



**2015-16**

# **वार्षिक प्रतिवेदन**

## **ANNUAL REPORT**



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

**ICAR Research Complex for N. E. H. Region**  
(Indian Council of Agricultural Research)  
Umiam-793 103, Meghalaya





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ICAR Research Complex for NEH Region  
Umroi Road, Umiam – 793103, Meghalaya  
Telephone: 0364-2570257, Fax: 0364-2570355  
Email: svngachan@rediffmail.com  
Website: www.icarneh.ernet.in and http://kiran.nic.in

## **Annual Report 2015-16**

### **Guidance**

Dr S. V. Ngachan  
Dr N. S. Azad Thakur  
Dr Satish Chandra  
Dr A. K. Tripathi

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## P R E F A C E

It gives me immense pleasure to present the Annual Report of the ICAR Research Complex for NEH Region for the year 2015-16. This premier institute has a glorious history and has been contributing immensely in technology development through basic and applied research in hill agriculture since 1975. The institute has scaled new heights in name and fame, initiated many new activities in research and extension to meet the current national policy and global environment. The years 2015 and 2016 have been two landmark years in the world Agriculture; 2015 being the international year of soil and 2016 the international year of pulses. The institute prepared soil health cards for more than 5000 farmers in all the seven hill states of the North East India. To increase the productivity of pulses large scale demonstration on pulses in rice fallow such as lentil, pea, moong bean etc were conducted through its six regional centers and its 15 KVKs. In Tripura and Manipur, more than 500 ha have been covered under pulses. The institute also undertook massive awareness campaign of the Prime Ministers fasal bima yojna through its KVKs. To fulfill the objective of the '*har khet me pani*', the institute has contributed in preparing irrigation plans of two districts of Meghalaya as model plans for further replication by the line departments. In order to enhance productivity and increase cropping intensity, technologies such as Zero tillage and crop residue management have been standardized and popularized. Organic farming has been another area of focus in the last year. Cultivation practices of 32 crops have been standardized by the Institute. The regional center at Sikkim has recently been declared as a full-fledged institute on organic agriculture and renaming it as ICAR-NIOF by the Union Government. The institute has continued to conduct further research on its main flagship programmes on *Jhum* improvement, Temperate horticulture and trans-boundary diseases. A number of technologies such as rice varieties, rice soybean intercropping, organic rice production, integrated land management and agroforestry systems have been field tested and modified to suite the *Jhum* lands and sustain *Jhuming* which fits into *Jhumia's* socio-cultural acceptability. One rice variety, RC Maniphou-13, which has resistance to neck and leaf blast and has yield potential of 7 to 7.5 t/ha, has been released from Manipur center. A new classical swine fever vaccine has been developed and ready for field testing. Rapid diagnostic techniques have been developed for quick and reliable identification of diseases of animals and plants. The institute has also been providing technological support to the farmers in the north eastern hill region of India through its extensive extension network. With the special financial support from the Govt. of India under the Tribal Sub Plan, a total of 17,130 farmers were benefitted during 2015-16 with various technologies, physicals assets and inputs in the forms of seeds, improved breeds of livestock etc. The *Mera Gaon Mera Gaurav* Program has been running very successfully in more than 100 adopted villages where farmers of each village are directly interfaced with a conglomeration of 5 to 6 scientists. Scientists of the institute have also excelled in basic and strategic research, made good contribution in publication of quality research publications in international scientific journals.

I compliment the editorial board for their efforts in timely compilation of annual report in a crisp and abridged form. I also record my sincere thanks to the former secretary DARE and Director General ICAR, Dr S. Ayyappan, the Deputy Director General, Natural Resources Management, Dr A. K. Sikka, for their constant support and guidance that enabled the institute to excel in its programmes unhindered and uninterrupted.



(S. V. Ngachan)  
Director







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## विशिष्ट सारांश

उमियम में कुल वार्षिक वर्षा 2551 मि.मी. थी, जो कि सामान्य वर्षा से लगभग 156 मि.मी. अधिक थी। कुल वार्षिक पात्र वाष्पन 857 मि.मी. दर्ज किया गया। नवम्बर से फरवरी मासों को छोड़कर सभी मासों का औसत अधिकतम तापमान 26.6°C से 29.0°C के बीच था। त्रिपुरा के चावल जीनप्ररूप 'टीआरसी 2013-2/आईईटी 23947' को सीवीआईसी (केन्द्रीय किस्मगत पहचान समिति) द्वारा सिंचित या बरानी उथली निचली भूमि पारिस्थितिकी के तहत उत्तराखंड, हरियाणा, पश्चिमी बंगाल, मध्यप्रदेश, महाराष्ट्र तथा केरल राज्यों के लिए संस्तुत किया गया। चावल की पांच किस्मों, अर्थात् त्रिपुरा खाराधान 1, त्रिपुरा खाराधान 2, त्रिपुरा हकुचुक 1, त्रिपुरा हकुचुक 2, त्रिपुरा औसधान के लगभग 2.7 टन प्रजनक बीज का उत्पादन किया गया। "राज्य फसल मानक, अधिसूचना और किस्म मोचन बीज उप समिति, मणिपुर सरकार" द्वारा एक नयी चावल किस्म आरसी मनिफोउ-13 का मोचन किया गया (जिसकी उपज क्षमता 7-8 टन प्रति हैक्टेयर है और जो ग्रीवा विगलन रोग के प्रति प्रतिरोधी है), जो कि मध्यम अवधि वाली, अर्द्ध बौनी, उर्वरक अनुक्रियाशील है तथा निचली भूमि में उच्च उपज देने वाली किस्म है। चावल के दो जीनप्ररूपों, अर्थात् आरसीएम-32 और आरसीएम-33 को आईवीटी एमएच परीक्षण के तहत एआईसीआरपी के लिए नामित किया गया। मणिपुर के किसानों की 99 चावल किस्मों के डीयूएस लक्षणवर्णन में दो किस्मों, अर्थात् *चाहावो* और *चाहावो अमुबी* को काफी उत्कृष्ट पाया गया। चावल किस्म, भालुम-3 और गोमती को मिजोरम की क्रमशः ऊपरी भूमि और निचली भूमि स्थितियों के तहत उत्कृष्ट पाया गया। अरुणाचल प्रदेश में लगभग 42 स्थानीय चावल जननद्रव्य वंशक्रमों (23 डब्ल्यूआरसी और 19 झूम चावल) का संग्रहण किया गया और उनके विभिन्न गुणों को ज्ञात करने के लिए उनका लक्षणवर्णन किया गया। चावल किस्म, भालुम-3, रूखातांग और चाको यूह को नागालैंड में आशाजनक पाया गया। सिक्किम में स्थानीय किस्म कृष्णा भोग में चावल सघनीकरण (एसआरआई) विधि 1 की प्रणाली के तहत काफी ज्यादा उपज (2.94 टन प्रति हैक्टेयर) पायी गई। स्थानीय जीनप्ररूप 'आरसीपीएल1-412' में पोषक तत्व उदग्रहण और जल उत्पादकता सबसे ज्यादा पाई गई। जल का संवर्धन (हाइड्रोपोनिक) कर उगाए गए चावल पादपों में विविध प्रकार की जड़ आकारिकी पाई गई और उसे *Pup 1 QTL* की मौजूदगी के साथ सहसंबंधित किया गया। यूकार्योटिक ट्रांसलेशन इनिशिएशन फैक्टर 4A (*eIF-4A*), जिसे *पाइसम सतिवुम* से वियोजित किया गया था, तब अपरेगुलेट हुआ जब उसे विभिन्न अजैविक कारकों के प्रति

एक्सपोज किया गया। इससे अजैविक कारकों के प्रति सहिष्णुता की क्रियाविधि को और अधिक समझने में सहायता मिलेगी।

