19.9±2.2 and 71.6±5.8 Mg/ha and 21.8±2.6, 12.2±1.2, 16.4±2.3, 19.4±0.8 and 69.8±1.6 Mg/ha at 0-15 cm, 15-30 cm, 30-60 cm, 60-100 cm and 0-100 cm, respectively), carbon sequestration (615.3 & 551.4 kg/ha/year, respectively) relative to cultivated land (-57.4 kg/ha/year) in the surface layer.

Soil organic carbon pool and fractions under different planted fodder grasses: Plantation of three fodder grasses like hybrid napier (*Pennisetum glaucum* × *P. purpureum*), congosingal (*Brachieria rosenesis*) and combo napier (*Pennisetum purpureum*) and natural grasses increased total organic carbon (TOC) pools by 41.5 to 64.4% over the pools in soils under cultivated field (59.5 Mg/ha) over the 15 years. Soils under natural grasses had higher TOC pool (97.8 Mg/ha) and Walkey and Black carbon (69.6 Mg/ha) pool than those in soils under hybrid napier (84.6 and 61.5 Mg/ha), congosignal (84.8 and 66.3 Mg/ha) and combo napier (84.2 and 64.1 Mg/ha), respectively. Passive carbon pool in soils under natural grass (46.1 Mg/ha) was significantly higher than those in soil under hybrid napier (39.4 Mg/ha), combo napier (38.2 Mg/ha), congosignal (34.9 Mg/ha) and also in arable land (26.8 Mg/ha). The relative proportions of active carbon pools were higher than that of passive carbon pools across the treatments. In general, all the C fractions were higher in soils under grasses than those in soils under arable crops (Fig. 17).

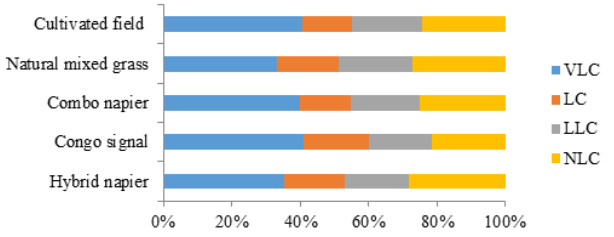


Fig 17. Effect of different grasses on relative proportion of various fractions of SOC pools

Soil organic carbon under mango plantation: The study was undertaken to evaluate the effect of plant canopy of 30 years old mango orchard on horizontal and vertical distribution of SOC. Soil cores were obtained from four depth profiles of 0 - 15 cm, 15 - 30 cm, 30 - 60 cm and 60 - 100 cm and composite soils samples were also obtained from respective systems. The SOC at 1 m distance from plant base ranged from 5.0 from 7.4 g/kg, whereas, with the increase in distance from plant base, the SOC reduced to 4.4-66 g/kg at 3 m and 3.9-5.3 g/kg at 6 m, irrespective of soil depths. SOC was found to be higher near to plant and as distance from plant base increases, SOC start decreasing (Fig. 18). Soil depth also had an effect on SOC content and it was observed that as depth increases SOC content decreases. At 6 m distance from plant SOC content was measured as 5.3 g/kg, 4.8 g/kg, 4.4 g/kg and 3.9 g/kg for 15 cm, 30 cm, 60 cm and 100 cm, respectively.

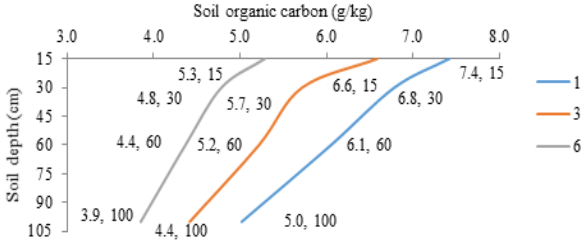


Fig 18. Effect of mango plant of horizontal and vertical distribution of SOC

HORTICULTURE

FRUITS

Rejuvenation techniques of old unproductive mango trees of cv. Himsagar: Rejuvenation of senile mango trees of cv. Himsagar under Tripura condition should be done during 15th December to 15th January; pruning height from the ground may

vary from 2.5 m to 3.5 m or even some time up to 4.5 m depending upon the trunk height. In the present experiment, pruning height of 2.5 - 3.5 m from the ground level was better along with 2 new shoots/ main branch. Two new shoots were allowed to grow to form tree canopy in the successive years. Better twig length and diameter was recorded (4.3 m and 92.8 cm, respectively) in the 5th year in comparison to pruning height 4.5 m with 4 numbers of new shoots/ main branch. Fruit production started from 4th year and in the 5th year, fruit yield was around 42.5 kg/ tree, fruit weight was 200.5 g and TSS was 18.3%.

Top working of old and unproductive inferior fruit quality mango seedlings : Old and unproductive seedling originated mango trees are to be pruned at 2.5-3.5m height during 15th December -15th January. Two- three main branches on the tree trunk are dehorned and all other branches on the trunk are removed. Latent buds sprouts on the bark during March-May. Selected healthy new shoots at the upper part of the dehorned branch were top grafted by wedge grafting method in April-May with scions of cultivars viz., Amrapali, Himsagar and Fazli. Scion shoots should be defoliated on the mother tree 7 days before the grafting operation. Grafting success was around 80-85% and only 2 grafted shoots are selected per dehorned branch and 6 grafted shoots/tree. Cultivar Amrapali starts fruiting in the 2nd year after top grafting. However, fruiting on top grafted Himsagar and Fazli starts in 4th -5th year. Top grafted Amrapali fruit weight was around 160.3 g. Fruit yield increased from 9.5 - 12.5 kg/tree to 43.5 - 47.6 kg/tree. Fruit TSS was around 18.4%. In case of Himsagar fruit yield was 40.6 - 44.5 kg/tree in the 5th year with fruit weight (194.3 g) and TSS (18.3%). However, in case of Fazli, fruit yield was 11.4 - 13.3 kg/tree with fruit weight around 350.5 g and TSS (12.8%). Irrigation was applied just after completion of pruning and basin preparation at weekly intervals @ 100 litres/tree and thereafter @ 200-250 litres/tree at weekly interval till 3rd year and then one month interval during winter - spring season. Fertilizer schedule followed : 50Kg FYM + 800g urea + 800g SSP + 400g MOP in the 1st year, 60Kg FYM + 1.0Kg urea + 1Kg SSP + 600g MOP in the second year, 70Kg FYM + 1.5Kg Urea + 1.5Kg SSP + 800g MOP in the 3rd year, 80Kg FYM + 2Kg Urea + 2Kg SSP + 800g MOP in the 4th year and 90Kg FYM + 2.0Kg Urea + 1.8Kg SSP + 1.5Kg MOP. Application schedule: ½ dose in October-November and rest half in the month of June-July. Regular shoot pruning and thinning was done to regulate the tree canopy. Insects and pests are managed as per the recommended IPM schedule.

Effect of shoot pruning and foliar feeding of nutrients on flowering, fruit set and fruit quality of Litchi under Tripura Condition

On bearing Litchi trees (10-12 years): Shoot pruning and foliar sprays of nutrients: Shoot pruning of 20-30 cm length from the tip of the shoot during 2nd- 3rdweek of June followed by pre-bloom foliar sprays of zinc (0.1%) at one month before panicle emergence + boron (0.5%) at one week before flowering, thereafter, post-bloom foliar sprays of urea (1%) at green fruit stage in first week of April + boron (0.1%) at fruit maturity stage in last week of April has been found to be very much effective for better shoot maturation, flowering, fruiting and higher yield & quality fruits with significantly minimum fruit cracking. However, it is essential to follow the fertilizer schedule of 60 kg FYM, 2.0 kg urea, 1.8 kg SSP and 600g MOP per tree and irrigation at 15 days intervals during fall-winter season and at 7 days intervals during flowering, fruit development and maturity.

All India Coordinated Research Project on Fruits

Augmentation and evaluation of germplasm in mango: Survey was done in the major mango growing areas and 12 local mango germplasms were collected and evaluated their physico- chemical parameters.

Soil nutritional status of mango orchards: A total of 13 orchards/ mango growing sites from 3 districts of Tripura were surveyed and further categorized according to the age viz., 0 - 10 years, 10 – 20 years, 20 - 30 years, 30 - 40 years & above. The major soil attributes were in the range: Soil pH (4.10 – 5.70), Soil Organic carbon (0.61– 1.77%), Available N (136.75 – 385.40 kg/ha), Available P (12.94 – 34.95 kg/ha) and Available K (119.88 – 293.71 kg/ha).

Mango diversity fair: A one-day Mango diversity fair and farmer-scientist interaction meet was organized on 20th June, 2018 at ICAR Tripura Centre. Around 50 types of local and commercial mango varieties were displayed in the exhibition. More than

150 farmers from all the districts attended the fair and also brought mango fruits for display in the fair.

In vitro mass multiplication and conservation of some endangered *Citrus* species of NEH Region of India'

During the reporting period, surface sterilization of the in-vivo seed explants obtained from freshly harvested fruits of Elaichi lemon collected from orchard identified at Hawaibari, Teliamura, Tripura were standardized. In vivo nodal explants and seeds were used for shoot induction and multiple shoot regeneration studies. The maximum 70 per cent shoot induction were observed from the MS media supplemented with 0.5 mg/L BAP. The maximum length of the proliferated shoots varies from 0.17 cm (1.0 mg/L BAP + 0.5 mg/L Kin) to 0.57 cm (control) at 3 weeks after shoot induction. Shoot tips obtained from *in-vitro* grown seedlings of Elaichi lemon with various concentrations of BAP alone and in combinations with Gibberellic acid (GA3) after 50 days of inoculation were used for multiple shoot regeneration studies. The maximum number of shoots/explants was recorded from the media supplemented with 0.5 mg/L BAP i.e., 2.58 with highest mean shoot length of 0.82 cm. The combination of BAP (1.0 mg/L) + GA3 (1.0 mg/L) possessed the highest mean number of shoots/ explants (2.85). The maximum shoot length of (1.21 cm) was recorded from the MS media supplemented with 2.0 mg/L BAP in combinations with 1.0 mg/L GA3 at 50 days of subculture.

VEGETABLES

Improvement of cucurbits along with sustainable production technology

Total 35 genotypes of sweet/spine gourd have been collected and evaluated. Genotypes TSG 9, TSG 12, TSG 21, TSG 25, TSG 28 and TSG 29 were superior in yield and quality. The genotype TSG 29 with maximum yield per plant (6.47 kg/plant) considered as a promising line for yield followed by TSG28, whereas TSG35 recorded lowest yield as compared to all the other genotypes. In addition, all total 39 genotypes of Dolichos bean have been colected and evaluated. All have been found superior with high yield and good cooking quality. Passport data of 17 genotypes have been submitted to NBPGR, New Delhi for issuance of IC number.

Table 4. Best accessions for different genetic parameters

S.N.	Parameter	Range	Accessions of best performance
1	Days to first flowering (days) (short duration)	141.67 - 67.67	TSG 13, TSG 15, TSG 23, TSG 29 TSG-30
2	Fruiting Duration (days)	33 - 106.33	TSG 21, TSG 25, TSG 27, TSG -31, TSG 35
3	No. of fruits/plant	14.33 -123.33	TSG 2, TSG 5, TSG-9, TSG 12, TSG 21, TSG 25, TSG 28, TSG 27, TSG 29, TSG-30
4	Fruit length (cm)	5.46 – 9.57	TSG2, TSG 3, TSG 6, TSG 15, TSG 26,TSG 28, TSG 29, TSG-30, TSG 32
5	Fruit Diameter (cm)	8.07 - 15.13	TSG5, TSG8, TSG 13,TSG 23, TSG 30, TSG 32, TSG 33
6	Fruit weight (g)	34.28 - 158.43	TSG 12, TSG 13 TSG 23, TSG 28, TSG 29, TSG 30, TSG 33
7	TSS (Brix◦)	3.00 - 6.33	TSG 9, TSG -12, TSG 21, TSG – 29, TSG -31
8	Fruit yield/plant (kg)	1.24 – 6.47	TSG 8, TSG 9, TSG 12, TSG 21, TSG 25, TSG 28, TSG 29, TSG 34

Standardization of vegetable based intercropping system for upland conditions of Tripura.

The crop combination *viz.* Vine crops - Bottle gourd and Dolichos/Hyacinth bean, Ground crops Brinjal, Chilli, Peas, Beans, cowpeas, coriander, spinach, carrots during rabi season and Vine crops - Ridge gourd and Sweet gourd. Ground crops - Okra, Cowpea, Brinjal, Chilli, amaranthus for tender shoot, Leafy amaranthus, colocasia and green onion during Kharif season were tried. In the 1st year trial, dolichos bean and bottle gourd at spacing 6m x 3m is favaourable for cultivation of vegetables under its canopy. However, bottle gourd at spacing 4m x 4m is also at par and suitable under Tripura condition. Coriander and spinach can be cultivated two times with good yield. Brinjal var. Singhnath and chilli var. Ojaswi performed better with yield range of 27-28 t/ha and 11-12 t/ha, respectively. However, under open conditions the yield of brinjal and chilli were 29-31t/ha and 13.5-14.5t/ha respectively. Carrot as intercrop performed better under bottle gourd in comparison to Dolichos bean. Intercropping of cowpea, french bean and peas performed well under both the vine crops.

AICRP on Vegetables

Evaluation of bacterial wilt resistant brinjal varieties (AVT-II): Entries: 2016/BRBW-2(345.7 q/ha) and 2016/BRBW-1 (344.5 q/ha) gave higher total yield which was significantly higher than the local checks, TRC Brinjal Laffa (33.2.5 q/ha), Bholanath (323.5 q/ha) and Singhnath (325.3 q/ha). No incidence of bacterial wilt was recorded on these varieties.

Varietal evaluation of leafy vegetables Mastard green (IET): Entries 2018/MGVAR 1 (12.8 t/ha), 2018/MGVAR 5 (11.9 t/ha), 2018/MGVAR 2 (11.7 t/ha) and 2018/MGVAR 4 (10.7 t/ha) gave higher yield even in comparison to the local check (7.5 t/ha).

Varietal evaluation of Radish (IET): Entries 2018/RADVAR 1 (51.4 t/ha), 2018/RADVAR 6 (48.5 t/ha), 2018/RADVAR 2 (48.5 t/ha) gave higher yield in comparison to local check (45.8 t/ha).

AICRP on Tuber Crops

Taro : One colocasia local selection namely Tripura Colocassia-3 with cylindrical oblong corm shape, green semi drooping leaves, moderately resistant to taro leaf blight and yield of 16.8-17.9 t/ha is at advance stage of evaluation. Passport data has been submitted to NBPGR, New Delhi for issuance of IC No. Colocasia IET entries were evaluated under Tripura condition and better performing entries are TTr 17-2 TTr 17-4, TTr 17-5 TTr 17-9, TTr 17-10, Ttr 17-11, TTr 17-12, TTr 17-13 and TTr 17-14. Various insects recorded are Armyworm (Spodoptera litura), Whitefly (Bemisia tabaci) and Aphids (Aphis gossypii) in taro. Imidacloprid 17.8 SL (0.5 ml l-1), Imidacloprid 17.8 SL (0.7 ml l-1) and Dimethoate 30 EC (1.5 ml l-1) were on par and effective for controlling the population of armyworm and aphids; whereas, Thiamethoxam 25 WG (0.5 g l-1) was more effective in controlling the white fly population. Nanma (7 ml l-1) and Neem oil (7 ml l-1) were significantly effective in controlling the sucking type of insects in comparison to control.

Elephant foot yam: Efficient weed management was achieved by treatment of pre-emergence herbicide (1 DAP) + post emergence herbicide at 45 and 90 DAP. Post-emergence herbicide application at 30, 60 and 90 DAP was also very efficient and on par with hand weeding at 30, 60 and 90 DAP. Incidence of collar rot in elephant foot yam was minimized on to 4.0 - 5.2% from 82.4% (in control) by sequential treatment by dipping the corms in 0.1% Mancozeb + carbendazim before storing the corms, then treating the corms in cow dung slurry + Trichoderma @ 5g/kg corm at 3 days before planting, followed by drenching twice with 0.2% Mancozeb + carbendazim after intercultural operations and removal of infected plants carefully and giving an additional drenching application with 0.2% Mancozeb + carbendazim to the surrounding plants. Among the organic treatments, 14.4% incidence was recorded on treatment comprising dipping the corms in 0.7% Nanma (tapioca based biopesticide developed by ICAR-CTCRI) for 10 minutes before storing the corms, then treating the corms in cow dung slurry +Trichoderma @ 5g/kg corm 3 days before planting, followed by application of Trichoderma enriched FYM @2.0 - 2.5 kg/pit at the time of planting, again application of Trichoderma + vermicompost (150-200 g) twice after intercultural operations and removal of infected plants carefully and give an additional application of Trichoderma + vermicompost (150-200 g)) to the surrounding plants.

Tuber crop based IFS : Two tuber crops based farming systems viz., Horti. + agri. + poultry + Fishery

and Horti. + Agri. + piggery. + Fishery and Horti. + Agri. + Piggery + poultry have been established at 6 nos. of Tribal farmers. BC ratio increased to 4.2 after adoption of IFS.

Tuber Crop Festival : One tuber crop festival organized on 21st August, 2018 at Tripura Centre. Around 350 farmers attended the programme and more than 40 types of major and minor tuber crops and around 120 tuber crop based traditional food items were displayed.

Network Project on Organic Farming

Optimization of vermicompost dose for organic brinjal production: An experiment was conducted to identify the optimum dose of vermicompost for organic brinjal production. Thirty days old seedlings of brinjal (Bholanath) were planted at 50 x 50 cm spacing on 21st December 2017 with five levels of vermicompost (0, 2, 4, 6 and 8 tonne vermicompost/ha). Application of vermicompost increased the brinjal yield by 71.2-260.4% (Fig. 19) over control.

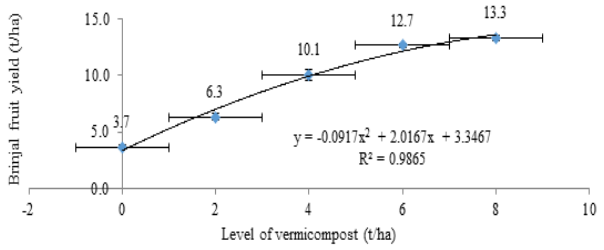


Fig 19. Effect of vermicompost levels on brinjal fruit yield

Okra responses to organic nutrient management system: Okra is an important vegetable crop cultivated in Tripura and has good potential for organic production. However, the management practices for organic production is not available to famers in the state; therefore, a field experiment was conducted to optimize nutrient management practice for organic okra cultivation. Results revealed that fruit yield of okra differed significantly with combined application of organic manures like vermicompost (VC) with agriculture lime (AL) and rock phosphate (RP) (Fig. 20 and 21). Among different organic sources of nitrogen, the treatment 5 t VC/ha + 500 kg AL/ha + 150 kg RP/ha recorded the highest fruit yield (6.8 t/ha) while it was least under control (5.7 t/ha). It has observed that application of RP along with VC increases the yield of okra.

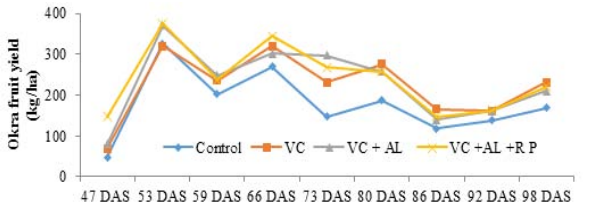


Fig 20. Effect of different nutrient management system on okra yield pattern

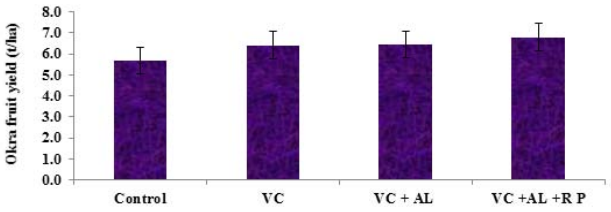


Fig 21. Effect of different nutrient management system on okra yield

Evaluation of rajmash varieties under organic production systems : Seven varieties (SR-2, 3, 4, 5, 6, 7 and Tripura rajmash selection 1) of rajmash were evaluated under organic management system. Among the rajmash varieties, Tripura Rajmash selection 1 (900 kg seed yield/ha) and SR-6 (850 kg seed yield/ha) produced highest seed yield over the other varieties.

SPICES

All India Network Project on Onion & Garlic (AINRP-O&G): IET, AVT-I and AVT-II of Rabi onion

IET: Entries ON 16-39 (24.0 t/ha), ON 16-54 (23.7 t/ha), ON 16-24 (23.3 t/ha) gave significantly higher yield than local checks Bhima Shakti (22.5 t/ha).

AVT-I: Entries ON 15-16 (26.42 t/ha), ON 15-23 (24.6 t/ha) gave significantly higher yield than local checks Bhima Shakti (22.8 t/ha).

AVT-II: Entries ON 15-16 (26.42 t/ha), ON 15-23(24.6 t/ha) gave significantly higher yield than local checks Bhima Shakti (23.4 t/ha).

Storability: Storage studies revealed that percentage of loss in terms of bulb rotting and weight loss were minimum after 2 months of storage in KH M-1 (3.6%), NHRDF Red-2 (7.6%), Bhima Shakti (9.6%), Arka Pragati (9.8%), Arka Kalyan (11.5%), Arka Niketan (11.5%), Arka Kirtiman (12.5%), Pusa Red (12.5%) and Pusa Ratnar (14.5%). Whereas,

maximum storage losses was recorded on varieties/ entries namely PKV White (97.5%) and DOGR-WHY-1 (98.5%) under Tripura condition. After 3 months of storage all most all the varieties recorded maximum loss in the range of 55.5-100%.

Production technology : Results show that treatment of NPKS (100%)+ 10 t/ha FYM + VAM + PSB + Lime gave the highest total bulb yield (35.5 t/ha) as well as marketable yield (34.2 t/ha), bulb weight 110.5g, TSS (11.6%), reducing sugars (3.6%), non-reducing sugars (6.4%), twin bulb + bolters (2.5%), bulb uniformity scoring (8.5) and storage loss after 3 months (35.5%). This treatment was statistically at par with treatment NPKS (75%) + FYM + VAM + PSB+ Lime with marketable bulb yield of 35.3 t/ha. The respective B : C ratio of these treatments were 2.9 and 2.6. Soil pH was raised to around 6.2 from 4.7. Soil organic carbon was also improved from 0.8% to 2.6%.

Onion var. Arka Kalyan was tested for thrips population dynamics. Results showed that at different planting dates starting from 1st September, 2016 to 15th June, 2017 at 15 days interval, thrips population per plant was around 3.6-4.5 in December which significantly increased to the range of 20.4 to 35.5 thrips/plant during 3rd week of January to 2nd week of March with peak population during February (31.3 to 35.5 thrips/plant). However, thrips population decline after March reaching almost nil in April-May. It was observed that under Tripura condition temperature range of 13 – 30^{o}C with dry spell and RH 65-70% favoured rise in thrips population.

Further, total bulb yield (24.3 t/ha) was found to be highest with treatment of Boric acid + $ZnSO_4$ + $CaCl_2$ spray, whereas, under control the marketable yield was only 12.3 t/ha. The same treatment resulted in minimum storage loss (22.5% and 46.5% in 3rd and 4th month of storage, respectively) by rotting, sprouting and weight loss.

FISHERIES

Seed Production under integrated seed-based farming system (ISFS)

The objective of the study was production of stunted fingerling for early market capture thereby ensuring higher returns. All total 10000 nos. fingerlings was produced. Of this, 5000 nos. of fingerling have been distributed among the farmers of Tripura. The remaining 5000 fingerlings will be used for early stocking of farm ponds by stunted fingerling during April-May.

Fig 22. Production of quality fish seed

Fishery based integrated farming system

The objective was to develop an IFS model for intensive fish farming to ensure income and profitability. The area of the pond was 0.16 ha. Standard procedures of pre-stocking pond fertilization using cowdung at 3t/ha and SSP at 30 kg/ ha was carried out 10 days prior to stocking. Water quality parameters were measured in the laboratory following standard methods and maintained at optimal condition. Liming and intermittent fertilization were carried out depending on the productivity status of the ponds. Fish growth was assessed through monthly sampling (25 fish of each species) and the quantity of daily feed was calculated based on the average fish growth with an assumed 80% survival. Stunted fingerling was stocked @ 10,000/ha during April 2018. Supplementary feeding was provided @ 3% of body weight on a daily basis. Culture duration was 8 months. Three harvesting has been done in the period of 8 months. The total production of fishes from the system was 500 kg till December 2018.

The important measures that were adopted to increase the per hectare production of fish are introduction of stunted fingerlings (as carps attain better growth in the second year of their culture), multiple stocking and multiple harvesting (when the fishes attained a size of 500 gms, they were harvested and the same number of fingerlings were restocked) and use of aerators (to enhance the oxygen level of the pond).

Backyard farming system

A Farming system model (Fig. 23) was developed to address the food and nutritional security of landless families. Integration of fish, duck, fruits, vegetables, pulses and spices were done in 300 sq. m area (100 sq. m land area and 200 sq. m pond area).

Fish species incorporated was Indian major carps and Small Indigenous species at a stocking density of 150 fingerling and 2 kg each of mola and puti. Fifteen Khaki Campbell duck were introduced for which a shed was constructed at one corner of the pond. Recycling of nutrients was done through compost pit. In a year, 962 kgs of vegetables and fruits and 35.5 kgs of fish was harvested.

Table 5. Input and Output of backyard farming system

Input	Output
➢ Seed - Self Produced ➢ Fertilization/ Manure - Farm Yard manure by recycling farm residues (100% green) ➢ Water - Recycling of pond water ➢ Workforce - 2-3 hours/ day of unpaid domestic workforce	➢ Multiple multistorey relay of seasonal vegetable ➢ Tuber crops (Colocassia, Yam): 2 times more than family requirement ➢ Spices (Turmeric, ginger, coriander, chilli, pudina, mustard seed, garlic, fenugreek): upto 4 times than requirement ➢ Fruits (Banana, papaya, Guava, Mandarin, Pineapple, Jackfruit, Lemon): Complete Family requirement ➢ Pulses /Dal (Pea, pigeopea, Cow pea, Beans): 1/3rd of family requirement ➢ Fish (Self recruting species with carps): Full family requirement ➢ Eggs & Meat (15 ducks/100 m^2 pond); 6-10 eggs/week: Full Family requirement

Fig 23. Backyard farming system

Floodplain based farming system

A farming system was developed for addressing the areas that regularly gets inundated with water during monsoon season. As the intensity of flood varies, hence the system was developed in two tier system (upper bed and lower bed) so that even if one crop gets fully submerged, there will be still another crop left for the farmer. The height of upper bed from the lower bed was kept at 1 m to ensure that sufficient water was available for the fishes for growth and survival. Rice was transplanted through 3 methods namely, ICM (21 days old seedling was transplanted at 20X20 cm spacing), SRI (12 days old seedlingwas transplanted at 25X25 cm spacing) and conventional methods. In the upper bed, 2 varieties of paddy viz. Hakuchuk-1 and Gomati Dhan was transplanted. In the lower bed, 30 days old seedlings were transplanted at 15X15 cm spacing to avoid total seedling mortality due to complete submergence during heavy flooding. Mixed species of fishes were introduced after 30 days of rice transplantation. Colocassia was planted in one of the plot to provide shade to fishes and also for additional income to the farmer. In the upper bed, maximum yield of paddy (0.51 kg/sq.m.) was recorded with Gomati, closely followed by Hakuchuk (0.49 kgs/sq.m.) under SRI method. In lower bed (conventional method), Swarna gave highest yield (0.24 kg/sq.m.) over Gomati (0.20 kg/sq.m.).

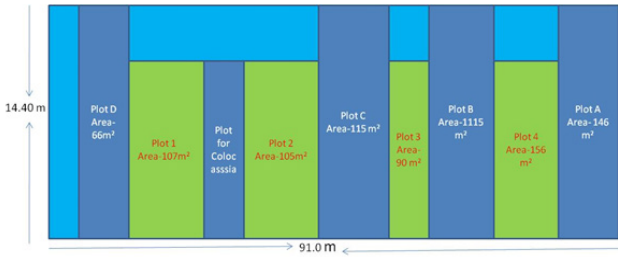


Fig 24. Representative model of Floodplain based farming system

Isolation of *Aeromonas hydrophila* and their specific phages

A total of 117 water samples from two districts of West Tripura and Gomati were used. Twenty one (21) *Aeromonas* spp. And 16 lytic phages specific to *Aeromonas hydrophila* were isolated out of 117 samples (Table 6). These isolates were also further confirmed by PCR targeting 16SrRNA gene and (Fig. 25).

Table 6. Details of samples analysed for isolation of Aeromonads and their lytic phages

Samples	Number of samples analyzed	*Aeromonas* spp. isolated	Number of samples positive for phage
West Tripura water bodies	37	7	6
Gomati water bodies	80	14	10
Total	117	21	16

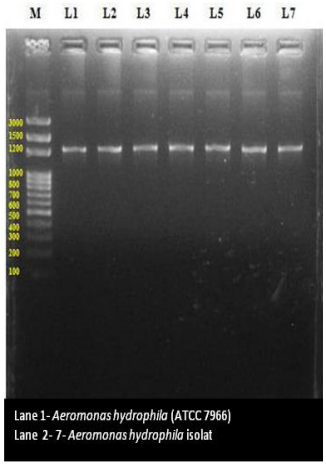


Fig 25. Amplification of 16S rRNA gene for *A. hydrophila*

Fig 26. Sampling locations for Aeromonas and bacteriophages

The phages obtained were tested for their ability to lyse 2 different strains of *Aeromonas hydrophila*. Nine isolated bacteriophages exhibited clear zone at the spotted region on the respective hosts (standard *A. hydrophila* ATCC 7966, Ahw-1) on host bacterial lawn. Propagation of phage was done by using soft agar overlay technique. The purified phages were stored and phage titer value was analyzed by soft agar overlay technique for determining the phage titers by counting the plaques. The titers were found to be in the range of 10^7 – 10^{10}pfu/ ml for the phages.

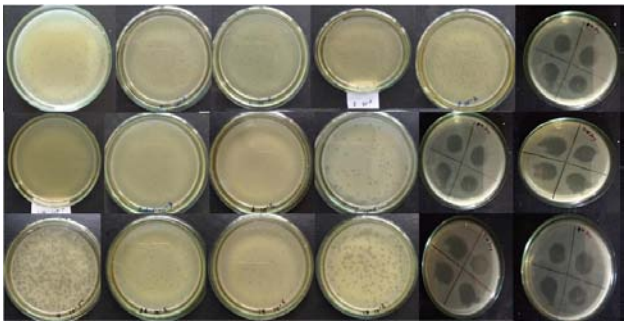


Fig 27. Representative figure for the estimation of phage titre and host range

Habitat Ecology, Productivity, Fish and Fisheries of Rudrasagarlake, Tripura

Assessment of water quality and productivity of Rudrasagar lake was performed. The observed average values of salient water quality parameters of the lake are water temperature: 26.3°C, pH: 6.65, DO: 7 ppm, free CO_2: 8.85 ppm, BOD: 1.68 ppm, alkalinity: 37.3 ppm, hardness: 28.07 ppm , chloride: 14.13 ppm. The mean observed value of nutrients viz., nitrite, nitrate and phosphate were 0.005 ppm, 0.397 ppm and 0.582 ppm respectively. The observed values of primary productivity parameters were gross primary productivity (450 - 833.33 mgC/m³/hr) and net primary productivity (171.87 - 433.33 mgC/m³/hr). The fish fauna was also studied to assess its composition and diversity. A total of 46 fish species belonging to 31 genera, 21 families and 8 orders were observed. The findings revealed that order Cypriniformes contributed 17 fish species belonging to different families viz., Cyprinidae (16 species) and Cobitidae (1 species); order Osteoglossiformes contributed 2 fish species under family Notopteridae; order Perciformes had 12 species under different families viz, Anabantidae (1 species), Ambassidae (2 species), Badidae (1 species), Nandidae (1 species), Gobiidae (1 species), Channidae (3 species), Osphronemidae (2 species) and Cichlidae (1 species); order Siluriformes had 8 species belonging to different

families viz., Clariidae (1 species), Heteropneustidae (1 species), Ailiidae (1 species), Siluridae (3 species) and Bagridae (2 species); order Synbranchiformes contributed 4 species under different families viz., Mastacembelidae (3 species) and Synbranchidae (1 species), order Clupeiformes had 1 species under Clupeidae; order Beloniformes had 1 species under Belonidae order Characiformes contributed 1 species under Serrasalmidae. Out of the total 46 species observed during the study, 33 species were enlisted as least concern (LC), 7 species as near threatened (NT), 1 listed as vulnerable (VU), 1 species listed as endangered (EN), 3 species as not evaluated (NE), 1 species listed as data deficient (DD). The presence of an illegal exotic fish, Piaractus brachypomus (Red bellied Pacu) was observed during the study.