उमियम में मक्के में किण प्रेरण और पादप विकास के लिए एक उत्कृष्ट प्रोटोकॉल भी विकसित किया गया। पुनरावृत्त परीक्षणों में 96 मक्का वंशक्रमों में से 30 वंशक्रमों को उमियम में टर्सिकम पर्ण अंगमारी के प्रति प्रतिरोधी पाया गया। लेमन ग्रास ऑयल का 7 मि.ली. प्रति कि.ग्रा. की दर से इस्तेमाल किए जाने से भंडारित मक्के में न्यूनतम घुन नुकसान पाया गया। अरुणाचल प्रदेश में मक्का किस्म 'वीएल बेबीकॉर्न-1' को आशाजनक पाया गया। मिजोरम से मक्के की 70 देशज प्रजातियों का संग्रहण किया गया और आप्ठिक स्तर पर उनका लक्षणवर्णन किया गया। *स्वस्थाने* अपशिष्ट प्रबंधन परीक्षणों में "मेज़ स्टाक कवर (एमएससी) + कुक्कुट खाद + एमब्रोसिया" का 5 टन प्रति हैक्टेयर की दर से प्रयोग किए जाने से मक्का (32.2%) और सरसों (15.8%) की बेहतर उपज पाई गई, जो कि उमियम में कंट्रोल की तुलना में अधिक थी। मंडुवा (*Finger Millet*) किस्म वीएल-324 को सिक्किम की कृषि जलवायु स्थितियों में सबसे अधिक उपजशील पाया गया।

मणिपुर के थोउबल, पश्चिमी इम्फाल तथा पूर्वी इम्फाल के जिलों में 62 किसानों को तथा 60 हैक्टेयर से भी अधिक क्षेत्रफल को शामिल करते हुए मसूर फसल की खेती के बारे में प्रदर्शन किया गया। टीआरसीएम 151-1 (1.01 टन प्रति हैक्टेयर) से सबसे अधिक मूंग उपज प्राप्त की गई। मिजोरम में मसूर की दो किस्मों, अर्थात् डीपीएल-62 और डीपीएल-15 में सबसे ज्यादा उपज (0.71 टन प्रति हैक्टेयर) दर्ज की गई। तोरिया किस्म, टीएस-36 और मूंग जीनप्ररूप टीआरसीएम-1-2-2 को नागालैंड में सबसे अधिक उपजशील पाया गया। मूंग की किस्म टीआरसीएम 314-1 तथा हरी मटर किस्म वीएल-42 को त्रिपुरा में आशाजनक पाया गया।

अरुणाचल प्रदेश की स्थितियों के तहत तोरिया के लिए बुआई करने हेतु अक्टूबर के मध्य के समय को सबसे ज्यादा उपयुक्त पाया गया। मिजोरम में शून्य जुताई प्रणाली के तहत निचली भूमि के अंतर्गत चावल परती भूमि में तोरिया-सरसों की बीज उपज एम-27 में 1.26 टन प्रति हैक्टेयर से पी-27 में 0.94 टन प्रति हैक्टेयर के बीच पाई गई। सिक्किम की कृषि जलवायु स्थितियों में सूरजमुखी किस्म डीआरएसएच-1 को सबसे अधिक उपज देने वाली किस्म के रूप में पाया गया। त्रिपुरा में मूंगफली की किस्म एचएनजी-10 को आशाजनक पाया गया। एआईसीआरपी के तहत किट्ट के विरुद्ध कुल 75 सोयाबीन



जीनप्ररूपों की संवीक्षा की गई, जिनमें से दो जीनप्ररूपों, अर्थात् ईसी 241778 और ईसी 241780 को लगातार तीन वर्षों तक किट्ट के प्रति पूर्णरूप से रोगरोधी पाया गया। सोयाबीन के फली अंगमारी रोग प्रबंधन के लिए थियोफिनेट मिथाइल कवकनाशक का 55 और 75 डीएस पर 0.1 प्रतिशत की दर से दो बार छिड़काव को काफी प्रभावकारी पाया गया।

सिक्किम में चावल-मेथी-मक्का फसलीकरण प्रणाली में सबसे अधिक उत्पादकता (82.2 टन प्रति हैक्टेयर) दर्ज की गई। मक्का-मटर फसल प्रणाली में जैविक स्रोतों के जरिए नाइट्रोजन की 100 प्रतिशत संस्तुत खुराक (आरडीएन) के साथ शून्य जुताई में सबसे अधिक उत्पादकता (14.0 टन प्रति हैक्टेयर) और उत्पादन दक्षता (28.9 कि.ग्रा. प्रति हैक्टेयर प्रति दिन) दर्ज की गई। एफवाईएम के जरिए 100 प्रतिशत आरडीएन के साथ 2 टन प्रति हैक्टेयर की दर से बायोचार के मिश्रणों का प्रयोग किए जाने से मक्के की उच्च उपज (3.82 टन प्रति हैक्टेयर) दर्ज की गई।

कृषि-बागवानी प्रणालियों में, जिसके अंतर्गत मुख्य फसल मूंगफली की थी, नाशपाती + मूंगफली फसल प्रणाली में 7.89 टन प्रति हैक्टेयर की सर्वाधिक चावल समतुल्य उपज (आरईवाई) प्राप्त की गई। मुकुना रियूरेन के 11 आशाजनक जीनप्ररूपों के मूल्यांकन में यह पाया गया कि WBNMP 03 में सबसे अधिक बीज उपज (1.96 टन प्रति हैक्टेयर) पाई गई। केजंगलवा के बीज स्रोत से परकिया रॉक्सबर्घी के सात बीज स्रोतों के संतति मूल्यांकन में सबसे अधिक ऊंचाई (10.25 मीटर) तथा कॉलर डायमीटर (16.95 से.मी.) पाया गया। गैर-छिद्रिल एलडीपीई और एचडीपीई में गार्सिनिया लैन्सिफोलिया की पैकेजिंग की निष्पत्ती आयु (सेल्फ लाइफ) को बढ़ाने हेतु बेहतर पाया गया।

झूम सुधार के अंतर्गत ढलान पर 25 से.मी. पंक्ति की दूरी में हाथों से धान की बुवाई किए जाने से मेघालय की स्थितियों के तहत की गई बुवाई की तुलना में चावल की उपज में काफी ज्यादा वृद्धि पाई गई। मिजोरम की विभिन्न भूमि उपयोग प्रणालियों में खाली छोड़े गए झूम खेतों में मृदा pH सबसे अधिक पाया गया, जबकि तेल ताड़ में प्राप्य नाइट्रोजन और फास्फोरस सबसे अधिक पाया गया। वन की मृदा में जैविक कार्बन सबसे अधिक पाया गया। अरुणाचल प्रदेश में बागवानी उपायों के जरिए झूम सुधार पर प्रमुख कार्यक्रम के तहत 35 हैक्टेयर क्षेत्रफल को शामिल करते हुए नारंगी संतरे (किस्म खासी संतरा), केला (किस्म ग्रांड नेइन), अन्नानास (किस्म विव) की रोपण सामग्रियां तथा चावल की उन्नत किस्मों, जैसे कि भालुम-1, 2, 3; मक्का, दलहन, तिलहन, सब्जी बीजों और कन्द फसलों की किस्में किसानों को वितरित की गई। ट्राइकोड्रमा हर्जियेनुम, स्फ्यूडोमोनस प्लूरोसंस तथा सरसों के तेल की खली के मिश्रण के प्रयोग को नागालैंड में झूम की खेती में अदरक के प्रमुख रोगों को रोकने में काफी प्रभावकारी पाया गया।

कृषि प्रणाली अनुसंधान में 8 सूक्ष्म जलसंभरों का दीर्घकालिक आधार पर मूल्यांकन किया गया। इन जलसंभरों में डेरी आधारित भूमि उपयोग (एफएसडब्ल्यू-1), मिश्रित वानिकी (एफएसडब्ल्यू-2), सिल्वी-पास्टोरल भूमि उपयोग (एफएसडब्ल्यू-3), कृषि-पास्टोरल प्रणाली (एफएसडब्ल्यू-4), कृषि-बागवानी-सिल्वी-पास्टोरल (एफएसडब्ल्यू-5), सिल्वी-बागवानी प्रणाली (एफएसडब्ल्यू-6), प्राकृतिक वन ब्लॉक (एफएसडब्ल्यू-7) तथा टिम्बर आधारित कृषि प्रणाली (एफएसडब्ल्यू-8), शामिल थे। जैविक कार्बन प्राच्छादन तथा जैविक कार्बन के अन्य घटकों की दृष्टि से अध्ययन की गई कृषि प्रणाली अनुसंधान (आईएफएस) में एल्डर आधारित आईएफएस, एल्डर + कोलोकेसिया + ईएफवाई का प्रदर्शन मणिपुर में आईएफएस के तहत अन्य फसल संयोजनों की तुलना में बेहतर पाया गया।