Development of a field guide for identification of striped Mystus catfishes

Striped Mystus catfishes (*M. tengara, M. vittatus* and *M. carcio*) exhibit significant morphological similarity in terms of colouration, fin shape and body size. Existing taxonomic keys to distinguish between these morphologically cryptic congeners pose a real problem in species level identification of live brooders of these species for seed production purposes. A simple morphometry based field identification guide was developed to circumvent this issue for brood stock selection at species level just using a ruler (Fig. 28).

It was also observed that the species hitherto classified as *Mystus carcio* includes at least two reproductively isolated sub groups that differ with respect to body morphometrics clearly discernible in N-means clustering. The ratio of distance between the dorsal fins to base length of adipose dorsal was significantly different ($p \leq 0.05$) between the two clusters. This ratio was consistently ≥ 3.0 in one of the clusters and < 3.0 in the other (n=30; k=2). In addition, the shape of the posterior end of the adipose dorsal fin was observed to differ between the two groups. While the posterior terminus in the first cluster remained in contact with the body profile, it was free and detached at the posterior extremity in the latter cluster. The Cytochrome oxidase1 (COI) nucleotide sequence between the two groups exhibited consistent variability at 3 positions (+116bp, +465bp, +482bp) indicating genetic level differences.

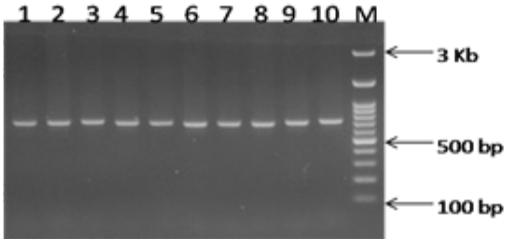
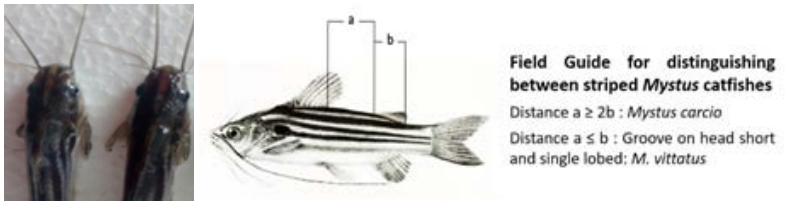


Fig 29. PCR amplicons of mitochondrial Cytochrome c Oxidase 1 gene; Lanes 10 : PCR amplification products showing bands at expected size; Lane M: 100bp DNA Ladder

Characterization of key genes involved in nacre secretion process in *Lamellidens marginalis*

Partial nucleotide sequence characterization of five genes involved in the shell biomineralisation process in *Lamellidens marginalis* has been performed. All the partially characterized sequences exhibited homology to the relevant genes from bivalve molluscs (Table 7) indicating the specificity of the sequences. Additionally, the partial cDNA sequences exhibited maximum similarity to relevant genes from known nacre secreting bivalves. Functional knockdown of these sequences *in vivo* will help elucidate the exact role of these genes in nacre secretion potential of *Lamellidens marginalis*.



(A) **(B)**

Fig 28. Field Guide developed for distinguishing between the striped Mystus catfishes *(M. vittatus, M. tengara and M. carcio)*. (A) Dorsal portion of the head of *M. tengara* (left) and *M. vittatus* (right) showing relative sizing of fontanelle groove and (B) Schematic representation of morphometric measurements required

Table 7. Partial characterization of five genes of *Lamellidens marginalis*

Gene Characterized	Size of sequence (bp)	Reported sequence to which maximum similarity exhibited	Degree of similarity* (%)
Lmar-Pif	247	*Crassostreagigas* Serine-threonine protein phosphatase6 subunit 3 (XM_022436611.1)	78
Lmar-Calreticulin	222	Hyriopsiscummingii Calreticulin (JX416227.1)	95.05
Lmar-Beta actin	548	Hyriopsiscummingii Beta actin (HM045420.1)	92.15
Lmar-Chitin synthase	511	Hyriopsiscummingii chitin synthase (KR149328.1)	98
Lmar-Calmodulin	168	Hyriopsisschigelli Calmodulin (FJ194962.1)	96.49

*Sequence similarity above 60% is considered acceptable level of indication of homology

Development of bio-piscicides for sustainable aquaculture

Indigenously available plant species were surveyed, collected, processed and tested for the piscicidal properties against a weed fish, *Puntius sophore* through static bioassay. Aqueous extracts (1:5) of the *Moringa* leaves and barks, Tea leaves, Champak barks, Chinaberry seeds and *Glycyrrhiza* leaves evaluated. The 24h LC_{50} and 48h LC_{50} were estimated 324.3 ml/L and 288.8 ml/L, respectively using *Moringa* leaves, 315.7 ml/L and 297.0 ml/L using *Moringa* bark, 10.9 ml/L and 8.6 ml/L using Tea leaves. 336.8 ml/L and 296.9 ml/L using Champak bark, 222.7 ml/L and 135.6 ml/L with Chinaberry seeds and 203.3 ml/L and 154.5 ml/L with *Glycyrrhiza* leaves.

Thermal tolerance limits of *Amblypharyngodon mola* (molacarplet)

Critical thermal maximum (CT_{max}) was increased from 32^{0}C to 34^{0}C, critical thermal minimum (CT_{min}) from 16^{0}C to 18^{0}C and oxygen consumption rate in fish from 28 mg to 38 mg with increase of acclimation temperature from 26 to 32^{0}C in the fish of 1.2-2.9 g. Temperature quotient (Q_{10}) was 1.66 at 26-28^{0}C, 1.36 at 28-30^{0}C and 1.54 at 30-32^{0}C. The results indicate that *A. mola*is more resilient to thermal stress if acclimatised at 28-30^{0}C (Fig. 30 and 31).

Fig 30. Experimental fish (*A. mola*)

Fig 31. Thermal tolerance study using polystyrene boxes and thermostats

POULTRY

AICRP on Poultry Breeding (Rural Poultry Production)

Evaluation of mean performance of different poultry germplasms: The mean performances of different poultry germplasms including BND Cross (Dual type) are evaluated at institute farm. Growth performance of coloured broiler was found to be superior over other germplasm.

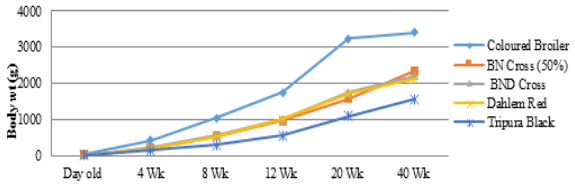


Fig 32. Mean performance of different poultry germplasms at Institute farm

Table 8. Production performance of different poultry germplsm

Traits	Tripura Black	Dahlem Red	Coloured Broiler	BN Cross (50%)	BND Cross (Dual type)
ASM (Days)	176	158	165	169	160
E.P. upto 40 wk	38.10	61.50	35.48	36.30	50.24
E.P. upto 52 wk	70.93	111.45	63.58	66.24	89.90
Egg wt at 40 wk (g)	38.89±.57	53.18±.61	59.57±.67	50.89±1.01	53.20±0.87

Evaluation of fertility and hatchability of different chicken germplasms : A total of 28706 chicks of different breeds / varieties / lines were hatched out at 21st day. Estimation of fertility, hatchability on fertile eggs and hatchability on set eggs were calculated. Overall average percent fertility was estimated 77.06% in different breeds/varieties/lines of chicken. The highest percent fertility was found in Coloured broiler Commercial (85.53%) and lowest percent fertility was found in Tripura Black (74.13%). The overall average percent hatchability on total egg set (TES) and fertile egg set (FES) were estimated as 60.83% and 78.94%, respectively. The highest hatchability on total egg set (TES) and on fertile egg set (FES) was found in Coloured broiler commercial (66.70) and BN cross (82.20%) respectively. The lowest hatchability on total egg set (TES) and on fertile egg set (FES) was found in Dahlem red (56.03% and 71.50%) respectively.

Table 9. Fertility and Hatchability of different chicken germplasms

S.N.	Breed/ Variety/ Strain	Total no of eggs set	No of fertile eggs	Fertility (%)	Total no of Chicks hatched	Hatchability (%)	
						Fertile eggs set (FES)	Total eggs set (TES)
1.	Dahlem Red	4003	3137	78.4	2233	71.5	56.0
2.	Coloured Broiler (Commercial)	802	686	85.5	535	78.0	66.7
3.	Coloured Broiler (Dam line)	9487	7874	83.0	6086	77.3	64.2
4.	Tripura Black	15652	11604	74.1	9446	81.4	60.4
5.	BN Cross (50%)	2588	2034	78.6	1682	82.2	
6.	Dual type (BND)	14653		75.3	8724	79.1	59.5
TOTAL		**47185**	**36363**	**77.1**	**28706**	**78.9**	**60.8**

Dissemination of knowledge on backyard poultry production through training and meeting: All total 5 training and 3 meeting programmes were organized covering 338 tribal farmers on backyard poultry farming at different villages of Tripura. In each meeting fruitful discussions were held with the farmers about their problems and solutions were suggested.

Fig 33. Joint Director, ICAR, Tripura Centre addressing to farmers during training

Fig 34. Student visit at ICAR- Poultry farm

ANIMAL SCIENCE

Image based systems for identification of individuals, breeds and diseases of pigs and goats (Image IDGP under ITRA)

The project was initiated with the objective to identify and image which alone or in combination, unique to individual animals, capture images of unique traits using minimal optical facilities and transmission, storage and use of unique identification data. During the period image of candidate traits in goats and pigs viz. Iris, retina, nose, inside of ear and tail, snout, muzzle, facial and body contours were recorded as per the protocol standardized by the Govt. Engg. College, Kalyani. In addition, a set of morphometric parameters were collected from Black Bengal goat and Mali pig at 15 days interval and regularly transmitted to lead centres for analysis. Data of more than 50 goats and pigs were collected for different breeds for individual identification. Rules for different type of image were standardized for capturing unique image. Images for the said traits were captured at a regular interval after standardization to find uniqueness of venation pattern over the age.

Table 10. Morphological Parameters of Mali Pig

Age group	No. of animals	Body weight (kg)	Head length (cm)	Shoulder width (cm)	Heart girth (cm)	Head width (cm)	Muzzle diam. (cm)	Neck length (cm)
1 y	7	31.41	21.86	7.36	62.71	12.57	20.43	8.21
1 y 15 d	6	31.71	22.00	7.50	68.33	12.50	19.83	8.17
1 y 1 m	3	29.67	21.33	7.00	65.00	14.33	7.33	9.00

Age group	Nos. of animals	Body length (cm)	Paunch girth (cm)	Height @ wither (cm)	Height @ rump (cm)	Corpus length (cm)	Rump length (cm)	Tail length (cm)
1 y	7	72.14	67.96	37.14	38.71	60.86	12.86	18.71
1 y 15 d	6	67.50	69.33	41.67	43.00	61.67	12.83	18.83
1 y 1 m	3	65.00	65.00	45.33	47.67	61.00	9.33	18.00

Age group	Nos. of animals	Pelvic width (cm)	Ear length (cm)	Ear distance (cm)	Muzzle length (cm)	Muzzle width (cm)	Distance bet eyes (cm)
1 y	7	11.71	8.57	9.00	5.00	7.64	8.57
1 y 15 d	6	11.83	8.40	9.25	4.75	5.50	8.22
1 y 1 m	3	15.00	8.33	8.00	5.33	5.67	8.67

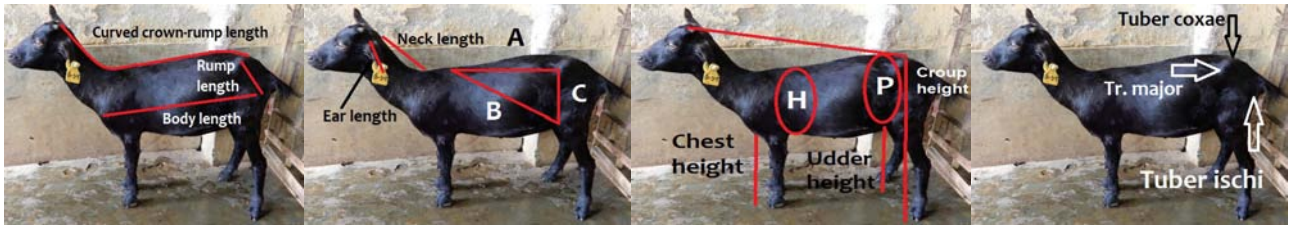


Fig 35. Morphometric measures of Black Bengal Goat

Performance of Murrah buffalo under Tripura condition

Aiming at exploring the prospects of buffalo in Tripura, indigenous Murrah buffalo has been brought from Rohtak of Haryana to ICAR-Tripura Centre to investigate the performances of Murrah buffaloes in Tripura agro-climatic conditions. At present, there are 16 buffaloes including 5 calves (4 female and 1 male) at livestock farm. The highest lactation yield for 305 days was 1602.95 litres with the highest peak milk production of 11 liters per day during 2018. At farm conditions, buffaloes showed estrus throughout the year, but in many places a seasonal pattern of ovarian activity has been reported. The signs of estrus in buffalo were less clear than in cattle and homosexual behavior between females was absent. Though silent heat feature in Murrah buffalo was recorded at farm, bull parading detected estrus in she buffaloes at farm. The Buffaloes were vaccinated against FMD, Haemorrhagic septicaemia and dewormed periodically and there was no incidence of diseases.

NATIONAL INNOVATIONS IN CLIMATE RESILIENTAGRICULTURE (NICRA)

Analysis of rainfall and temperature data of NE for assessment of climate change

Detecting trend and magnitude of change in district level rainfall and temperature of NE India

Pattern of Annual Rainfall: The annual rainfall at a temporal interval of 30 years was studied for entire NE region, including Sikkim, using 0.25^0x0.25^0 gridded data (Fig 1). The study reveals that mean rainfall does not vary much among different time periods. But the range increased distinctly, from 1255-2855 mm (1901-1930) to 1226-5162 mm (1991-2015). The trend of rainfall reversed in every temporal cycle and at present it is showing a negative trend, though not significant. But, the most important change is happening in case of coefficient of variation (CV, %). The CV increased by almost 2 fold, from 14.7% in 1901-30 to 27.8% in 1991-2015. It is indicating more and more uncertainty associated with rainfall leading to frequent occurrence of drought and floods.

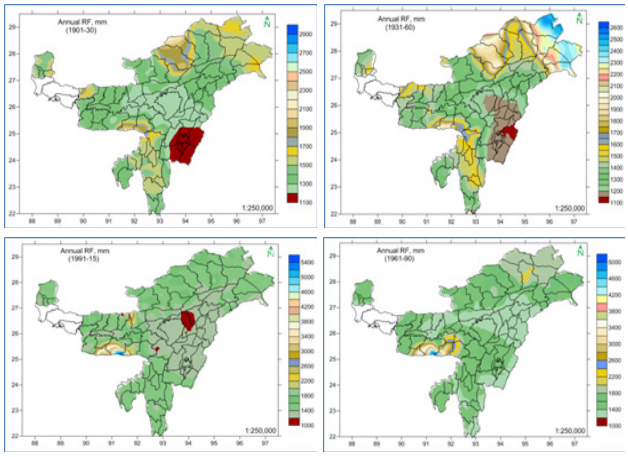


Fig 1. Trend of annual mean rainfall in the North Eastern region (1901-2015)

Pattern of Seasonal Rainfall: Rainfall pattern was studied in relation to different seasons. Average rainfall during the monsoon season is decreased by almost 115 mm during 1991-2015, compared to 1931-60 levels. It indicates increasing level of water stress during the main crop period. On the other hand the present period (1991-2015) is experiencing an increasing trend of rainfall during the summer season.

Seasonal Rainfall Distribution: Except in the summer season, all other seasons experiencing a drop in numbers of rainy days, which is very much spectacular during the monsoon. A drop of almost 4 rainy days has been noticed during monsoon in the recent period.

Pattern of Annual Mean Maximum Temperature:

The region is experiencing a statistically significant increase of annual mean maximum temperature. Data (1^0x1^0grid) analysed between 1951-90 and 1991-2015 has shown an increase of 0.2^0C in maximum temperature in the recent period. The annual mean maximum temperature of the region at present is 29.2^0C. The increasing trend of maximum temperature during 1951-90 was highly non-significant, but the same trend become highly significant (at 1% level of probability) during 1991-2015. At present annual mean maximum temperature is increasing @ 0.04^0C per annum. Increase in maximum temperature may lead to increasing level of day time heat stress of the crops along with high level of evaporation loss.

Pattern of Annual Mean Minimum Temperature:

The annual mean minimum temperature exhibited a highly significant decreasing trend during 1951-90, but that was reversed during 1991-2015, though not significant. The annual mean minimum temperature, at present, is increasing @ 0.01^0C per annum. The increase of night time temperature is associated with increasing level of respiration and high yield loss.

Long period wetness periodicity assessment using wavelet analysis:

Periodicity of wetness events were evaluated from long term rainfall observations in Kolasib (1986-2016). The wetness events were characterized in terms of Standardized Precipitation Index calculated over 1 month (1-SPI), 2 months (2-SPI), 3 months (3-SPI), 4 months (4-SPI), 6 month (6-SPI), 12 months (12-SPI) and 24 months (24-SPI) time domain (Fig 2). There are no significant long persisting periodicity for short term wetness events expressed by 1 SPI series and some discrete events 2 SPI series (winter

wetness). The 64 months periodicity towards the middle of the series from 1995 till 2005 was evident for agricultural wetness as expressed by 3 SPI, 4 SPI and 6 SPI series. For hydrological wetness (12 SPI and 24 SPI), 32-64 months periodicity was evident over the entire study period.

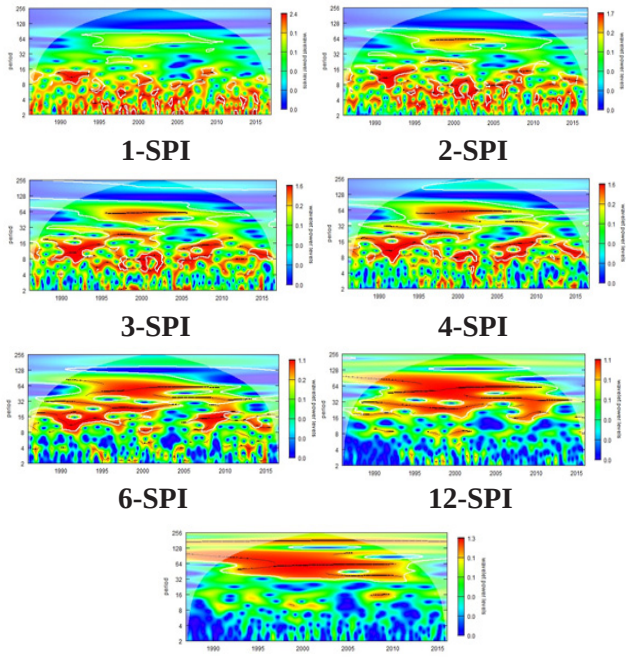


Fig 2. Long term periodicity assessment of seasonal wetness time seriesat Kolasib (1986-2016)

Seasonality analysis and entropy evaluation over thirteen rain gauge stations in Mizoram

Long term trend in seasonality pattern and rainfall entropy was evaluated for thirteen rain gauge stations across Mizoram over past 30 years. A significant decrease in entropy with concomitant increase in rainfall seasonality was evident at Champhai, Serchhip, Bilkhawthlir, Saiha,Lunglei, Sialsuk and Neihbawih station. For Aizawl and Lawngthlai, the changes in seasonality behavior were significant but not the degree of randomness. The precipitation distribution pattern as expressed in terms of Precipitation Concentration Index (PCI) showed variable trend. The wet period PCI (April to October) showed a significant increase at Serchhip, Bilkhawthlir, Saiha and Lunglei.

The linear regression plot for consecutive derived rainfall indices values showed a strong correlation with locational specifics, particularly expressed by latitude observation. The latitude of the rain gauge stations was inversely proportionate with the respective seasonality index and fulcrum or center of gravity values. In contrast, the rainfall return period and absolute entropy values of showed the proportionate increase in the regression plot. However, no statistically significant correlation was observed for the longitude and altitude information of the respective rain gauge stations.

Daily extreme event analysis over North East India using R Climdex model:

For extreme event analysis, the daily weather data of 33 weather stations were procured from IMD, Pune and analysed the dataset for assessing the trend in weather extreme event occurrence across north eastern India. The assimilated trend analysis report confirmed a variable degree of increase in average annual mean of maximum and minimum temperature but with variable degree of statistical level of significance. Annual summer days with maximum temperature >25^{0}C occurred more frequently at Imphal (Manipur); Cherrapunjee and Shillong (Meghalaya); Kohima (Nagaland); Guwahati, Lakhimpur and Dibrugarh (Assam) during the study period (1969-2017), while decreased at Gangtok (Sikkim), Agartala (Tripura) and Tangla station (Assam) of NE India. The occurrence of cool nights decreased significantly at the majority of surface weather stations except Aizawl (Mizoram). The annual counts of tropical nights has increased at Aizawl (Mizoram), Imphal (Manipur), Kailashar (Agartala), Tangla and Tezpur (Assam) station in north east India. We observed for the recorded changes in daily weather pattern as percentage of days when minimum temperature Tn>90th percentile i.e. warm nights and percentage of days when maximum temperature (Tx) >90th percentile i.e. warm days, in majority of the stations like Imphal, Shillong (Meghalya), Agartala and Kailashar (Tripura); Guwahati, Dibrugarh and Tezpur (Assam) etc. For Gangtok (Sikkim) and Tangla (Assam) station, the occurrence of warm nights has increased with consecutive reduction in number of warm days. Warm spell is significantly increasing in the majority of the surface stations of NE India (except: Chaparmukh and Tangla from Assam, Aizawl from Mizoram, Kohima from Nagaland and Gangtok from Sikkim). Significant increase in cumulative dry days

(CDD) were evident at Aizawl (Mizoram), Imphal (Manipur), Cherrapunjee and Shillong (Meghalaya). In contrast, a successive increase in Consecutive wet days (CWD) were significant at Chaparmukh and Tangla (Assam).

Identification of abiotic stress tolerant rice, maize and tomato for NE Hill ecosystem

Identification of major QTLs for grain yield under drought stress in rice of North East region for use in marker assisted breeding

Drought screening completed for 2178 upland and lowland rice. Identified promising rice genotypes for higher yield under drought stress. Developed 6 mapping populations by crossing drought tolerant lines from NEH: Bhalum 3, kataktara and Phulbadam with Swarna and Naveen for drought QTL studies, which are presently in F6. Drought phenotyping and whole population genotyping of 311 RILs of the Mapping population CT 9993-5-10-1-M/2*SAMBHA MAHSURI is completed with 286 SSR markers. Data analysis for QTL is continuing. Parental polymorphism survey and genotyping of the Bhalum 3 x Naveen mapping population (811 RILs) is ongoing.

Several entries from the material generated under NICRA were promoted to AVT1 and AVT2. One of the entry - TRC 2015-12 / IET 25662 (Naveen x Kataktara) has qualified for CVRC VIC proposal in Aerobic trials in 2018 (Table 1 & Fig 3). Entries from NICRA material which are promoted in different trials are presented below. Performance of the promoted entries and the entry qualified for VIC proposal is presented below.

Table 1. Performance of TRC 2015-12 / IET 25662 (Naveen x Kataktara) has qualified for CVRC VIC proposal in Aerobic trials in 2018

Year of testing	Name of the trial	No. of locations tested	Proposed variety IET 25662	NC	RC	LC	IET 25610	IET 25647
2015	IVT-AEROB	7	4464	3814	3846	3763	4016	4083
2016	AVT-1 AEROB	9	4922	4056	4069	4253	4618	4174
2017	AVT-2 AEROB	11	4360	4558	4313	3841	4450	4342
Weighted mean			4574	4197	4110	3958	4393	4218
% increase of over	2015			17.04	16.06	18.62	11.15	9.33
	2016			21.35	20.96	15.73	6.58	17.92
	2017			-4.35	1.08	13.51	-2.02	0.41
% increase of over Weighted mean				+8.98	+11.28	+15.56	+4.12	+8.44

Fig 3. TRC 2015-12 / IET 25662 – field view, paddy and milled rice

Nagaland centre also evaluated 990 lowland rice lines and 250 upland rice germplasms for drought tolerance during 2018. Rice lines and germplasms were grown in both drought and normal situations and evaluated for drought tolerance parameters such as leaf rolling score, drought score and RWC at reproductive phase. Experiment was conducted using Sahbagi dhan upland rice variety as a national drought tolerant check. The Soil moisture status was determined at an interval of 5 days.

Based on leaf rolling score, drought score and RWC, 15 upland rice germplasm have performed better than check variety Sahbagi dhan under drought situation. Among upland germplasm, the following 8 genotypes (Table 2) have shown better performance as compared to check variety Sahbagidhan under drought situation.

Table 2. Yield estimates of genotypes under drought situation

Sl.no	Name of germplasm	Yield (q/ha)	Sl.no	Name of germplasm	Yield (q/ha)
1	Marichitpi	54	6	Teke	41
2	Leimphou	51	7	Roshalha	40
3	Kemenya	47	8	Bacheri	39
4	Mekhrilha Kecha	44	9	Sahbagidhan (Check)	27

Physiological Characterization for Drought Tolerance Traits in Rice

Association of shoot and root traits with grain yield in rice under irrigated and reproductive drought stress conditions

For this study, nine rice genotypes belonging to three different groups (I, II, III) were identified from the previous experiment. Group-I representing germplasms exhibiting high root to shoot ratio and high grain yield *viz.* TRC-2015-10, TRC-2015-17, Nagina-22, Tripura Chikan Dhan, Naveen; Group-II representing germplasm exhibiting low root to shoot ratio and high grain yield *viz.* TRC-2017-7, Bhalum-3 and Group-III representing germplasm exhibiting low root to shoot ratio and low grain yield *viz*. TRC-2013-14, TRC-2017-39 were subjected to drought stress at reproductive stage by withholding water at 45 DAS for 20 days and a detailed studies on root and stomatal traits were carried out. The salient findings of this study are presented as below:

- Under stressed condition, Naveen, Nagina-22 and Tripura Chikan Dhan showed sustained root growth, Bhalum-3 and TRC-2015-17 showed good stress recovery. Root volume was reduced in all the germplasm studied except for Naveen and stress recovery was observed in TRC-2015-17, Tripura Chikan Dhan, Bhalum-3 and Nagina-22. Similarly, Naveen, Nagina-22 and Tripura Chikan Dhan showed good stress recovery in terms of root biomass.
- Under stressed condition, at 0-15 cm soil depth, Bhalum-3, TRC-2015-17, Naveen, Nagina-22 and Tripura Chikan Dhan showed high root volume; root length density (RLD), surface area and minimal changes in average root diameter as compared to the non-stressed plants (Fig 4). Whereas, at 15-30 and 30-45 cm depths only Naveen and Tripura Chikan Dhan were least affected by stress.
- In response to stress, reduction in number of stomata per field of view (FOV) was observed in TRC-2013-14, Bhalum-3, Nagina-22, TRC-2017-7, Naveen and Tripura Chikan Dhan, whereas, an increase in number was observed in TRC-2017-39, TRC-2015-17 and TRC-2015-10 (Fig 5).

Minimum grain yield reduction noted in case of TRC-2015-17, Bhalum-3, Naveen, Nagina-22 and Tripura Chikan Dhan may be attributed to innate stress recovery capacity in these genotypes in terms of root traits. Besides, RLD and average root diameter at 0-15 cm could be important for drought screening, given the efficiency of water extraction by long and fine roots. Additionally, screening of genotypes for reduced number of stomata will be important as such feature will enable plants to reduce the transpirational water loss, thereby, improving the plant water status.

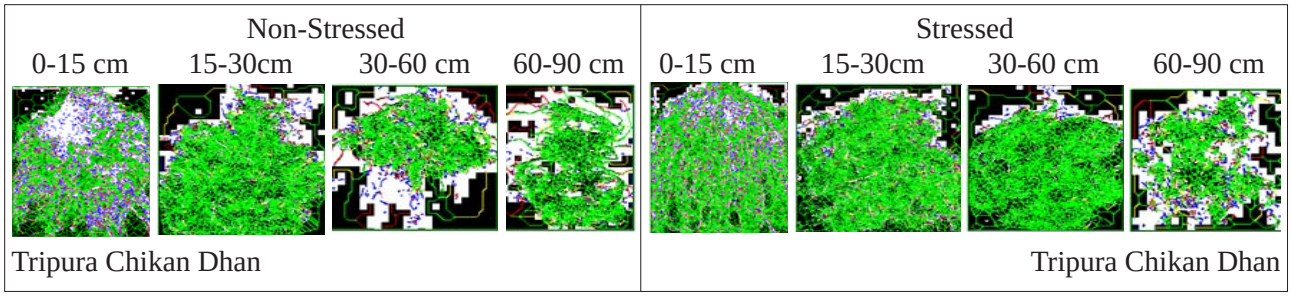
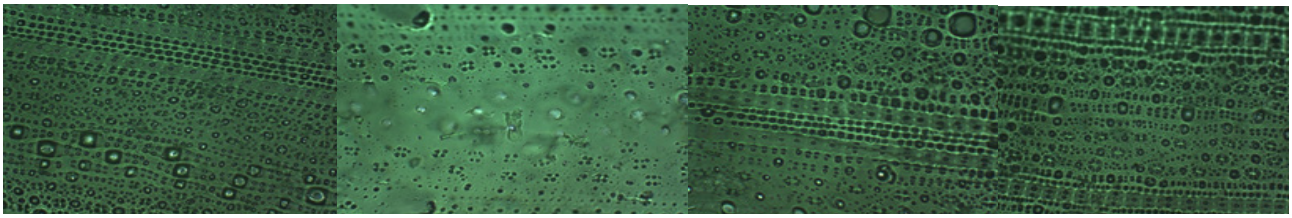


Fig 4. Representative root scanning images showing depth-wise root distribution in germplasm exhibiting drought stress recovery



Tripura Chikan Dhan (Non-Stressed) | **Tripura Chikan Dhan (Stressed)** | **TRC-2015-17 (Non-Stressed)** | **TRC-2015-17 (Stressed)**

Fig 5. Representative images showing reduction or increase in stomatal number in response to drought stress (400 X magnification)

Drought phenotyping of indigenous rice germplasm collected from North East India

Reproductive drought stress phenotyping of 368 rice germplasm collected from North East India were carried out based on morpho-physiological and yield parameters. Significant variation were observed in plant height, SPAD index, leaf rolling score, flag leaf area, harvest index, upper ground biomass and yield per line. Cluster analysis based on these parameters revealed five cluster groups (Fig 6). Among these clusters, the germplasm belonging to cluster group 1 (C1) *viz.* Dzuku Nya, Temesung Tsuk, Mapok Tsuk, Aohah, Nukayie, Shangya, Tzuti Sangtsuk, Helipong, Dyong, Hakuchuk-2, 119, Dilong (White), JumViron, 31 and TRC-2014-8 could be grouped as tolerant genotypes exhibiting higher SPAD index, flag leaf area, yield, harvest index and lower leaf rolling score. These germplasm could be further evaluated to ascertain its utility as a donor for drought breeding.