मेघालय में जैविक खेती प्रणाली के अंतर्गत उत्थित और जलमग्न क्यारी को निचली भूमि में प्रभावकारी भूमि एवं जल प्रबंधन के लिए तथा तथा उपरी भूमि में फसल सघनता बढ़ाने हेतु अंतर-प्लॉट जलसंचयन के लिए एक महत्वपूर्ण प्रौद्योगिकी के रूप में काफी प्रभावकारी पाया गया। मक्के में जैविक खेती प्रणाली के तहत उत्तर पूर्वी पर्वतीय क्षेत्र में डीए 61ए और आरसीएम-76 को तथा फ्रेंचबीन में नागा लोकल और उसके बाद आरसीएम-एफबी-18 को आशाजनक पाया गया।

संरक्षण कृषि प्रणाली के अंतर्गत पारंपरिक खेती (सीटी) में (3.69 टन प्रति हैक्टेयर) की तुलना में शून्य जुताई (एनटी) में सबसे ज्यादा चावल उपज (3.75 टन प्रति हैक्टेयर) दर्ज की गई। शून्य जुताई फसल उत्पादकता को बढ़ाने में, मृदा की उर्वरता को कायम रखने में तथा ऊपरी एवं निचली भूमि स्थितियों, दोनों, के तहत प्राकृतिक संसाधनों को संरक्षित करने में बड़ी भूमिका निभाती है। ढलान वाली भूमि में अध्ययन की गई विभिन्न फसल प्रणालियों में चारा फसल आधारित प्रणाली को पहाड़ी कृषि में मृदा एवं पोषण तत्व के क्षय को कम करने के लिए काफी प्रभावकारी पाया गया। अवशिष्ट प्रतिधारण के साथ शून्य जुताई से उमियम में अवशिष्ट निष्कासन के साथ पारंपरिक जुताई की तुलना में चावल (17.2 प्रतिशत) में तथा अनुवर्ती रबी फसलों, अर्थात् सरसों (34.6 प्रतिशत), मटर (16.4 प्रतिशत), कुट्टू (27.4 प्रतिशत) में उच्च उपज प्राप्त की गई।

अन्य जैविक खादों की तुलना में, जिनमें उच्च क्षारीयता होती है, कुक्कुट खाद में लाइमिंग क्षमता सबसे अधिक पाई गई (उत्पादन का सीसीई 449 कि.ग्रा. प्रति टन)। अन्य खादों की तुलना में, जैविक खादों में कुक्कुट खाद (लाइम की सहयोगी खाद) का प्रदर्शन उमियम में सरसों की उपज के संबंध में उत्कृष्ट पाया गया। उमियम में गैर मूल परिवेशी मृदा की तुलना में, मूल परिवेशी मृदा में जैविक कार्बन के विभिन्न घटकों की मात्रा काफी



ज्यादा पाई गई। कारबेंडाजिम के कवकनाशी एवं कीटनाशक संरूपण (क्रॉस्टिन 50 प्रतिशत डब्ल्यूपी) और कार्बोफुरान (फ्यूरेसेक 3 प्रतिशत G सहित) का प्रयोग किए जाने से 80 पीपीएम पर एल्युम सेपा की जड़ लम्बाई को काफी ज्यादा अवरोधित किया गया।

उत्तर पूर्वी भारत की अम्लीय मृदाओं के लिए बहु-पोषण एक्सट्रेक्ट (यूनिवर्सल एक्सट्रेक्ट) के रूप में मेहलिच-3 की उपयोगिता की पुष्टि की गई जिसके लिए अनाज (मक्का) और दलहन (मटर) जैसी फसलों का उपयोग किया गया। मेहलिच-3 एक्सट्रेक्ट का प्रयोग करते हुए मृदाओं में फास्फोरस तथा जिंक की सीमा निर्धारित की गई और बोरॉन B की उपलब्धता सुनिश्चित की गई और पादपों में उनके सांद्रणों का प्रयोग किया गया। मशदा में फास्फोरस की उपलब्धता को बढ़ाने तथा अम्लीय मशदा में फसल विकास और फसल उपज को बढ़ाने के लिए सिट्रिक अम्ल को काफी प्रभावकारी पाया गया। सिक्किम की फील्ड स्थितियों के तहत वर्मीकम्पोस्ट 2.5 टन प्रति हैक्टेयर की दर से प्रयोग किए जाने से 23 प्रतिशत अधिक मृदा कार्बन पदार्थ दर्ज किया गया। सिक्किम में एलनुस-लार्ज इलायची आधारित कृषि वानिकी प्रणाली में पादप में प्राप्य NPK (नाइट्रोजन, फास्फोरस, पोटेशियम) तथा संचित बोरॉन काफी ज्यादा पाया गया। मणिपुर के 5 जिलों से कुल 1250 मशदा नमूनों की जांच की गई और किसानों को मशदा स्वास्थ्य कार्ड वितरित किए गए। त्रिपुरा में फास्फोरस के उपयोग के संबंध में चावल जननद्रव्य, 'लालगुरा' को काफी बेहतर पाया गया। तत्काल रूप से परोसे जाने (आरटीएस) वाले पेय पदार्थ के लिए 9:1 अनुपात में खासी संतरा रस और चाउ-चाउ के गूदे को उपयुक्त पाया गया। नागालैंड में नींबू वर्गी उद्यानों की संख्या में गिरावट आने के पीछे नाइट्रोजन तथा फास्फोरस तत्वों में कमी आना है। नागालैंड में उपज के आधार पर अमरुद की किस्म 'आरसीजीएच-4' को बेहतर पाया गया।

अमरुद का नेक्टर, स्प्रेड और चीज बनाने के लिए प्रोटोकॉल का मानकीकरण किया गया। कम लागत वाले पॉली हाऊस में लाइम (250 कि.ग्रा. प्रति हैक्टेयर) + पॉलीमल्व का प्रयोग किए जाने से खीरे (2.48 कि.ग्रा. प्रतिपादप) तथा किंगचिली (647 ग्राम प्रतिपादप) की सर्वाधिक फल उपज प्राप्त की गई। चाउ-चाउ (74) में फल के वजन, विटामिन-सी, शर्करा एवं फिनॉल की मात्रा में काफी ज्यादा विविधताएं देखी गईं। शुष्क चाउ-चाउ शेड बनाने के लिए 0.5 से.मी. की स्लाइस मोटाई को उपयुक्त पाया गया। उत्तर पूर्वी भारत में पैशन फ्रूट के डेप्लड फल रोग और येलो मॉटलिंग से संबद्ध नए पॉटीवायरस के लिए एक एसीपी-ईलीसा आधारित इम्यूनो डायग्नोस्टिक विकसित किया गया। 'क्वि अन्नानास' के लिए परिपक्वता सूचकांकों का मानकीकरण किया गया जिसके अनुसार अरुणाचल प्रदेश की स्थितियों के तहत फल की तुड़ाई पादप पर पुष्प आने के

पश्चात 151 से 160 दिनों के भीतर की जानी चाहिए। सिक्किम में बेहतर गुणवत्ता वाले कीवी फल की उपज को ज्यादा बढ़ाने के लिए प्रातःकाल 10.00 बजे से लेकर दोपहर 12.00 बजे के बीच हाथों के जरिए परागण को काफी बेहतर पाया गया।

47 एसएसआर मार्करों का प्रयोग करते हुए उपज गुणों के लिए मिर्च के कुल 106 जननद्रव्यों का मूल्यांकन और लक्षणवर्णन किया गया। सीमित नमूना आकार के अंतर्गत आण्विक विश्लेषण में औसतन 4.36 एलिल प्रति लोकस के साथ 205 एलिलों की खोज की गई और सीएमएस 91 (1.956) को सबसे अधिक सूचनाप्रद मार्कर के रूप में पाया गया। डेल चिली (कैपसिकम चाइनेन्स) में 9 एलिल को और बर्ड आई चिली (सी.फ्रूटेसेन्स) में 5 एलिल को उत्कृष्ट पाया गया। किंग चिली (कैपसिकम चाइनेन्स) में भी 2 एलिल बेहतर पाए गए। कलस्टर विश्लेषण में यह पाया गया कि किंग चिली और बर्ड आई चिली के बीच उपज गुणों के संबंध में काफी करीबी समानता है। आक्रमणकारी मिलीबग, फोरमिकोकुस पॉलीस्पेरस तथा फेनोकोकुस पारवुस को क्रमशः हल्दी और नागा किंग चिली को संक्रमित करते हुए पाया गया। मिजोरम में बर्ड आई चिली के 2 वंशक्रमों को फ्रूट प्लार्ड प्रजातियों, बैक्ट्रोसेरा डोरसेलिस को सबसे ज्यादा प्रतिबलित नाशीजीव के रूप में पाया गया। इसके अलावा, मिजोरम में बैक्ट्रोसेरा ताउ (वाकर) को मिर्च के नाशीजीव के रूप में पहली बार पाया गया। नागालैंड से एंडोफाइटिक बैक्टीरिया आईसोलेट 'केईबी-7' को कोलेट्रोड्रिचुम कैपसिसी के विरुद्ध काफी प्रभावकारी पाया गया। नागालैंड की किंग चिली से एंडोफाइटिक बैक्टीरिया के 20 आईसोलेट पाए गए।

टमाटर की खेती में ड्रिप सिंचाई और काली पॉलीथिन की मल्टिप्लेक्स का प्रयोग किए जाने से किसानों की विधि (1.15 टन प्रति हैक्टेयर) की तुलना में टमाटर की उपज (1.77 टन प्रति हैक्टेयर) में वृद्धि हुई। सोलेनुम टोरवुम के नुकसान को एस.खासिएनुम के नुकसान के काफी करीब पाया गया तथा सोलेनुम टोरवुम को जीवाणुज म्लानि के प्रति काफी रोगरोधी पाया गया।

एसएसआर मार्करों का प्रयोग करते हुए कंद फसलों के 66 जननद्रव्यों का लक्षणवर्णन किया गया। जेंथोसोमा प्रजाति के ताजीटिंग पर्पल ताजीटिंग व्हाइट के बोए गए जननद्रव्यों को उनके वंशतक का विश्लेषण करने हेतु चिगी (जिसकी पहचान नहीं की गई है) के साथ संयोजित कर उनकी पत्तियों और वंशतक के लिए विश्लेषण किया गया और इनमें अन्य प्रजातियों की तुलना में काफी विविधता पाई गई। मायडकुर (हल्दी) और नाडिया (अदरक) में क्रमशः 542.76 ग्राम और 562.88 ग्राम का सर्वाधिक ताजा राइजोम वजन/पादप पाया गया। मणिपुर की स्थिति के लिए हल्दी (आरसीएमटी-19) और अदरक (आरसीएमजी-1) के आशाजनक क्लोनों की पहचान की गई। अरुणाचल प्रदेश में हल्दी '40-60 ग्राम' के बीज राइजोम



आकार को सबसे ज्यादा उपयुक्त पाया गया। हल्दी की राइजोम उपज सबसे ज्यादा पाई गई (15.2 प्रतिशत – 17.9 प्रतिशत) और कुकुरबिट केनोपी की तुलना में उनकी शेडिंग की डिग्री भी अधिक पाई गई।

यूरोमाइसेस वाइसिया-फाबा द्वारा उत्पन्न किए गए रतुवा रोग को तथा पीला मोजेक रोग को भारत में पहली बार फाबा बीन का संक्रमण करते हुए पाया गया। नागालैंड में कसावा किस्म 'श्री विजय' को मोजेक वायरस के प्रति सहिष्णु पाया गया।

मेघालय में जरबेरा हाइब्रिड आरसीजीएच-12 में प्रति पादप प्रति माह सबसे अधिक पुष्प संख्या (7.09) पाई गई और उनकी वेस लाइफ 6.84 दिन थी।

मेघालय में जायगेनिड प्रोक्राईडायन जीनस अरटोना (अमूरिया) वाकर की नई प्रजातियां पाई गईं। प्राथमिक परिणामों में यह पाया गया कि मणिपुर में ट्री बीन में समय से पहले फल झड़ जाने के लिए आलमोड मौथ (काइजा काउटेला) जिम्मेदार था। मिली बग, पैरापुटो थिएकोला (ग्रीन) को सिक्किम में बड़ी इलायची का संक्रमण करते हुए पहली बार पाया गया। मेघालय में घरेलू मधुमक्खियों तथा उनकी फोरेजिंग गतिविधियों को संरक्षित करने के लिए एक नीम आधारित संरक्षण पद्धति विकसित की गई।

मेघालय से फल को संक्रमित करने वाली टेफरिटिड मक्खी की 10 प्रजातियों की पहचान कर आण्विक स्तर पर उनका लक्षणवर्णन किया गया। बैक्ट्रोसेरा प्रजाति 1, जो कि बी. एथरियोबेसिस और बी. रुलेन्सिस की तरह दिखाई देता है, को भारत में पहली बार पाया गया। ब्राकोनिड तथा साइनिपिड वास्प की 6 प्रजातियों को अमरुद में ओरियंटल फ्रूट पलाई का परिभक्षण करते हुए पाया गया। कोल फसल पारिस्थितिकी से 29 कीट और प्राकृतिक शत्रुओं के लिए डीएनए बारकोड पूरे किए गए। सिट्रस ट्रंक बोरोर, स्युडोनेमोफस वरस्टिगी में काफी ज्यादा आनुवांशिक विविधता पाई गई और प्राथमिक परिणामों में यह पाया गया कि पी. वरस्टिगी की भारत की समष्टि क्राइप्टिक प्रजातियां हो सकती हैं।

स्कैनिंग इलैक्ट्रॉन माइक्रोकोपी और आण्विक लक्षणवर्णन का प्रयोग करते हुए सोयाबीन (ग्लाइसिन मैक्स) पर एरिसाइफ डिफूसा के एनामोर्फ को और खासी संतरे (सीट्रस रेटिकुलेटा) पर एरिसाइफ क्वेरीस्कोला के एनामोर्फ को रिपोर्ट किया गया। त्रिपुरा की बीबीटीवी समष्टि की गुच्छन प्रवृत्ति तथा आनुवांशिक विविधता से प्रशांत-भारतीय महासागर (पीआईओ) समूह के समान पैटर्नों के अधिकतर प्रतिनिधि वियुक्तों की आकारिकी एक समान पाई गई। सोयाबीन में पीला मोजेक रोग से संबंधित पीला मोजेक वायरस की पहचान कर उसका लक्षणवर्णन किया गया। मेघालय में पाया गया पीला मोजेक रोग एमवाईएमवी डीएनए B रिक्म्बीनेन्ट के साथ एमवाईएमआईवी डीएनए A से सम्बद्ध है। केले के सिगाटोका रोग कॉम्प्लेक्स के तीन रोगजनकों की

पहचान के लिए एक त्वरित एवं प्रजाति विशिष्ट आण्विक डायग्नोस्टिक टूल विकसित किया गया।

जंगली खुम्ब की लगभग 32 विभिन्न प्रजातियों की पहचान की गई और खाद्य खुम्ब 'स्कीजोफाइलुम काम्यून' की अरुणाचल प्रदेश में पहली बार खेती की गई। मिजोरम में पी. फ्लोरिडा की खेती के लिए जंगली केले की पत्तियों को सर्वश्रेष्ठ वैकल्पिक सामग्री के रूप में पाया गया।

एएमएफयू द्वारा कुल 102 मौसम पूर्वानुमान प्राप्त किए गए तथा 96 एएस बुलेटिन तैयार कर ग्रामीण कृषि मौसम सेवा के तहत किसानों को वितरित किए गए। मशीन की उपयुक्तता और दक्षता को बढ़ाने हेतु धान श्रेणर एवं क्लीनर का उन्नयन किया गया। पहाड़ी क्षेत्रों में संकुचित टीलों पर पावर टिलर चालित बीज ड्रिल एवं हल्के वजन वाले पावर टिलर पर साध्यता परीक्षण किए गए। किसानों के खेतों में धान ड्रम सीडर, स्वचालित रीपर, कोनोवीडर, पोस्टहोल डिगर, हस्तचालित विनोवर तथा पावर वीडर पर एफएलडी आयोजित किए गए। कुल 1939 कृषि औजार एवं उपकरणों का फेब्रिकेशन किया गया और प्रतिवेदित अवधि के दौरान विभिन्न संगठनों और किसानों को उनकी आपूर्ति की गई।

सूअरों के लिए स्व जीव प्रजनन तकनीक का मानकीकरण किया गया। असम पहाड़ी बकरियों की विशिष्ट पहचान की पुष्टि करने हेतु उनका फिनोटाइपिक एवं जीनोटाइपिक लक्षणवर्णन किया गया। उमियम में एक हाइजेनिक मांस प्रसंस्करण इकाई स्थापित की गई। मेघालय के नेकड नेक वाले चूजे में एक जीनप्ररूप तथा सामान्य फीदर वाले चूजों में दो जीनप्ररूपों की पहचान की गई। उमियम की कृषि जलवायु स्थितियों के तहत एमू पक्षियों के प्रजनन गुणों में सुधार लाने तथा कुक्कुट पक्षियों में जलवायु अनुकूलनशीलता के लिए फीडिंग कार्यनीति का इष्टतमीकरण किया गया जिसके लिए उनके आहार अनुपूरण में हल्दी और रोसेल पाउडर मिलाया गया।