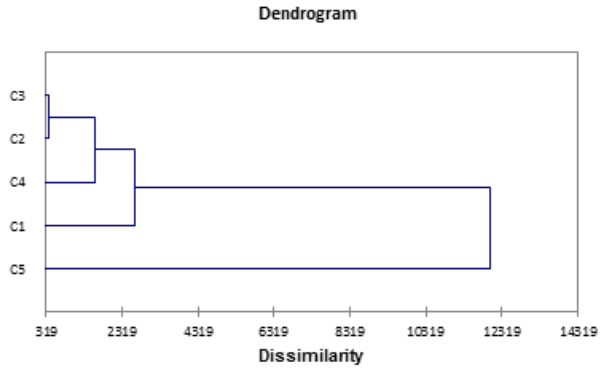


Fig 6. Cluster analysis of 368 rice germplasm based on the observed values of plant height, number of tillers, number of effective tillers, SPAD index, leaf rolling score, flag leaf area, harvest index, upper ground biomass and yield per line under reproductive drought stress

Identification of Rice Genotypes Tolerant To Heat Stress

Performances of rice genotypes for various morphological and physiological traits under ambient and elevated temperature were recorded. With respect to spikelet fertility (%) TRC-2016-301 (94.57%) followed by RCM-19 (93.32%), RCPL 1-190 (93.17%), TRC-2016-321 (92.74%), TRC-2016-8 (92.47%), NDR-97 (92.02%) and PANKANG (91.88%) were the high performers under elevated temperature. A set of heat responsive rice germplasm namely, MEETU-6, MANIPUR, SAKURD, DAYA, RCM-17, TRC-2016-301, TRC-2016-413, TRC-2016-515, TRC-2016-33 and TRC-2016-420 genotype were selected based on yielding ability in elevated temperature. These lines were used for crossing with heat sensitive genotypes (TRC-2016-413 and TRC-2016-420) as well as check genotypes (Bhalum 1, Bhalum 3 and Bhalum 5, Megha SA-2, Ngoba and Mynri and Nagina-22) with an objective to get the superior lines from segregating generation *vis-a-vis* mapping of the genes responsible for heat tolerance. The F_1s were grown under CTGC during February as off season crops. The F_2 generation will be evaluated in *Kharif* 2019 for their response under both elevated and ambient temperature.

Investigations on heat adaptive traits of rice genotypes for identification and selection of protein biomarkers under elevated temperature

Selected rice genotypes (46 nos.) were screened in CTGC under ambient and elevated (+3 ^{0}C ambient) temperature conditions. The ambient temperature varied between 20.7 and 27.5^{o}C and the elevated temperature varied between 24.2 and 30.6 ^{o}C. The average crop growth temperature in the CTGC and the descriptive statistics of yield performance under elevated temperature is shown in Table 3.

Table 3. Descriptive statistics of trial under elevated temperature

	Count	Min	Max	Mean	SE	SD	Variance	Kurtosis	Skewness
SPAD Index	45	26	45.43	36.84	0.61	4.11	16.85	-0.01	-0.16
Height (cm)	46	30.67	106.67	72.72	2.96	20.06	402.40	-0.50	-0.34
Tiller no	46	2	6.67	4.33	0.17	1.15	1.33	-0.60	-0.04
Effective Tillers	46	1	5	2.20	0.17	1.13	1.28	-0.47	0.73
Biomass	46	2	23.33	10.84	0.72	4.87	23.72	0.27	0.56
100 SW	46	1.1	2.66	1.86	0.05	0.36	0.13	-0.26	0.17
Yield plt^{-1}	46	0.08	5.76	1.91	0.21	1.45	2.09	0.25	1.06

Source-Sink studies in leaves and grains

Three pre-screened genotypes viz. RCPL-1-185, RCPL-1-409 and RCM-17 were selected for evaluating the source-sink relationship under ambient and elevated temperature conditions. Leaves were sampled at 7 DAA, 14 DAA, 21 DAA, and developing grains were sampled at 30 DAA, respectively. Active starch accumulation and reduced sucrose content is observed in leaves of RCPL-1-409 with increase in days after anthesis under elevated temperature conditions with respect to control (Fig 7). Starch synthesizing AGPase activity is also more or less maintained in RCPL-1-409 and RCM-17 under elevated temperatures, and starch synthesized is mostly stored as transient starch.

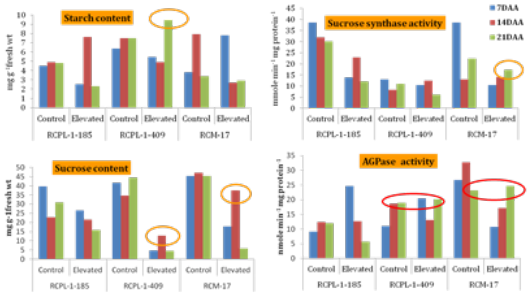


Fig 7. Source activity in leaves under control and elevated temperature during grain filling period

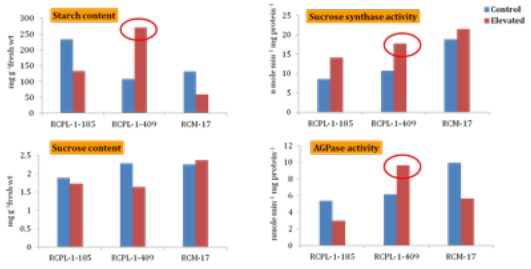


Fig 8. Sink activity in grains at 30 DAA under control and elevated temperatures

Under elevated temperature, a higher sink activity was observed with sucrose synthase-mediated breakdown of sucrose in all genotypes (Fig 8). A higher starch synthesizing AGPase activity in RCP-1-409 is observed under elevated temperatures, and this is supported by parallel higher starch content at 30 DAA. Correlation studies show that in leaves, the initial periods of sucrose accumulation post anthesis positively determined its subsequent accumulation with increase in days after flowering under both control and elevated conditions. Source AGPase activity in leaves showed high positive correlation with sink AGPase activity in grains. A higher leaf AGPase activity resulting in leaf starch accumulation as transitory starch is a significant metabolic trait contributing to higher grain starch under elevated temperature.

Identification of submergence tolerant rice for NER

Rice genotypes (18 nos.) were screened after keeping under full submergence condition for 12 days at different growth stages of the crop (i.e. seedling stage-upto 25 days; tillering stage-upto 45 days; booting stage-upto 80 days; seedling + tillering stage). At seedling stage, all the rice genotypes were kept under full submergence condition in polythene lined earthen pond for 12 days. Genotypes such as Moirangphou, Tamphaphou, Ahutnei and Taothabi exhibited better response relative to other genotypes when compared with control (no submergence). At tillering stage, after 12 days full submergence, genotypes viz. RC Maniphou-11, Akutphou and Yungramakrei performed better in comparison to other genotypes. Similarly, when 12 days full submergence was done in both seedling and tillering stages, genotypes viz. Langphou, LangphouAngam

and Langphouangouba could not survive. Genotypes such as Yungramakrei, Moirangphou, RC Maniphou-7 gave better performance as compared to the control. Finally, when full submergence was done for 12 days at booting stage, most of the genotypes could not survive and those survived gave very poor yield. Genotypes such as Taothabi, Akutphou and RC maniphou-6 performed better when compared with control.

Heat Tolerant Maize Genotypes for North East Region

A set of 106 maize genotypes representing all the states of North East India were assembled based on the superiority. The set was evaluated extensively for tolerance to heat stress. The genotypes were grown in both ambient and elevated (+3^{0}C ambient) temperatures and the data was recorded for yield contributing traits, yield and physiological traits. In general, data on plant height, number of kernel rows/ ear, number of Kernel /rows, 100 kernel weight (g) and plant yield were recorded. As far as yield per plant is concerned, RCGMP 73 (79.0 g) followed by RCM 1-61 (61.9 g) ME 29 (61.3 g) and ME-31 (60.6 g) have shown their superiority in elevated temperature conditions (Table 4 & Fig 9). SPAD index was higher in MZ-4 (56.70) followed by Ma-7(51.20), Ma-16(49.95), Ma-17(49.10) and Ma-8 (48.80) in elevated condition.

Table 4. Lines with high performance under elevated temperature

Genotypes	Height of Plant (cm)*	No of kernel rows/ear*	No of Kernel /rows*	100 kernel weight (gm)*	Grain yield/ plant(g)
RCM 1-75	306.7	5.0	6.0	19.0	50.0
HEMANT	305.0	8.3	13.7	26.3	52.7
ME-31	311.7	11.0	28.5	20.0	60.6
MZ-4	268.3	12.0	29.5	25.6	56.9
RCGMP 40	208.3	4.0	4.0	27.0	55.0
RCM 1-61	358.3	11.0	21.0	21.3	61.9
RCGMP 34	316.7	8.3	14.0	29.7	56.7
RCGMP 73	350.0	6.0	13.0	27.0	79.0
ME 29	271.7	10.0	34.0	22.3	61.3

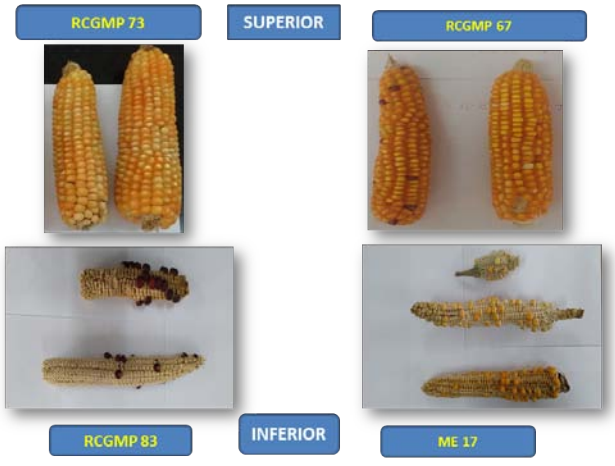


Fig 9. Performance of genotype under elevated temperature

Excess moisture stress tolerant maize for NE Region

Maize germplasms (452 nos.) collected from different hill states *viz.* Manipur, Meghalaya and Mizoram were screened for water logging tolerance both at seedling stage (using pot) and flowering stage (at field). Out of 452 germplasm, a total of 227 germplasm (171 from Meghalaya, 14 from Manipur and 42 from Mizoram) survived at the seedling stage after 15 days of excess water stress. Crown root initiation took place in some of the entries during the seedling stage as a response to excess water stress. Under field conditions, water logging at flowering stage only 42 germplasm (out of 452) survived (Fig 10 to Fig 12). These germplasm (selfed seeds) will be further evaluated for excess water stress tolerance in the next generation.

Fig 10. Waterlogging treatment (pot experiment)

Fig 11. Adventitious root growth after excess water stress

Fig 12. Waterlogging treatment (field experiment) at flowering stage

Identification of drought tolerant tomato:

Tomato varieties (21 nos.) were screened under elevated temperature and moisture stress condition during three growth stages *viz.* initial growth stage, flowering stage and fruiting stage as compared to natural growing condition in Manipur. The maximum and minimum temperature inside the polyhouse was 6-7°C and 0.5-4°C higher as compared to open field. The volumetric water content in the pots during stress condition was measured in the range of 32.6% to 37.8%, as compared to 69.0% to 77.8% in open field.

On inducing stress during initial growth stage, Arka Vikash was found to be the best yielder as compared to other varieties. The performance of the variety RC Manikhamenashinba-1 was the best over other varieties when stress was induced during the flowering stagae. The variety Arka Abha was found to be the best in terms of fruit yield over other varieties tested when stress was induced during fruiting stage. Stress during fruiting period was found to be the most critical for tomato. Based on the yield performance of different varieties, the stress tolerance index was worked out. Maximum stress tolerance index during initial growth stage, flowering stage and fruiting stage was exhibited by Manileima, RC Manikhamenashinba-1 and Arka Abha, respectively. Irrespective of varieties and growth stages, maximum mean stress tolerance index was observed in case of Arka Abha, followed by Kashi Hemant (Fig 13). Stress tolerance efficiency also showed similar results.

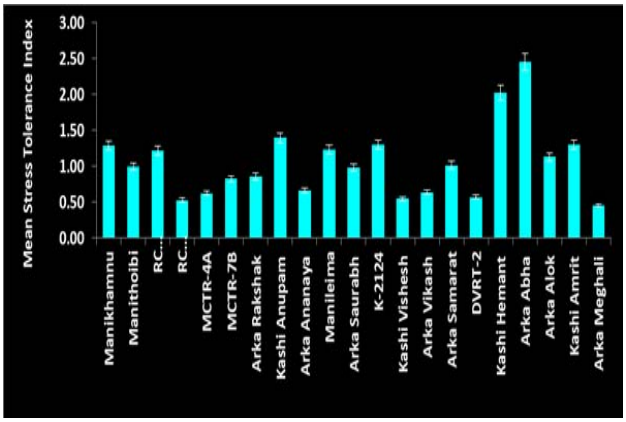


Fig 13. Mean Stress Tolerance Index of Different Tomato Varieties

In terms of quality, irrespective of varieties, there was 67.64%, 74.24% and 153.11% increase in TSS under stress during initial growth stage, flowering stage and fruiting stage, respectively over natural growing condition. The decrease in total sugar content, irrespective of varieties, under stress found to be 62.45%, 82.49% and 44.42% at initial growth stage, flowering stage and fruiting stage, respectively. Irrespective of varieties, drought stress caused reduction in chlorophyll content index (23.12-32.34%) and total sugar content (44.42-82.19%); but increase in TSS (67.64-153.11%) and lycopene content (15.52-37.59%) over non-stressed condition.

The effect of stress on the micronutrient content in tomato fruits was also studied. Irrespective of varieties, there was increase in Fe (61.51%, 269.78% and 60.43%), Cu (96.67%, 210.00% and 60.43%) and Zn (114.29%, 172.11% and 404.76%) content under stress in all the stages studied. In case of Mn, 78.72% and 45.74% decrease was registered during initial growth stage and flowering stage, respectively; however, Mn content was found to be increased by 11.70% during fruiting stage over natural field condition.

Effect of biochar application on soil health, productivity, nutrient use efficiency and C-sequestration maize based cropping system.

Characterization of Biochar produced from different agro-residues

Biochar produced from different biomass materials (weed biomass, maize and pine wood) were characterized for different physico-chemical properties. The values for pH, TOC, major and micro nutrinets are given in Table 5. The average surface area ranged from 13.758 to 15.454 (m^2/g), total pore volume ranged from 2.401 to 4.028 (cc/g), and average pore radius ranged from 2.83 to 3.75 (A^o). The highest surface area was found in weed biochar, followed by maize and pinewood biochar (Table 6).