री-भोई जिले में जेपनीज़ एनसेफालिटिस की काफी बहूलता पाई गई और दूध के नमूनों से गैर-ट्यूबरकुलोस मायकोबैक्टीरिया को अलग किया गया। पोरसीन वायरल रोगों पर किए गए आण्विक अध्ययनों में पोरसीन सिरको वायरस 2 के लक्षण पाए गए। पोरसीन सिरको वायरस और पोरसीन पारवो वायरसों के लिए रियल टाईम पीसीआर आधारित क्वांटिटिव ऐस्से का इष्टतमीकरण किया गया। घरेलू पादप (रोसेल) की एंटीकंसर गतिविधि पर किए गए अध्ययनों में यह पाया गया कि एपोप्टोसिस को सेल कल्चर सिस्टम में सफलतापूर्वक अवरोधित किया गया। घरेलू पादप अर्कों के साथ सम्बद्ध सिल्वर नैनोपार्टिकल की ग्रीन सिंथेसिस तकनीक का सफलतापूर्वक मानकीकरण किया गया। एरोमोनस प्रजाति के लिए जीवाण्विक रोगाणुजनक के तुलनात्मक जिनोमिक मानचित्र बनाए गए।



स्वाइन कोसिडिया की आकारिकीय दृष्टि से पहचान करते हुए *इमेरिया* की विभिन्न प्रजातियों की मौजूदगी पाई गई। मेघालय में *क्राइप्टोस्पोरिडियम* प्रजाति, *गियारडिया इनटेस्टीनेलिस*, *एन्टामोइबा पोलेकी*, *इमेरिया परमिनुटा*, ई. *सेरडोनिस* तथा ई. *स्पीनोसा* जैसे प्रोटोजोन परभक्षियों को सूअरों में पहली बार पाया गया। मेघालय में कुक्कुट में गेस्ट्रोइन्टेस्टीनल परजीवी संक्रमण सबसे अधिक पाया गया (68 प्रतिशत)। उत्तरी सिक्किम की उच्च तुंगता वाले क्षेत्रों में डेरी पशुओं में प्रसव के बाद मादा मद चक्र अंतराल (पोस्टपार्टुम इंटरवल) सबसे ज्यादा पाया गया और 'मादा मद चक्र (एनोस्ट्रस)' को सूअरों में कम प्रजनन के लिए मुख्य कारण पाया गया। वैज्ञानिक कुक्कुट और शूकर उत्पादन पर 12 प्रशिक्षण एवं प्रदर्शन आयोजित किए गए जिससे अरुणाचल प्रदेश के 148 किसान लाभान्वित हुए। नागालैंड, अरुणाचल, असम और मेघालय में लाभार्थियों को कम दरों पर कुल 39,044 चूजे और 541 पिगलेट वितरित किए गए। त्रिपुरा ब्लैक, रंगीन ब्रायलर तथा देहलम रेड की क्रासिंग कराकर दो किस्म के चूजे विकसित किए गए।

मेघालय के विभिन्न किसानों के तालाबों में परभक्षी मछली रोग 'अरगुलोसिस' को पहली बार पाया गया। मेघालय में *लेबियो गोनीयस* फिंगरलिंगों से सेपरोलेगनाइसिस रोगों को पहली बार पाया गया और यह रोग अगस्त माह तक जारी रहा। पेंगबा (*ऑस्टियोब्रेमा बेलनगेरी*) एडवांस फ्राई कल्चर के विकासमूलक गुणों का अध्ययन विभिन्न भंडारण सघनताओं के तहत किया गया। माइटोकान्ड्रियल डीएन के सीओआई जीन के आधार पर *पेथियामेनिपुरेन्सिस* और *पुन्टियस चोला* तथा पी. *सोफोरे* का आण्विक स्तर पर लक्षणवर्णन किया गया और उनका वर्गिकी संबंध निर्धारित किया गया। त्रिपुरा में स्टेन्डेड फिंगरलिंगों और कान्ला (*नोटोप्टेरस नोटोप्टेरस*) कल्चर का प्रयोग करते हुए बत्तख एवं मछली पालन का प्रदर्शन दिखाया गया। त्रिपुरा के 380 किसानों को कुल 255000 फिंगरलिंगों का वितरण किया गया। *लेबियो बाटा* मछली में जीवाण्विक संक्रमण को कम किया गया जिसके लिए उनके प्रति किलो आहार में 50 ग्राम चिटोसन मिलाया गया।

मणिपुर में झूम की खेती के सामाजिक आर्थिक एवं पारंपरिक गतिकियों पर किए गए अध्ययन में यह पाया गया कि अबोरिजनल इनपुई जनजाति अपनी मुख्य आजीविका के लिए प्रमुख रूप से झूम की खेती करती है जिससे उन्हें अन्य सहायक आय के अलावा, प्रति परिवार प्रति वर्ष 35,000 रूपयों की औसत आय प्राप्त होती है। *कार्टनग्रेना एलोयूनु* मेघालय के हावोचांग गांव के इनपुई जाति के लोगों का एक पारंपरिक त्यौहार है जिये झूम की खेती के लिए वन कटाव/ वन साफ-सफाई के समय पर मनाया जाता है, जिसे सामान्यतः अच्छे फसल उत्पादन के लिए खेतों को 10-13 वर्षों तक की अवधि के लिए खाली छोड़कर पुनः खेती

आरंभ करने के समय पर मनाया जाता है। मेघालय, नागालैंड और त्रिपुरा राज्यों में कार्यान्वित जनजातीय उपयोजना (टीएसपी) कार्यक्रमों के प्रभाव मूल्यांकन पर किए गए अध्ययन में यह पाया गया कि प्रौद्योगिकी प्रदर्शन को वर्तमान कृषि प्रणाली के साथ समेकित किए जाने की जरूरत है ताकि उसका प्रभाव अधिक पड़े और प्रौद्योगिकी प्रदर्शन को मात्र एक औपचारिकता के रूप में नहीं लिया जाना चाहिए। अरुणाचल प्रदेश में एनएमएसएचई के तहत 6 फील्ड प्रदर्शन इकाइयां स्थापित की गईं।

'ग्रामीण कृषि मौसम सेवा' (जीकेएमएस) के तहत अरुणाचल प्रदेश के 16 जिलों में मौसम के बारे में सलाह भेजी गई और 2 किसान जागरूकता कार्यक्रम आयोजित किए गए जिनसे 112 किसान तथा अन्य हितधारक लाभान्वित हुए। मिजोरम में खुम्ब उत्पादन पर एनआईसीआरए, एनएमएसएचई, टीएसपी, जीकेएमएस, एआईसीआरपी के तहत कुल 23 प्रशिक्षण कार्यक्रम आयोजित किए गए।

जल दबाव स्थितियों के तहत भालुम 1 और भालुम 3 की तुलना में, आरसीपीएल 1-412 तथा IURON 514 का प्रदर्शन काफी खराब पाया गया। मक्के के 14 स्थानीय जीनप्ररूपों में से, *थाराथई*, *खामाथई* व्हाइट, *चेचाटा* और *वेमिनफेई* को शीतकालीन स्थितियों के लिए अति उपयुक्त पाया गया। संवर्धित तापमान और प्रतिबंधित सिंचाई के तदवशिष्ट प्रतिधारण के साथ टिलेज उपचारों से मृदा के एसओसी में काफी वृद्धि हुई। उर्वरीकरण कार्यानेटिक अध्ययनों में यह पाया गया कि अनुकूलनीय नमी परिवेश में बायोचार का उर्वरीकरण होता है। मेघालय की स्थितियों के तहत मुख्य खरीफ फसल की कटाई करने के पश्चात यदि खेती में जल्दी बुवाई कर ली जाती है तो यह देखा गया है कि अवशिष्ट मृदा नमी के तहत सरसों की फसल बहुत अच्छी होती है। टिलेज विधि (पारंपरिक-सीटी, अपचयित-आरटी और शून्य जुताई-एनटी) में एनटी (3.31 हैक्टेयर प्रति हैक्टेयर) में तथा उसके बाद आरटी (3.28 टन प्रति हैक्टेयर) में चावल की सर्वाधिक उपज प्राप्त की गई और सीटी (3.03 टन प्रति हैक्टेयर) में न्यूनतम चावल उपज दर्ज की गई। रोगों के प्रकोप में कमी आने के पश्चात डीप लिटर हाऊसिंग में सूअरों का विकास दर बहुत अच्छा पाया गया। रसोई में प्रतिबलित आहार के अपशिष्ट को सूअर को दिए जाने से सूअरों का विकास दर बेहतर पाया गया। वर्ष 2015-16 के दौरान उमियम में जलवायु अनुकूल कृषि पर 6 किसान प्रशिक्षण और 44 प्रशिक्षक प्रशिक्षण कार्यक्रमों का आयोजन किया गया जिनसे क्रमशः 180 किसान एवं 1234 प्रशिक्षक लाभान्वित हुए। जनजातीय उपयोजना (टीएसपी) के तहत वर्ष 2015-16 के दौरान विभिन्न आजीविका कार्यक्रमों के आयोजन से उत्तर-पूर्वी राज्यों के 17130 से भी अधिक जनजातीय किसान लाभान्वित हुए। उत्तर-पूर्व के विभिन्न जनजातीय गांवों में 491 भौतिक परिसंपत्तियां नामतः कम लागत वाले पॉलीहाऊस,



कम लागत वाले सूअर शेड, कम लागत वाले कुक्कुट शेड, कम लागत वाले गाय शेड, जलकुंड/जलसंचयन संरचनाएं आदि उपलब्ध कराये गये। जनजातीय किसानों को विभिन्न कृषि निविष्टियां नामतः अनाज तथा दलहनी फसलों के 56 टन बीज, सब्जी फसलों के 180 कि.ग्रा. बीज, फल के 80,000 पौध, 20,000 ग्रास स्लिप, 25 टन अदरक बीज राइजोम आदि वितरित की गई। इन निविष्टियों के अलावा, 1280 कि.ग्रा. मशरूम स्पॉन, 2 इनोकुलेशन हुड और दो प्रेशर कुकर भी किसानों को वितरित किए गए जिससे कि मशरूम की खेती का प्रसार किया जा सके और किसानों की आय बढ़ायी जा सके।

जनजातीय किसानों की आजीविका में सुधार लाने हेतु उन्हें कुल 892 उन्नत नस्ल वाले पिगलेट, 85041 कुक्कुट चूजे, 296 बत्तख, 12 खरगोश, 5 दूधारू गायें, 34 बकरियां, 10000 केंचुवे, 25000 मछली बीज एवं 220217 मछली फिंगरलिंग, 18198 कि.ग्रा. पशुघन एवं कुक्कुट आहार, 4180 कि.ग्रा. आहार

अनूपूरण, 3000 कि.ग्रा. मछली आहार भी वितरित किया गया। इसके अलावा, 200 कुक्कुट चूजों का टीकाकरण किया गया और विभिन्न पशु रोगों के प्रबंधन के लिए उन्हें दवाईयां भी वितरित की गई। जनजातीय किसानों को बड़ी संख्या में बैकपैक स्प्रेयर, मक्का शेलर, शहद रखने के लिए डिब्बे, एडजेस्टेबल पंक्ति मार्कर, यू-ब्लैड वीडर, कीट जाल, हैमर मिल ग्राइंडर, सीलिंग मशीन आदि भी वितरित किए गए। कृषि के विभिन्न क्षेत्रों में (यानी फसल उत्पादन, पशु उत्पादन एवं प्रबंधन, खुम्ब उत्पादन, बागवानी फसलों आदि का उत्पादन एवं प्रबंधन) किसानों के क्षमता विकास के लिए प्रशिक्षण (173 कार्यक्रम), जागरूकता कार्यक्रम (64) तथा प्रदर्शन कार्यक्रम भी आयोजित किए गए जिनमें 330 हैक्टे. से भी अधिक क्षेत्रफल को शामिल किया गया। जनजातीय किसानों के हित में कृषि प्रौद्योगिकियों के प्रदर्शन के लिए दो किसान मेलों को भी आयोजन किया गया।

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## EXECUTIVE SUMMARY

The total annual rainfall of Umiam was 2551 mm which was about 156 mm higher than normal. The total annual pan evaporation recorded was 857 mm. The mean maximum temperature varied between 26.6° C to 29.0° C for all the months except November to February. Rice genotype ‘TRC 2013-2 / IET 23947’ of Tripura has been qualified for CVIC (Central Variety Identification Committee), for the states of Uttarakhand, Haryana, West Bengal, Madhya Pradesh, Maharashtra and Kerala under irrigated or rainfed shallow lowland ecosystem. About 2.7 tonnes breeders seed of five rice varieties viz., Tripura Khara Dhan 1, Tripura Khara Dhan 2, Tripura Hakuchuk 1, Tripura Hakuchuk 2, Tripura Aus Dhan was produced. A new medium duration semi-dwarf, fertilizer responsive high yielding lowland rice variety RC Maniphou-13 (yield potential of 7-8 t/ha and resistant to neck blast) was released by “State Seed Sub-Committee on Crop Standards, Notification and Release of Varieties, Govt. of Manipur”. Two rice genotypes RCM-32 and RCM-33 were nominated for AICRIP 2016 under IVT MH trial. In DUS characterization of 99 rice varieties of farmers of Manipur, two varieties viz., *Chahao* and *Chahao amubi* were found to be distinct. Rice variety, Bhalum-3 and Gomati were found best under upland and lowland conditions of Mizoram, respectively. About 42 local rice germplasm lines (23 WRC And 19 *jhum* rice) were collected and characterized for different characters at Arunachal Pradesh. Rice varieties Bhalum-3, Rukhatang and Chakko Youh were found promising in Nagaland. In Sikkim, local rice cv., Krishna Bhog recorded significantly higher grain yield (2.94 t/ha) under system of rice intensification (SRI) method. Nutrient uptake and water productivity were found highest in local rice genotype ‘RCPL-412’. Hydroponically-grown rice plants shown diverse root morphology and same has been correlated with the presence of *Pup 1* QTL. Eukaryotic Translation Initiation Factor 4A (*eIF-4A*), isolated from *Pisum sativum*, was up-regulated when exposed to different abiotic stresses which will help in further understanding the mechanism of abiotic stress tolerance.

A highly efficient protocol for callus induction and plant regeneration has also been developed in maize

at Umiam. Out of 96 maize lines in replicated trials, 30 lines were found to be resistant to Turicum leaf blight at Umiam. Lemon grass oil @ 7 ml/kg recorded least weevil damage in stored maize. Maize variety “VL Babycorn-1” was found promising in Arunachal Pradesh. Seventy landraces of maize were collected from Mizoram and characterized at the molecular level. In *situ* residue management experiments revealed increased yield of maize (32.2 %) and mustard (15.8 %) in “Maize Stalk Cover (MSC) + Poultry manure + Ambrosia” @ 5 t/ha as compared to control at Umiam. Finger millet variety ‘VL-324’ was found high yielder in agro-climatic conditions of Sikkim.

Cultivation of the lentil crop was demonstrated over 60 ha area comprising 62 farmers at Thoubal, Imphal West and Imphal East districts of Manipur. The highest grain yield of green gram was recorded from TRCM 151-1 (1.01 t/ha). Two lentil varieties viz., DPL-62 and DPL-15 recorded higher grain yield (0.71 t/ha) in Mizoram. Toria cv. ‘TS-36’ and green gram genotype ‘TRCM-1-2-2’ were found to be high yielding in Nagaland. The varieties ‘TRCM 314-1’ of green gram and ‘VL-42’ of field pea were found promising in Tripura.

Mid of October was found to be best sowing time for toria in Arunachal Pradesh. Seed yield of rapeseed-mustard ranged from 1.26 t/ha in M-27 to 0.94 t/ha in P-27 in lowland rice fallow under no till system in Mizoram. Sunflower variety ‘DRSH-1’ recorded the highest yield in agro-climatic conditions of Sikkim. The variety ‘HNG-10’ of groundnut was found promising in Tripura. Under AICRP, total 75 soybean genotypes were screened against rust, of which 2 genotypes namely EC 241778 and EC 241780 were found absolute resistant continuously for three years. Two sprays of thiophanate methyl fungicide @ 0.1% at 55 and 75 DAS were found to be very effective for the management of pod blight disease of Soybean.

Rice-fenugreek-maize cropping recorded the maximum (82.2 t/ha) system productivity in Sikkim. Zero tillage with 100% recommended dose of Nitrogen (RDN) through organic sources recorded maximum system productivity (14 t/ha) and production efficiency (28.9 kg/ha/day) in maize-pea cropping system. Combinations of Biochar@2 t/ha along with 100%



RDN through FYM recorded higher grain yield of maize (3.82 t/ha).