Table 5. Characteristics of Biochar material produced from different agro-wastes

Particulars/ Parameters	Weed Biochar	Maize Biochar	Pinewood Biochar
pH	09.83	09.31	05.84
TOC	37.46	45.67	55.97
Total N (%)	01.03	0.65	0.59
Total P (%)	0.050	0.029	0.004
Total K (%)	06.14	01.98	0.21
Fe (ppm)	1.00	3.60	0.74
Mn (ppm)	0.31	0.69	0.64
Cu (ppm)	0.63	1.06	1.01
Cr (ppm)	0.16	0.28	0.17
Se (ppm)	1.14	1.84	1.05

Table 6. BET surface area and pore volume of biochar

Particulars	BET surface area (m2/g)	Total pore volume (cc/g)	Average pore radius (A^o)
Maize	15.453	2.401	3.12551
Weed	18.370	3.419	3.75229
Pine wood	13.758	4.028	2.83223

Estimation of runoff, soil losses, and erosion potential of Hilly watersheds (micro) with different farming systems under climate change scenarios- Field and simulation approaches

A simulation study was carried out for estimation of soil losses across 24 years old (1983-2006) well established eight micro-watersheds (MW) at ICAR Research Complex for NEH Region, Umiam, Meghalaya (Fig 14). The eight MWs had different farming systems (FS) based on livestock (W1), forestry (W2), agroforestry (W3), agriculture (W4), agri-horti-silviculture (W5), horticulture (W6), natural fallow (W7) and jhum (as control, W8). These MWs were gauged for 24 years (1983-2006) and many hydrological information including runoff and soil losses were observed over the periods. The observed data on long period average (LPA: 1983-2006) annual soil losses across the eight MWs revealed differential responses of FS to soil losses (Fig 15). Among the eight combinations of FS, horticulture based system was most resilient against erosion evident from lowest annual soil losses (LPA: 9.36 t/ha) while traditional jhuming (with sparse broom grasses) practices encouraged the soil losses and recorded the highest LPA soil losses (17.62 t/ha). These observed soil losses reported here is the re-estimated/recalibrated soil losses from the original hydrographs recorded during the course of study period (1983-2006).

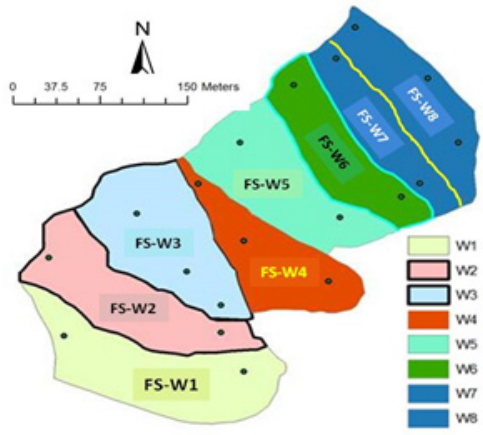


Fig 14. Farming system based eight micro-watersheds (MWs) at ICAR(RC) for NEH

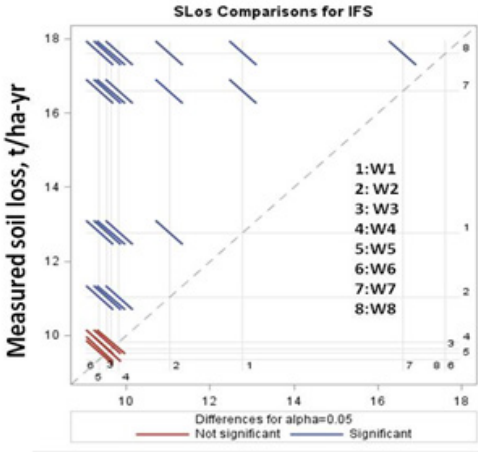


Fig 15. Measured annual soil losses across eight micro-watersheds (1983-2006)

To study the likely effect of projected climate change scenarios on runoff and soil losses under different FS combinations in the eight MWs, we calibrated and validated two suitable hydrological models – RUSLE (Revised Universal Soil Loss Equation) and WEPP (Water Erosion Prediction Project). For calibration and validation of RUSLE, different components of the model namely rainfall erosivity (R), soil erodibility (K), topography factor (slope & length), land cover management (C) and conservation practices (P) factors were estimated/ standardized following standard methods including literature information on landuse practices and conservation measures adopted over the years across the 8 MWs. The study area received wide variation in annual temporal rainfall: average rainfall varied from 1830 mm (in 2006) to 3323 mm (in 1988). The estimated rainfall erosivity (R) also increased with the increase in annual rainfall: from 2415.1 (in 2006) to 9675.4 (in 1988) Mj-mm/ha-hour-year. Similarly, for WEPP, information on climate, topography, soil and management practices as inputs were compiled / supplemented in the prescribed format. Both the hydrological models (RUSLE & WEPP) were calibrated using initial twelve years (1983-1995) measured annual soil losses and validated from the remaining years (1996-2006) measured soil losses. The root mean square error (RMSE) for calibration as well as in validation of the models was less than 10%. Similarly, we obtained model efficiency (Nash Sutcliffe) above the critical threshold limit of acceptance (>0.5, Moriasi et al., 2007) in calibration as well as validation of both the models. Study on climate projection scenarios are on progress.

Soil, carbon and nutrient losses from *Jhum* field under the changing climate

Five units of runoff plot were established for the study of sediments, runoff, nutrients and organic carbon losses from 16, 25, 40, 50 and 60 per cent slope gradient under Jhum field at Langol experimental farm. All together 31 rainfall events occurred during January to November 2018. The rainfall received from January to December, 2018 was recorded to be 7.8 mm, 10.6 mm, 58 mm, 60.4 mm, 170.3 mm, 306.3 mm, 142.0 mm, 121.5 mm, 25.6 mm, 118.7 mm, 0.0 mm and 22.7 mm, respectively. Total runoff loss from 16, 25, 40, 50 and 60% slope gradient was to the tune of 293.95, 189.08, 131.37, 95.46, 58.33 m^3/ha, respectively against receipt of 1043.9 mm total rainfall during the period of observation (Fig 16). Maximum soil loss was recorded under 60% slope (9.34 t/ha) as compared to other slopes. Similarly, three units of runoff plot were installed in jhum field having 3 different fallow period (3, 10 and 20 years, slope gradient 50%) at Monsangpantha, Chandel District of Manipur. Runoff and soil loss from jhum fields were recorded and compared against fresh jhum fallow with similar slope gradient. The maximum runoff (9.57 t/ha) and soil (295.95 m^3/ha) loss was recorded from fresh jhum as compared to that under different period of jhum cycles ((3, 10 and 20 years) (Fig 17). Nutrients and organic carbon losses were also recorded from jhum fields with various slope gradients and fallow periods (Fig 18). Losses of N, P, K and organic carbon was maximum from 60% slope gradient and fresh jhum fields.

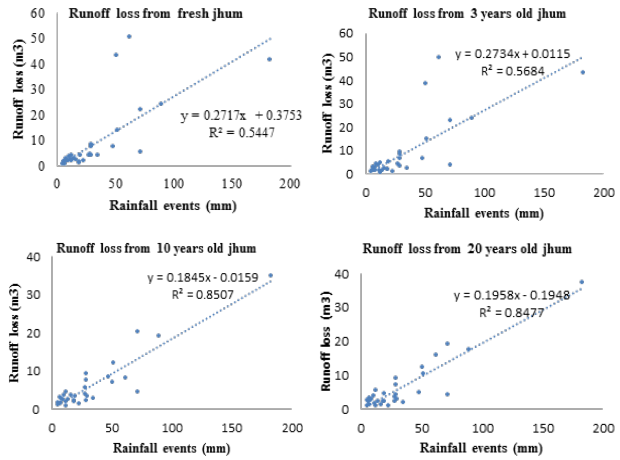


Fig 16. Relationship between rainfall events and Runoff loss under various jhum fallow periods

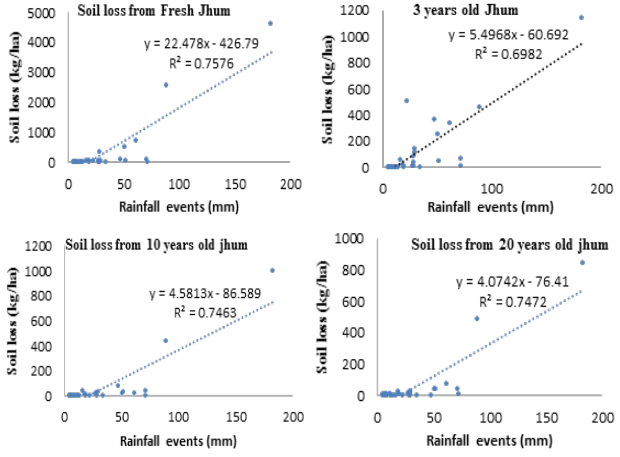


Fig 17. Relationship between rainfall events and soil loss under various jhum fallow periods

Fig 18. Installed runoff structure under various slope gradients and fallow jhum period

Amelioration of climate stress through nutrition and housing management in pig and poultry

Effect of supplementation of herbs to ameliorate the heat stress in poultry:

The effect of dietary supplementation of locally available herbs/leaf (Mulberry leaf: *Morus alba*, curry leaf: *Murraya koenigii* and Chinese palak) on body weight, egg production performance, egg quality, heamato-biochemical profile and immune response in laying hens were studied (Fig 19 & Fig 20). The treatment were: stress free + Basal diet (Control)-T1, Heat stressed + Basal diet –T2, Heat stressed + Basal diet + Mulberry leaf meal (5%)-T3, Heat stressed + Basal diet + Curry leaf meal (3%)-T4 and Heat stressed + Basal diet + Chinese palak (5%)-T5. Results revealed the following:

- Growth Performance: The mean body weight was increased by 163 g in the control group (no heat stress) and it was reduced in other groups due to heat stress. Highest reduction in mean body weight (73 g) was recorded in T2 group (laying hens fed with basal diet) and the lowest reduction (10 g) was recorded in T4 group (laying hens fed with basal leaf + curry leaf powder). Similar trend was recorded in case of the other parameters mentioned above.
- Production performance**:** Mean egg production, egg weight, egg mass and feed intake recorded in control group was 62.86%, 54.70 g, 240.20 g and 117.01g respectively. However, these parameters were reduced significantly to the tune of 14.29%, 6.4%, 27.64% and 11.77%, respectively in heat stressed group having basal diet only. However, egg production, egg weight, egg mass and feed intake were improved, but not upto control level, when laying hens were fed with basal+ 3% curry leaf powder. The mean FCR in control group was 3.42 and it was found to be the worst (4.22) in heat stressed group (T2) fed with basal diet only. Among the heat stressed group, minimum FCR (3.88) was recorded in case of hens fed with basal diet supplemented with 3% curry leaf powder.
- Egg quality traits**:** No significant change observed in shape index, specific gravity, albumen index and yolk index of eggs among different treatments. The highest shell weight,

shell thickness and haugh unit are recorded in control group. However, these parameters were reduced significantly in heat stressed group. The lowest values were found in heat stressed group (T2) fed with basal diet only but improved markedly when basal diet was supplemented with curry leaf powder (@3%).

- Haemato-biochemical parameters**:** No significant change in cholesterol, triglyceride and haemoglobin was observed among different treatments. However, significant change observed in glucose and protein of serum due to different dietary treatments. The highest level of glucose (239.4 mg/dl) was found in heat stressed group (T2) containing basal diet only whereas lowest level of glucose (177.6 mg/dl) was recorded in control. In the heat stressed groups, lowest level of glucose (209.6 mg/dl) was found in heat stressed group (T4) fed with 3% curry leaf supplemented basal diet. The lowest protein (4.78 g/dl) was found in heat stressed group (T2) whereas highest level of protein (5.94 g/dl) was recorded in control. In the heat stressed groups, lowest level of protein (5.24 g/dl) was found in heat stressed group (T4) fed with 3% curry leaf supplemented basal diet.
- Curry leaf (3%) is beneficial to ameliorate the heat stress in laying hens than other herbal supplementation used in this feeding trial.

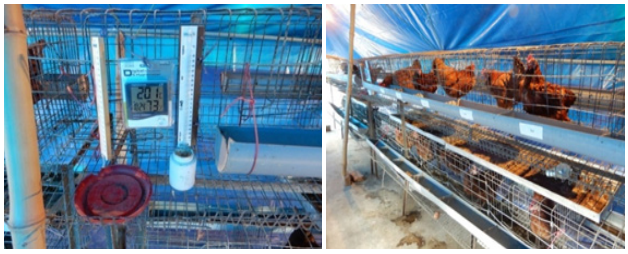


Fig 19. Experimental setup

Fig 20 (A). Mulberry leaf powder

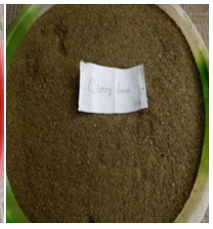


Fig 20 (B). Curry leaf powder

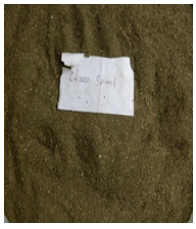


Fig 20 (C). Chinese Palak

Effect of dietary supplementation of commercial feed additive on the performance of Vanaraja and Srinidhi parents under the agro-climatic condition of Meghalaya

An experiment was conducted to evaluate the effect of a commercially available feed additive on the performance, egg quality and certain stress biomarkers in Vanaraja and Srinidhi parent layers maintained under the agro-climatic conditions of Meghalaya. The treatment groups of both the varieties were fed with basal layer mash supplemented with a commercial feed additive containing a combination of probiotics (*Propionibacterium freudenreichii*), neem (*Azadirachta indica)*, MOS and toxin binder at the level of 1 kg/ton of feed for 4 months (28^{th} to 43^{rd} weeks of age). The control groups received only basal layer mash. There was significant ($P<0.05$) increase in the hen day egg production (%) in Vanaraja treated group compared to control (57.57±1.57 and 40.27±3.71 %, respectively). However, in Srinidhi parent groups a non-significant increase in the hen day egg production was reordered in comparison to control. Vanaraja parents showed no significant difference between treatment and control groups in terms of fertility and hatchability percentage. In Srinidhi parents, fertility percentage showed significant ($P<0.05$) improvement in treatment (78.86 ± 6.62) than control (67.84 ± 5.81) group. Different egg quality traits did not differ significantly between treatment and control groups in both varieties. The mean values of serum catalase, superoxide dismutase, glutathione peroxidase and cortisol also did not differ significantly between treatment and control groups in both Vanaraja and Srinidhi parents. Feed additive in the diet caused moderate improvement in performance traits of Vanaraja and Srinidhi parent layers maintained under the agro-climatic conditions of Meghalaya (Fig 21 & Fig 22).

Fig 21. Srinidhi parent layers

Fig 22. Vanaraja parent layers

Nutritional management to ameliorate climatic stress in grower pigs

The heat stress is the major climatic stress to young grower pigs during summer (here termed as summer diet). In order to alleviate heat stress, a feed was formulated (Table 7, Fig 23 & Fig 24)) with low crude protein content (15.31 vs 17.17 %) for better adaptability. During the experiment, 3 months old 8 numbers of cross bred pigs (Niang Megha x Hampshire) were given formulated feed and its effect on growth performance, feed conversion and heat stress biomarker studied. Control group (8 nos.) fed with standard grower ration. The effect of the summer diet relative to standard grower ration on growth performance, FCR and stress biomarkers are presented in Table 8. Grower pigs fed with summer diet had significantly (P <0.05) higher body weight, body weight gain, feed conversion ratio and SOD (U/ml) (1.45±0.04 vs 1.67±0.03) but significantly lower cortisol (ng/ml) (38.34±3.13 vs 32.44±2.67) than the control group. In a similar experiment, the effect of another feed formulation (here termed as Winter feed) was tested to alleviate cold stress in grower pigs. The composition of the winter feed is given in Table 9. Study revealed that the winter diet significantly (P<0.05) improved the body weight, weight gain, feed conversion ratio and SOD but significantly lower cortisol as compared with that under control group (Table 10). The efficiency of male pigs in utilizing diets containing mustard oil was better than that of the female counterparts.

Table 7. Formulation for Hot feed

Ingredient	Control	Summer feed
Maize	52	47
Molasses	-	11
Soybean meal	10.5	9
Wheat bran	23	20
Groundnut cake	12	10
Mineral Mixture	2	2
Salt	0.50	0.50
Total	100 %	100 %
Calculated		
CP %	17.17	15.31
ME (KCal/Kg)	3320.6	3376.6

Table 8. Effect of hot feed on growth performance and stress biomarker of growers pigs

Parameters	Summer (hot feed)	
Body weight (Kg)	Control (8)	Treatment (8)
Initial	18.38±0.65	18.43±0.85
Final	53.62±1.85^{a}	56.13±1.44^{b}
Weight gain (Kg)	35.24±1.33^{a}	37.70±1.74^{b}
ADG (g/d)	391^{a}	418^{b}
FCR	3.54^{a}	3.38^{b}
Cortisol(ng/ml)	38.34±3.13^{a}	32.44±2.67^{b}
SOD (U/ml)	1.45±0.04^{a}	1.67±0.03^{b}
Means with different superscript differs significantly (P <0.05)		

Table 9. Formulation for Cold feed

Ingredient	Control	Winter feed
Maize	52	54
Mustard oil (MO)	-	8
Soybean meal	10.5	10.5
Wheat bran	23	23
Groundnut cake	12	11
Mineral Mixture	2	2
Salt	0.50	0.50
Total	100 %	100 %
Calculated		
CP %	17.17	17.04
ME (KCal/Kg)	3320.6	3511.2

Table 10. Effect of cold feed on growth performance and stress biomarker of growers pigs

Parameters	Winter (cold feed)	
Body weight (kg)	Control	Treatment
Initial	14.93±0.15	14.93±0.75
Final	36.37±1.03^{a}	41.62±0.95^{b}
Weight gain (kg)	21.43±0.88^{a}	26.68±0.20^{b}
ADG(g/d)	238^{a}	296^{b}
FCR	3.38^{a}	2.93^{b}
Cortisol (ng/ml)	41.21±3.02^{a}	35.48±2.83^{b}
SOD (U/ml)	1.32±0.04^{a}	1.47±0.03^{b}
Means with different superscript differs significantly (P <0.05)		

Fig 23. Mixing of mustard oil (10%) with Conc. feed for winter feed formulation for grower pigs

Formulation of low-cost feed with locally available feed resources to alleviate climatic stress in grower pigs

Fig 24. Mixing of molasses (11%) with Conc. feed for hot/summer feed formulation for grower pigs

A total of twelve (12) samples of wild Banana pseudo-stem (*Musa* spp.) were collected from Meghalaya. The proximate analysis of collected samples was done and reported in Table 11. A study was conducted to evaluate the effect of banana pseudo-stem as a partial replacement of maize (10 and 20%) in feed concentrate on growth performance of crossbred (Niang Megha x Hampshire) grower pigs (3 months old, av. Body weight 15.62±1.09 kg) to ameliorate climatic stress (Fig 25). The ingredients and chemical composition of the experimental diet is given in Table 12. The grower pigs were divided randomly into three groups (I, II and III) and all the three groups were fed with iso-calorie and iso-nitrogenous diets as per NRC (1988) recommendation. Group I was fed with control diet (T2), group II was fed with 10% pseudo-stem replaced diet (T2) and group III was fed with 20% pseudo- stem replaced diet (T3). Health care was taken as per recommendation. All the animals (36 nos., 12 in each group) under experimentation were initially served a standard grower diet and kept for acclimatization for a period of 10 days. The experiment lasted for 120 days. The effects of the diets on different parameters are presented in Table 13. Replacement of maize (10-20%) in pig feed by banana pseudo stem has significant positive effect on growth, FCE and reduction of stress in pig.

Table 11. Nutritive value of Processed Wild banana Pseudo-stem

Parameters	Mean±SE
1. Dry matter % as fed	7.45±2.1
2. Crude protein % DM	5.09±2.6
3. Crude fibre % DM	28.9±5.4
4. Ether extract % DM	3.5±1.6
5. Ash % DM	15.4 ± 7.2
6. Gross energy (Kcal/kg)	3284 ± 4.1
Element of micronutrients (4)	
1. Manganese (Mn) ppm	0.83±0.14
2. Zinc (Zn) ppm	0.24 ± 0.02
3. Copper (Cu) ppm	0.029 ± 0.08
4. Iron (Fe) ppm	4.54 ± 0.06
Element of Macronutrient (6)	
1. Calcium (Ca) ppm	0.34±0.06
2. Potassium (K) ppm	559.91 ± 2.75
3. Magnesium (Mg) ppm	12.87 ± 0.14
4. Nitrogen (N) %	0.44
5. Sulphur (S) %	0.36
6. Phosphorus (P) %	0.01

Table 12. Ingredient and chemical composition of the experimental diets (%) for grower pigs

Ingredient (%)	Dietary treatment		
	Control (T1)	T2 (10%)	T3 (20%)
Maize	55	45	35
Banana pseudostem	0	10	20
Wheat bran	19	16	14
Soybean meal	10	10	10
Groundnut cake	13.5	16.5	18.5
Mineral Mixture	2	2	2
Salt	0.5	0.5	0.5
Total	100	100	100
Calculated			
CP %	18.32	18.20	18.70
ME (KCal/Kg)	3363	3357	3340
Protein:Enegry ratio	1:183	1:184	1:178

Table 13. Effect of replacement of maize in pig feed by banana pseudo stem on different growth parameters, FCE and stress indicators in pig

Partial replacement of maize by Banana Pseudo stem (10% and 20%) on dry matter basis feeding on growth performance in grower pig (3-6 months) to ameliorate climate stress			
Performance traits	**Control (n=12)**	**T-10% (n=12)**	**T-20% (n=12)**
Initial body weight (Kg)	15.63±1.09	15.63±1.01	15.63±0.94
Final body weight (Kg)	$55.12±3.15^{a}$	$57.46±3.48^{b}$	$55.07±3.78^{c}$
Weight gain (Kg)	$39.50±2.06^{a}$	$41.83±2.47^{b}$	$39.44±2.84^{c}$
Average daily gain (g/d)	329^{a}	348^{b}	328^{c}
FCE	$1:4.43^{a}$	$1:4.34^{b}$	$1:4.44^{c}$
SOD(U/ml)	$1.79±0.09^{a}$	$1.75±0.01^{b}$	$1.83±0.11^{c}$
Cortisol (µg/dl)	$2.70±1.14^{a}$	$2.36±1.02^{b}$	$2.49±1.36^{c}$

Fig 25. Low cost feed formulation with dried wild banana pseudo-stem to ameliorate climate stress in pigs

Study on thermoregulatory behaviors and body fluid mechanism of grower pigs in response to cold stress

Cold tolerance of local pig breed is generally correlated with their small size, its surface area to volume ratio, low production level and some unique morphological/anatomical traits such as properties of the skin or hairs, sweating capacity (>30/cm^2), tissue insulation, special appendages etc. as compared to exotic breed of pigs. These traits generally help the animal in dissipation/conservation of heat. A study was conducted to evaluate thermoregulatory mechanism of indigenous pigs relative to crossbred and exotic pigs. A total of six no. of CCTV video cameras were used for this study. Thermoregulatory behavior patterns of pigs were recorded for 24 hours and with the help of the video footage, quantitative estimates were made for different behaviors of the pigs. Local pigs have better homeostasis and adaptability than crossbred and Hampshire. It found that (Table 14) local pigs have better postural behaviours (Lying : lateral, sternal, half-lateral), huddling and shivering under cold stress in terms of size, surface area to volume ratio. Indigenous pigs can alter/modify their posture behaviours to either increase/decrease heat loss/gain (dissipation). Indigenous pigs have well acclimatized to heat/cold stress than crossbred and exotic pigs. Local pig has better thermoregulatory mechanism in terms of body fluids (Alkaline phosphatase, T4, Insulin, C-peptide, SOD, Acid phosphatase and Alanine transaminase) as compared to crossbred and Hampshire pigs (Table 15) . Therefore, Niang Megha of hilly origin has better thermoregulatory mechanisms in term of behavioural, body fluid and metabolism as compared to crossbred and exotic pigs under cold stress.

Table 14. Time (min)* and behavioral frequency (%) of grower pigs in response to cold stress under CCTV video camera

Criteria of behavior	Local pigs (n=6)		Crossbred pigs (n=6)		Hampshire pigs (n=6)		Significance
	min	%	min	%	min	%	
1. Lateral lying (LL)	298	20.69	350	24.31	401	27.85	**
2. Sternal lying (SL)	161	11.18	140	9.72	90	6.25	**
3. Half lateral lying (HLL)	90	6.25	105	7.3	128	8.89	NS
4.Huddling (H)	443	30.77	415	28.82	410	28.47	**
5.Shivering (S)	88	6.11	130	9.02	150	10.42	**
6.Physical activity (PA)	360	25	300	20.83	261	18.12	**
Overall total	1440	100	1440	100	1440	100	

*Time in minutes spent in each behavior for 24 hours daily (1440 min per day)

** Significant at 5% probability level; NS = non-significant.

Table 15. Body fluids profiles of different breeds of pig responsible for thermoregulatory mechanism

Metabolism and body fluid Mechanism in response to Cold stress			
Parameters	**Breed/Genetic group**		
	Niang Megha (6)	**Crossbred (6)**	**Hampshire (6)**
Alkaline phosphatase (ng/ml)	6.46±0.19^a	3.48±0.48^b	1.66±0.01^c
Insulin (µLU/ml)	5.48±0.07^a	7.42±1.01^b	12.48±1.76^c
C-peptide(ng/ml)	0.25±1.06^a	0.06±1.77^b	5.22±1.59^c
T4(ng/ml)	38.64±0.029^a	18.08±0.058^b	5.52±0.008^c
SOD (U/l)	1.83±0.25^a	1.79±0.33^b	1.54±.74^c
Acid phosphatase (µmol/min/ml)	0.022±0.01^a	0.026±0.02^b	0.09±0.02^c
Alanine transaminase (U/L)	13.72±0.23^a	19.47±0.45^b	17.88±0.68^c

Growth performance and Thermal tolerance of *Cyprinus carpio* var. Amur (Hungarian strain) acclimated to different temperature:

- The results implicate significant increase ($p<0.05$) in CTMax (39.5±0.18, 40.5±0.12, 41.5±0.12) and LTMax (40.3±0.09, 41.6±0.1, 42.7±0.11) in *Cyprinus carpio* varamur with increasing acclimation temperatures of 20, 25 and 30°C, respectively. Similarly, CTMin (3.1667±.16667, 4.3333±.16667, 5.7333±.14530) and LT Min (2.3333±.16667, 3.2667±.14530, 4.5333±.14530) increased significantly ($p<0.05$) with increasing acclimation temperatures.
- Growth performance and biochemical stress parameters (ALP,SGPT,SGOT) and nutrient composition of Common carp (*Cyprinus carpio*, Linnaeus*)* cultured in different thermal environments has been studied (Fig 26).
- Temperature tolerance and Q_{10} analysis of Pengba (*Osteobrama belangeri*) (Aerated and Non-aerated system) has been studied. Respiration rate at different temperature were recorded and Temperature coefficient (Q_{10}) at 37^0C was observed to vary from 2.106 to 2.12.

Fig 26. Experimental setup and growth performance of *Cyprinu scarpio*

CT_{max} and CT_{min} of a minor carp (Amblypharyngodon mola)

Amblypharyngodon mola, popularly known as Moka is a dual purpose (food value as well as ornamental value) small indigenous species (Fig 27). It is highly sought out in markets due to its unique taste, high protein (19.5% CP), vitamin-A (2500 RE/100g) and micro-mineral contents. The fish (1.2-2.9g) were acclimatized at 26, 28, 30 and 32^0C for 48 hrs. using thermostats in polystyrene boxes. Critical thermal maximum (CT_{max}) and critical thermal minimum (CT_{min}) were determined by gradually increasing and decreasing the water temperature of boxes from the acclimatized temperatures @ 1^0C/day with thermostats followed by observation of loss of equilibrium in fish. At point of CT_{max} and CT_{min}, water samples were estimated for dissolved oxygen level of water. CT_{max} was increased from 32^0C to 34^0C, CT_{min} from 16^0C to 18^0C and oxygen consumption rate in fish from 28 mg to 38 mg with increase of acclimation temperature from 26 to 32^0C. Temperature quotient (Q_{10}) was 1.66 at 26-28^0C, 1.36 at 28-30^0C and 1.54 at 30-32^0C. From this, it was concluded that *A. mola* is more resilient to thermal stress if acclimatised at 28-30^0C.

Fig 27(A). Experimental fish (*A. mola*)

Fig 27 (B). CT_{max} and CT_{min} assessment in polystyrene boxes using thermostats

TRIBAL SUB PLAN (TSP)

More than 22169 tribal farmers from seven North Eastern states were benefitted during 2018 by various livelihood programmes conducted under Tribal Sub Plan (TSP). Different physical assets (407 nos.) *viz.*, poultry shed, pigsty, processing unit, jalkund, beehive briquette making unit, vermicomposting unit, shade net house, low cost pig breeding unit, poly housewere created/distributed in different tribal villages of the hill states of North East.

Distribution of seeds/ planting materials

Agricultural inputs *viz.* seeds, planting materials, mushroom spawn, poly bags etc. were distributed among tribal farmers during 2018. Vegetable (coriander, radish, fenugreek, pea, cabbage, tomato, brinjal, broccoli, capsicum, bitter gourd, bottle gourd, lady's finger, palak, chilli, cauliflower, french bean, pumpkin, beet root, carrot, lettuce, soybean, cucumber, okra etc.) seeds (436.4 kg), seed of cereal crops viz. rice, maize, oat, buckwheat etc. (200 kg), oil seeds like groundnut (24 kg) were distributed. Besides these, 222792 numbers of planting materials (khasi mandrain, banana sucker, strawberry, dragon fruit, mango, large cardamom suckers etc.) were also distributed among the tribal farmers for their livelihood improvement. Mushroom spawn (1000 packets) and poly bags (150 kg) were distributed for popularizing mushroom cultivation as a source of livelihood.

Fertilizer/ bio-fertilizer/ manure/ soil amendment/ nutrient solution/ pesticides

Fertilizer/bio-fertilizer/manure/soil amendment *viz*. NPK, FYM, mustard oil cake, *Rhizobium*, VAM, vermin-compost, neem oil cake, bio-fertilizers and lime (23910 kg), bio-pesticide (46.2 litre), neem based bio-pesticide (114.5 litre were distributed among the tribal farmers of North East.

Livestock, fish fingerlings and medicines

A total of 172 nos. of improved breed of piglets, 128227 nos. of poultry chicks, 92 nos. of goat, 145300 nos. of fish fingerlings, 917 kg of feed supplements (livestock/ poultry feed, mineral mixture, wheat bran, maize, salt, vitamin etc) were distributed. Medicines *viz.* antibiotics (1260 gm), vitamins supplements (21 litres), anthelmintic (1260 ml), topical ointments (1600 gm) endectocide (2500 ml), rumeno tonic (440 gm) and $KMNO_4$ (400 gm) were also distributed for management of various animal diseases. Besides these, 230 nos. of artificial insemination (AI) in pigs was also carried out in different villages of North East.

Minor agricultural tools and implements

Small agricultural implements and tools viz., harrow, budding and grafting knife (175 nos.), were distributed among the tribal farmers. Pheromone trap (2200 nos.), pheromone lures (2100 nos.) and yellow sticky trap (2660 nos.) were also distributed for management of insects/ pest in crops. Apart from these, to promote apiary as a source of livelihood, honey bee box and its accessories (164 nos.) were distributed among the tribal farmers.

Training and capacity building

Training, front line demonstration and awareness programme (48 nos.) were organized for capacity building of tribal farmers in various field of agriculture (crop production, animal production and management, mushroom cultivation, production and management of horticultural crops, etc.).

AGRI-BUSINESS INCUBATION (ABI) CENTRE

Current year, ABI activities extended to different states of Northeast regions through its regional centres to promote enterpronership dvelvelopment through business development plan, hand-holding support mechanisms and networkworking. ABI has identified 14 promising technologies/potential ventures in the respective states of Northeast region and accordinlgy provided the support. Technical support through social media such as whatsapp group and Facebook including deliberation of 17 lectures in different State and Central Universities, Seminars and Meetings to popularize the ABI activities. Internal Mentoring Mechanism was created for effective business management which includes 8 Executive Members for policy decisions, Principal Investigator (PI) for overall implementation, monitoring and execution and 16 Subject Expert Members from different technical backgrounds. A total of 11 sensitizing workshops were organized in different Northeastern states in collaboration with State and Central Agencies, NGOs and Financial Institutions.