Among the four agri-horticulture systems with groundnut as under story crop, pear + groundnut produced maximum Rice Equivalent Yield (REY) of 7.89 t/ha. Evaluation of eleven promising genotypes of *Mucuna pruriens* revealed that, WBNMP 03 has highest seed yield (1.96 t/ha). Seed source from Kezanglwa resulted in maximum height (10.25 m) and collar diameter (16.95 cm) in a progeny evaluation of seven seed sources of *Perkia roxburghii*. Packaging of *Garcinia lancifolia* in non-perforated LDPE and HDPE were found extending shelf life significantly.

In *jhum* improvement, sowing of rice in lines 25 cm apart across the slope as well as dibbling resulted in significant enhancement in rice yield as compared to broadcasting under Meghalaya conditions. In different land use systems of Mizoram, soil pH was found maximum in abandoned *Jhum*, available N and P were highest in oil palm and organic carbon was highest in the forest. Under Flagship programme on the Improvement of *jhum* through horticulture interventions in Arunachal Pradesh, planting materials of orange (*var.* Khasi mandarin), banana (*var.* Grand naine), pineapple (*var.* Kew) and improved rice varieties like Bhalum-1, 2, 3, maize, pulses, oilseeds, vegetable seeds and tuber crops have been distributed covering 35 ha area. The combined application of *Trichoderma harzianum*, *Pseudomonas fluorescens*, and the mustard oil cake was effective against major diseases of ginger in the *jhum* farming of Nagaland.

In farming system research, eight micro watersheds comprising of 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 a long term basis. Amongst the IFS studied, alder based IFS, alder+colocasia+EFY performed better in sequestering organic carbon as well as other fractions of organic carbon as compared to other crop combinations under the IFS at Manipur.

In organic farming, raised and sunken bed is a useful technology for effective land and water management in case of lowland and inter-plot water harvesting in upland to increase cropping intensity in Meghalaya. Maize varieties 'DA 61A' and 'RCM-76' and French bean 'Naga local' followed by 'RCM-FB-18' were found promising in NEH Region under organic production system.

In conservation agriculture, No-till (NT) treatment recorded higher rice yield (3.75 t/ha) as compared to conventional tillage (CT) (3.69 t/ha). NT plays an important role in improving crop productivity, sustaining soil fertility and conserving natural resources in both upland and lowland condition. Among the different cropping systems studied in sloping land, the fodder crop based system was most effective in reducing soil and nutrient loss in hill agriculture. Zero tillage with residue retention resulted in significantly higher yield of rice (17.2%) and succeeding *rabi* crops, Mustard (34.6%), Pea (16.4%) and Buckwheat (27.4%) as compared to conventional tillage with residue removal at Umiam.

The liming potential of poultry manure was found to be maximum (CCE 449 kg/t of the product) as compared to the other organic manures because of high alkalinity. Among the organic manures, performance of poultry manure (as substitute of lime) was superior over other manures in increasing the yield of mustard at Umiam. Rhizosphere soil contained a significantly higher quantity of different fractions of soil organic carbon than that of non-rhizosphere soil at Umiam. Pesticide formulations of Carbendazim (Crossin 50% W.P.), and Carbofuran (Furasac 3% G Encapsulated), significantly inhibited root length of *Allium cepa* at 80ppm.

Utility of mehlich-3 as a multi-nutrient extractant (universal extractant) was established for the acidic soils of northeast India using both cereal (Maize) and pulse (Pea) crops. Critical limits of P, Zn and B availability in soils and their concentrations in plants were also established using Mehlich-3 extractants. Citric acid and PSB formulations were found to be most effective in improving soils 'P' availability, as well as crop growth and yield on the acid soil. Application of vermicompost @ 2.5 t/ha recorded 23% higher soil organic carbon under field conditions of Sikkim. Plant available NPK and accumulated Boron were significantly higher in *Alnus*-large cardamom based agroforestry system in Sikkim. Total 1250 soil samples from five districts of Manipur have been tested and soil health cards were distributed to the farmers. The rice germplasm 'Lalgura' was found to be highly efficient in phosphorus utilisation at Tripura.

Khasi mandarin juice and chow-chow pulp in 9:1 ratio was found suitable for ready to serve (RTS) beverage. Deficiency of N and P elements were the main cause of declining of citrus orchards in Nagaland. Guava variety 'RCGH-4' was found most promising in terms of yield in Nagaland.



The standardization of protocol for the preparation of guava nectar, spread and cheese completed. In low cost polyhouse, application of lime (250 kg/ha) + polymulch recorded highest fruit yield (2.48 kg/plant) in cucumber and King Chilli (647g/plant). Chow-Chow germplasm (74) showed a wide range of variations in fruit weight, vitamin-C, reducing sugar and phenol content. Molecular studies showed very high percentage of polymorphic fragments in the light green group. The slice thickness of 0.5 cm was found suitable in preparation of dehydrated chow-chow shreds. ACP-ELISA based immunodiagnosics were developed for a new *Potyvirus* associated with yellow mottling and dappled fruit disease of passion fruit in North East India. Maturity indices were standardized for 'Kew pineapple' and accordingly fruit should be harvested at 151 to 160 days after flowering in Arunachal Pradesh conditions. Hand pollination between 10 am to 12 noon showed a good response in producing high yield of good quality Kiwifruit in Sikkim.

Total 106 germplasm of chilli were evaluated for yield traits and characterized using 47 SSR markers. Within limited sample size, molecular analyses detected 205 alleles with an average of 4.36 alleles per locus in chilli and CAMS 91 (1.956) was appeared to be the most informative marker. Nine alleles were found unique in Dale chilli (*Capsicum chinense*) and five were unique in Bird eye chilli (*C. frutescens*). Two alleles were also detected only in King chilli (*Capsicum chinense*). Cluster analysis revealed that the king chilli is closer to Bird's eye chilli. Invasive mealybug, *Formicococcus polysperus* and *Phenacoccus parvus* were reported feeding on turmeric and Naga king Chilli, respectively. Fruit fly species, *Bactrocera dorsalis* was the dominant pest of two landraces of Bird's eye chilli in Mizoram. Moreover, *Bactrocera tau* (Walker) was recorded the first time as a pest of chilli in Mizoram. The endophytic bacteria isolate 'KEB-7' from Nagaland was found to be most effective against *Colletotrichum capsici*. Out of 20 isolates of endophytic bacteria from king chilli from Nagaland.

Use of drip irrigation and black polythene mulching in tomato cultivation resulted in increased in yield (1.77 t/ha) of tomato over farmers practice (1.15t/ha). In brinjal, *Solanum torvum* was closer to *S. khasianum* and *Solanum torvum* was found highly resistant against bacterial wilt.

Sixty six germplasms of tuber crops were characterized using SSR markers. Tajiting Purple and Tajiting White germplasm of *Xanthosoma* spp. cultivated for their peduncle were grouped together

with the Chigi (unidentified) cultivated for the leaves and peduncle and were most diverse from the other species. Mydkur (turmeric) and Nadia (ginger) recorded highest fresh rhizome weight/plant 542.76g and 562.88g, respectively. Promising clones of turmeric (RCMT-19) and ginger (RCMG-1) have been identified for Manipur condition. Seed rhizome size of turmeric '40-60 g' was found most suitable in Arunachal Pradesh. The rhizome yield of turmeric was significantly higher (15.2%-17.9%) with the increasing degree of shading from cucurbit canopy.

Rust disease caused by *Uromyces vicea-faba* and yellow Mosaic disease were reported for the first time infecting Faba bean in India. Cassava variety 'Shree Vijaya' was found to be tolerant to mosaic virus in Nagaland.

Gerbera hybrid RCGH-12 recorded highest no. of flowers/plant/month (7.09 no.) with a vase life of 6.84 days in Meghalaya.

A new species of the zygaenid procridine genus *Artona* (Amuria) Walker have been discovered from Meghalaya. Preliminary results indicated that Almond moth (*Cadra cautella*) was found responsible for premature fruit drop in tree bean in Manipur. Mealy bug, *Paraputo theaecola* (Green) recorded first time feeding on large cardamom from Sikkim. A need based conservation methodology was developed for the protection of native honey bees and their foraging activities in Meghalaya.