In the effort made, over 300 students, 2 Agricultural Universities and more than 500 Entrepreneurs were sensitized out of which more than 150 ideas were scouted and 15 more is yet to be assisted. At present, ABI has a total of 123 registered entrepreneurs (82 physical incubatees and 51 virtual incubatees) performing well in different agribusiness ventures. Out of these members, 5 entrepreneurs have graduated successfully and are running their business in the field of meat, fruit, spice and dairy processing. Mr. Kenneth Falcon (Tynrai Farms Pvt. Ltd.) and Mr. Teilang Kharmalki (Meat Tender) are successfully producing and marketing different meat products such as nuggets, sausage, salami, etc. and having annual turnover of Rs. 36 Lakhs and Rs. 12 Lakhs, respectively. Mrs. Khayiwon Shangh (Ngayam Foods) dealing with fruit and spice processing has developed more than 23 products and have an annual turnover of Rs. 25 Lakhs. Mrs. Ishabella Pakma (Pakma Foods Pvt. Ltd.) deals with processed spice and fruits such as Lakadang turmeric and has an annual turnover of Rs. 12 lakhs. Mr. Wungkui Zimik (Dansun Agro Products) deals with variety of dairy products and earns an annual turnover of Rs. 40 Lakhs.

Fig 1. Training cum Workshop on Gold Fish for entrepreneurship Development

Fig 2. Training on Fruit processing Under ABI

Fig 3. Training on Meat Processing under ABI

Survey was carried out on current status of entrepreneurs though pre-tested formats and constraints faced by them in the respective ventures were identified. Accordingly, entrepreneurs were guided with constructive solutions through participation of subject matter experts and officials under ABI. To meet the requirements of incubated entrepreneurs, ABI has collaborated with other State and Central Agencies including Meghalaya Basin Development Authority, National Institute of Design (NID), ASSOCHAM, SFAC, SIDBI, NABARD, PHD Chamber of Commerce, MSRLS, IIE, IIM and MIE in providing Institutional and Financial support mechanisms. A total of 57 MSME startup entrepreneurs were imparted technical knowledge and skills through 6 (Six) different training programmes in Meat processing, Fruit Processing, Animal Feed Making, Fish Breeding, Spawn Production and Mushroom Cultivation, Packaging and Labeling (Fig 1 to 3). Out of which 12 entrepreneurs were supported with labeling and packaging solutions for scaling up their business and more than 11 Entrepreneurs were provided with market linkage through different Buyers and Sellers Meet. ABI has also provided a pilot testing and Custom hiring platform for innovative startup ideas to 6 (Six) entrepreneurs in meat processing, food processing, spawn production and dehydration. Meattender, Shillong (Meghalaya) has signed MoU with ICAR RC for NEH region and has taken up marketing of the processed meat items such as sausage, nugget and curry cuts and is directly supplying processed and packed products to 20 different retailers with an annual turnover of Rs 12 lakhs and is expected to be doubled by next year. The centre has also facilitated testing of 74 different meat product and spice samples so far and entrepreneurs are provided test reports to improve their agribusiness activities. ABI has helped 6 (Six) entrepreneurs in food processing to obtained FSSAI license and 3

Fig 4. ABI incubatee receiving best entrepreneur award in Startup Samvaad

(Three) entrepreneurs have filed trademark for their agro-products under ABI incubation support system. Besides, ABI has inaugurated four well-furnished cabins for incubates, out of which two cabins have been provided to Dhar Enterprise, Shillong and MKC Enterprise, Shillong for their product pilot study, labeling and business office on rental basis. In the year 2018, the ABI Centre has successfully made an achievement by generating over 300 numbers of employments through start up entrepreneurs. More than 7500 farmers' lives have benefitted from the entrepreneurs under ABI with better farm income through supply of raw materials which ultimately improve their livelihood. ABI has facilitated over two Crores of funds for the development of Agribusiness Ventures. Mention can also be made of our incubatee, Mr. Rajeev Agarwal, Farmgram Foodbev Pvt. Ltd. who received best entrepreneur award in Startup Samvaad organized by NAARM, Hyderabad (Fig 4) and Ms. Watila Longkumer, another successful entrepreneur of ABI dealing with floriculture who was listed among the top 10 Women Entrepreneurs in India by NITI Aayog.

KRISHI VIGYAN KENDRA

The Institute is catering to the extension needs of farmers in the region through its 20 nos. Krishi Vigyan Kendras (KVKs-Anjaw, Longding, Namsai, West Siang in Arunachal Pradesh; Hailakandi in Assam; Chandel, Churachandpur, Imphal West, Tamenglong and Ukhrul in Manipur; Ri-Bhoi and West Garo Hills in Meghalaya; Dimapur, Peren, Longleng, Kiphere and Wokha in Nagaland; East Sikkim in Sikkim; South Tripura and West Tripura in Tripura). These KVKs have been tirelessly working for the upliftment of the farming community through dissemination of technologies, assessment and refinement of technologies, demonstrations, etc. During the reporting period 1,137 nos. of capacity building training programmes were organized wherein 37,043 nos. of farmers/ farm women, rural youth and extension personnel were benefitted (Table 1). The courses were on productivity enhancement of field crops, horticultural crops, empowerment of rural women, plant protection, livestock production and management, soil fertility management, farm machinery tools and implements, fisheries and agro-forestry, integrated farming system, etc. With the technology backstopping from the host Institute and other NARS Institutes, KVKs were able to assess and refine technologies by laying out 941 nos. of trials on the farmers' field (OFT) under various thematic areas *viz*., varietal evaluation, integrated farming systems, integrated disease management, integrated nutrient management, processing and value addition, storage techniques, etc. Thematic areas in livestock were evaluation of breed, disease management, feed and fodder management, nutrition management, fertility improvement, etc. The major livestock species included were pigs, dairy cows, goat, poultry birds and fisheries. Women specific income generation technologies related to technological empowerment of rural women were also assessed under thematic areas of drudgery reduction, women friendly tools, health and nutrition, small scale income generation and storage techniques, *etc*. A total of 2,013 nos of demonstrations were also conducted in cereals, pulses, oilseeds, vegetable crops, fruit crops, flower crops, plantation crops, fodder crops, livestock, fisheries, feeding management, vaccination, breed performance, etc. Extension programmes for creating awareness among farmers about improved technologies and to provide timely advisory to farmers were organized by the Institute KVKs. More than 1,163 nos. of extension programmes /activities in the form of advisory services, diagnostic visits, clinical services, exhibitions, exposure visits, ex-trainees *Sammelan*, field days, film shows, group meetings, Kisan Goshthis, Mahila Mandal convenors' meetings, method demonstrations, soil health camps, soil testing campaigns, *etc*. were organized in which more than 82,617 nos. of farmers participated. The KVKs also conducted extension programmes through electronic and print media for a wider coverage in the respective districts.

Apart from the mandated activities, KVKs were engaged in many other activities like distribution of Soil Health Cards, Pradhan Mantri Fasal Bima Yojna, Pre-Rabi Campaign, Swachhta Pakhwada, Swachhta hi Sewa, Skill India Programme, Krishi Kalyan Abhiyan I & II, Rashtriya Mahila Kisan Diwas. KVKs were also involved in Projects like National Initiative for Climate Resilient Agriculture, National Food Security Mission for Pulse and Oilseeds.

Table 1. Summary of activities undertaken by the Institute KVKs during 2018

Sl. No.	Name of KVKs	Training Programmes conducted		On Farm Trials (Nos.)	Frontline Demonstrations (Nos.)	Other Extension Activities	
		No. of courses	Beneficiaries (Nos.)			Nos.	Beneficiaries (Nos.)
Arunachal Pradesh							
1.	Anjaw	16	440	23	114	14	1,084
2.	Longding	7	285	11	2	19	756

3.	West Siang	37	774	10	90	32	2,705
4.	Namsai	177	9,052	5	123	370	19,173
	Sub-total	237	10,551	49	329	435	23,718
Assam							
5.	Hailakandi	124	5,537	45	122	16	9,508
	Sub-total	124	5,537	45	122	16	9,508
Manipur							
6.	Chandel	53	1,401	36	128	193	2,424
7.	Churachandpur	40	764	26	54	5	147
8.	Tamenglong	68	2,040	19	18	26	2,810
9.	Ukhrul	57	1,583	43	202	11	2,366
10.	Imphal West	40	825	38	111	11	4,635
	Sub-total	258	6,613	162	513	246	12,382
Meghalaya							
11.	Ri-Bhoi	71	1,247	52	106	13	9,230
12.	West Garo Hills	45	1,097	105	89	24	296
	Sub-total	116	2,344	157	195	37	9,526
Nagaland							
13.	Dimapur	74	1,725	72	180	13	7,323
14.	Longleng	84	3,730	34	66	11	3,409
15.	Peren	30	306	10	35	121	1,232
16.	Kiphere	39	1,272	6	15	226	546
17.	Wokha	31	933	175	99	13	925
	Sub-total	258	7,966	297	395	384	13,435
Sikkim							
18.	East Sikkim	64	1,954	54	166	16	10,099
	Sub-total	64	1,954	54	166	16	10,099
Tripura							
19.	South Tripura	62	1,449	133	178	19	3,218
20.	West Tripura	18	629	44	115	10	731
	Sub-total	80	2,078	177	293	29	3,949
	Grand Total	**1,137**	**37,043**	**941**	**2,013**	**1,163**	**82,617**

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Other publications:

Books	**: 05**
Book Chapters	**: 30**
Technical/Extension bulletins	**: 06**
Training Manual	**: 04**
Souvenirs	**: 02**
Proceeding papers	**: 05**
Abstracts	**: 25**
Leaflets/Folders	**: 08**
Popular articles	**: 08**
Total	**: 93**

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Other publications:

Book Chapters:	**: 09**
Training Manual:	**: 01**
Souvenirs:	**: 02**
Abstracts:	**: 16**
Leaflets/Folders:	**: 13**
Popular articles:	**: 27**
Total	**: 68**

MIZORAM CENTRE

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Saha S, Chatterjee D, Swain C K and Nayak A K. 2018. Methane emission from wetland rice agriculture-biogeochemistry and environmental control in projected changing environment. *Advances in Crop Environment Interaction* doi./10.1007/978-981-13-1861-0_3.

Other Publications:

Books	**: 01**
Souvenirs:	**: 03**
Proceeding papers:	**: 02**
Abstracts:	**: 02**
Leaflets/Folders:	**: 10**
Total	**: 16**

NAGALAND CENTRE

Research papers:

Sarkar D, Baishya L K, Meite C B, Naorem G C, Thokchom R C, Singh J, Bhuvaneswari S, Kaushik Batabyalc , RumaDasd , Dhaneshwar Padhanc , Narendra Prakasha , Feroze H. Rahman. 2018. Can sustainability of maize-mustard cropping system be achieved through balanced nutrient management? *Field Crops Research* 225 (1): 9-21. (NR 2018: 9.13)

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Singh M, Mollier R T, Rajesha G, Ngullie A M, Rajkhowa D J, Rajkumar U, Paswan C and Chatterjee R N. 2018. Backyard poultry with Vanaraja and Srinidhi: proven technology for doubling the tribal farmers' income in Nagaland. *Indian Farming* **68**(01): 80-82.

Other publications:

Book Chapters:	**: 05**
Technical/Extension bulletins:	**: 01**
Training Manual:	**: 02**
Abstracts:	**: 03**
Popular articles:	**: 04**
Total	**: 15**

SIKKIM CENTRE

Research papers:

Boopathi T, Singh S B, Singh A R, Dutta S K, Ramakrishna Y, Chowdhury S, Lungmuana and Dayal V. 2018. Susceptibility of okra to major insect pests under open field conditions. *Journal of Entomology and Zoology Studies* **6**(6): 1156-1159. (NR 2018: 5.53)

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Das S K, Avasthe R K, Singh M, Dutta S K and Roy A. 2018. Zinc in plant-soil system and management strategy. *Agrica* **7**(1), 1-6.

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Dutta S K, Akoijam R S, Boopathi T and Saha S. 2018. Bioactivity and traditional uses of 26 underutilized ethno-medicinal fruit species of North-East Himalaya, India. *Journal of Food Measurement and Characterization* **12**(4): 2503-2514.

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Singh R, Babu S, Avasthe R K, Yadav G S, Chettri TK and Singh A. 2018.Effect of organic mulches and vermicompost on productivity, profitability and energetic of mustard (*Brassica campestris*) in popcorn (*Zea mays* everta) - mustard cropping system in rainfed Sikkim Himalaya. *Indian Journal of Agricultural Sciences* **88** (11): 1735–39. (NR 2018: 6.23)

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Other publications:

Book Chapters:	**: 02**
Training Manual:	**: 01**
Proceeding papers:	**: 06**
Abstracts:	**: 19**
Leaflets/Folders:	**: 02**
Popular articles:	**: 08**
Total	**: 38**

TRIPURA CENTRE

Research papers:

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Meena H, Meena R S, Lal R, Yadav G S, Mitran T, Layek J, Kumar S B P S and Verma T. 2018. Response of sowing dates and bio regulators on yield of cluster bean under current climate in alley cropping system in eastern UP, India. *Legume Research* DOI: 10.18805/LR-3759 .(NR 2018: 6.23)

Meena R S, Mitran T, Kumar S, Yadav G S, Bohra J S and Datta R. 2018. Application of remote sensing for sustainable agriculture and forest management. *Information Processing in Agriculture* **5**(3): 295-297.

Meena R S, Vijayakumar V, Yadav G S and Mitran T. 2018. Response and interaction of *Bradyrhizobium japonicum* and *arbuscular* mycorrhizal fungi in the soybean rhizosphere. *Plant Growth Regulation* **84**(2): 207-223. (NR 2018: 8.05)

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Samborlang K W, Singh A K, Ram V, Das A, Ray Lala I P and Janaki Singh N. 2018. Effect of Organic and inorganic sources to vegetable pea in vegetable pea- maize cropping sequence on growth and yield parameters. *Journal of Agri Search* **5**(3): 147-152.

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Yadav G S, Das A, Lal R, Babu S, Meena R S, Patil S B, Saha P and Datta M. 2018. Conservation tillage and mulching effects on the adaptive capacity of direct-seeded upland rice (*Oryza sativa* L.) to alleviate weed and moisture stresses in the North Eastern Himalayan Region of India. *Archives of Agronomy and Soil Science* **64**(9): 1254-1267. (NR 2018: 8.25)

Yadav G S, Datta M, Babu S, Das A, Meena R S, Sarkar M and Debbarma C. 2018. Enhancing Lentil Productivity through Sustainable Nutrient Management Practices in Rice Fallow. *Indian Journal of Hill Farming* 31(2): 237-241. (NR 2018: 4.39)

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Yadav G S, Saha P, Babu S, Das A, Layek J and Debnath C. 2018. Effect of No-Till and Raised-Bed Planting on Soil Moisture Conservation and Productivity of Summer Maize (*Zea mays*) in Eastern Himalayas. *Agricultural Research* **7**(3): 300-310. (NR 2018: 5.9)

Pandey A, Kumar A, Ansari M A, Tyagi W, Rai M and Das A. 2018. Genetic divergence, path coefficient and cluster analysis of rice bean genotypes, in the Mid-altitudes of Meghalaya. *Indian Journal of Agricultural Sciences* **83** (12): 1300–4. (NR 2018: 6.23)

Other publications:

Books	**: 02**
Book Chapters:	**: 10**
Technical/Extension bulletins:	**: 01**
Training Manual:	**: 01**
Leaflets/Folders:	**: 07**
Total	**: 21**

Note : NR (NAAS Rating)

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Dr (Mrs) H. Lembisana Devi, Scientist (Horticulture)
Dr Vinay Singh, Scientist (Poultry Science)
Dr (Mrs) Rekha Das, Scientist (Fishery Science)
Mrs Huirem Bharati, Scientist (Fisheries)


ICAR RESEARCH COMPLEX
FOR N E H REGION
UMIAM, MEGHALAYA