Ten species of fruit feeding tephritid flies were identified from Meghalaya and characterized at molecular level. *Bactrocera* spp.1 which resembles similarities with *B. aethriobasis* and *B. ruiliensis* has been reported first time from India. Six species of braconid and cynipid wasps were found parasitizing oriental fruit fly in guava. DNA barcodes for 29 insect's pests and natural enemies from cole crops ecosystem have been completed. Significant genetic variation was observed in citrus trunk borer, *Pseudonemophas versteegi* and preliminary results indicated that Indian populations of *P. versteegi* could be a cryptic species.

Anamorph of *Erysiphe quercicola* on Khasi mandarin (*Citrus reticulata*) and anamorph of *Erysiphe diffusa* on soybean (*Glycine max*) was reported using scanning electron microscopy and molecular characterization. The clustering pattern and genetic diversity of BBTV population from Tripura suggested monophyletic origin of majority of representative isolates from a common ancestor of Pacific-Indian Oceans (PIO) group. Yellow mosaic virus associated



with yellow mosaic disease in soybean was identified and characterized. Yellow mosaic disease in Meghalaya is an association of MYMIV DNA A with a recombinant MYMV DNA B. A rapid and species-specific molecular diagnostic tool has been developed for the detection of three pathogens of Sigatoka disease complex of banana.

About 32 different species of wild mushroom were identified and edible mushroom '*Schizophyllum commune*' was successfully domesticated for the first time in Arunachal Pradesh. Wild banana leaves appeared to be the best alternative material for growing *P. florida* in Mizoram.

Total 102 numbers of weather forecasts were received by the AMFU and 96 numbers of AAS Bulletins were prepared and disseminated to the farmers under *Gramin Krishi Mausam Sewa*. Paddy thresher cum cleaner was modified to improve the suitability and efficiency of the machine. Feasibility trials were conducted on power tiller driven seed drill and light weight power tiller in narrow terraces of hills. FLD of paddy drum seeder, self propelled reaper, cono weeder, posthole digger, hand operated winnower and power weeder were conducted in the farmer's field. Total 1939 farm tools and equipments were fabricated and supplied to different organizations and farmers during the reported period.

*In vitro* fertilization technique standardized for pigs. Phenotypic and genotypic characterization of Assam Hill goats was done to claim its unique identity. The hygienic meat processing unit has been established at Umiam. One genotype in Naked Neck and 2 genotypes in Normal Feathered chicken of Meghalaya have been identified. Reproductive traits of Emu birds under agro-climatic conditions of Umiam improved feeding strategy was optimized for climate resilience in poultry birds by incorporating turmeric and roselle powder in the form of feed supplement.

*Japanese encephalitis* was found to be prevalent in the Ri Bhoi district and non-tuberculous Mycobacteria were isolated from milk samples. Molecular studies on porcine viral diseases identified emerging types of porcine circovirus 2. Real-time PCR based quantitative assay was optimized for porcine circo virus and porcine parvo viruses. Studies on the anticancer activity of indigenous plant (roselle) successfully inhibited apoptosis in cell culture system. The green synthesis technique of silver nano-particles tagged with indigenous plant extracts has been successfully standardized. Comparative genomics of

bacterial pathogen yielded genomic maps for *Aeromonas* spp.

Morphological identification of swine coccidia revealed presence of different species of *Eimeria*. Protozoan parasites like *Cryptosporidium* sp., *Giardia intestinalis*, *Entamoeba polecki*, *Eimeria perminuta*, *E. cerdonis* and *E. spinosa* were recorded for the first time from pigs in Meghalaya. Gastrointestinal parasitic infections in poultry were highest in Meghalaya (68%). Postpartum interval was found quite high in dairy cattle at higher altitude of North Sikkim and 'anoestrus' was found to be one of the major infertility problems. Twelve training cum demonstrations on scientific poultry and piggery production were organized benefitting 148 farmers in Arunachal Pradesh. Total 39,044 chicks and 541 piglets were distributed to the beneficiaries at subsidized rate in Nagaland, Arunachal, Assam and Meghalaya. Dual variety of chicken was developed by crossing of Tripura Black, Coloured Broiler and Dahlem Red.

Parasitic fish disease Argulosis was recorded for the first time from different farmer's ponds of Meghalaya. Saprolegniasis diseases of *Labeo gonius* fingerlings reported first time from Meghalaya and this disease was prevalent during the month of August. Growth performance of Pengba (*Osteobrama belangeri*) advance fry culture was studied under different stocking densities. Three fish species viz., *Pethia manipurensis* and *Puntius chola* and *P. sophore* were characterized at molecular level based on COI gene of mitochondrial DNA and their taxonomic relationship determined. Duck cum fish farming using stunted fingerlings and kanla (*Notopterus notopterus*) culture was demonstrated at Tripura. Total 255000 fingerlings were distributed among 380 farmers of Tripura. Bacterial infection in fish, *Labeo bata* was significantly reduced by adding 50 gm chitosan per kg feed.

The study on 'Socio-Economic and Cultural Dynamics of *Jhum* Cultivation in Manipur' revealed that the aboriginal *Inpui* tribe follow *Jhumming* as the main source of livelihood fetching an average income of Rs. 35,000 per annum per family besides other subsidiary income. *Katangrana allounu* is a ritual of the *Inpui* tribe in Haochong village in Manipur observed during the stage of forest cutting/clearing for *Jhum* cultivation, which is normally practiced with a fallow period of 10-13 years for regeneration. The study on impact assessment of Tribal Sub Plan (TSP) Programmes implemented in the states of Meghalaya,



Nagaland and Tripura delineated that the technology demonstration needs to be integrated with an existing farming system to have more impact rather than segmentation approach. Six field demonstration units were established under NMSHE in Arunachal Pradesh

Under 'Gramin Krishi Mausam Sewa' (GKMS), meteorological advisories were provided in 16 districts of Arunachal Pradesh and two farmer's awareness programmes were conducted benefitting 112 farmers and other stakeholders. A total of 23 training programmes under NICRA, NMSHE, TSP, GKMS, AICRP on mushroom production were taken in Mizoram.

Under water stress conditions, rice genotype RCPL 1-412 and IURON 514 perform poorly compared to Bhalum 1 and Bhalum 3. Among fourteen local genotypes of maize, *Tharathei*, *Khamathei* white, *Chechata* and *Vaiminphei* were found to be well suited for cold conditions. Arka Rakshak, Arka Ananya, Arka Meghali, RC Manikhamenshinba-I, MCTR 4 and Megha Tomato-3 have been found to be promising tomato varieties under elevated temperature and restricted irrigation. A land use model was developed for hill slopes (30-40%) under Meghalaya conditions to enhance water and nutrient use efficiency through in-situ moisture conservation practices. The tillage treatments with residue retention significantly increased the SOC of soil. Mineralization kinetics study revealed that favorable moisture regimes trigger the mineralization of biochar. Mustard grows well under residual soil moisture if planted immediately after harvesting of the main *kharif* crop under Meghalaya conditions. Among the tillage practice (conventional-CT, reduced-RT and zero tillage-NT) maximum grain yield of rice was recorded with NT (3.31 t/ha) followed by RT (3.28 t/ha) and lowest in CT (3.03 t/ha). The growth rate of pig was found better in deep litter housing with reduction in incidences of diseases. Formulation of fortified feed from kitchen waste revealed better growth rate in pigs. Six farmer's

training and 44 trainer's training on climate resilient agriculture were organized at Umiam and six trainer's training at regional centers during 2015-16 which benefited 180 and 1234 farmers respectively.

Under Tribal Sub Plan (TSP), more than 17130 numbers of tribal farmers of north eastern states were benefitted during 2015-16 by various livelihood improvement programmes. Four hundred ninety one (491) numbers of different physical assets *viz.*, low cost polyhouse, low cost pig shed, low cost poultry shed, low cost cow shed, *Jalkund* /water harvesting structures etc. were provided in different tribal villages of the north east. Agricultural inputs *viz.*, 56 tonnes of cereals and pulse seeds, 180 kg seeds of vegetables, 80,000 seedlings, 20,000 grasses slips, 25 tonnes of ginger were distributed to the farmers. Apart from these inputs, 1280 kg of spawn along with pressure cookers, inoculation hoods, inoculation needles, spirit lamps, cotton rolls, etc. were also distributed among farmers for popularizing mushroom cultivation as a source of livelihood. A total of 892 nos. of improved breed of piglets, 85041 nos. of poultry chicks, 296 nos. of ducks, 12 nos. of rabbits, 5 nos. of milching cows, 34 nos. of goats, 10000 nos. of vermiworms, 25000 nos. of fish seeds and 220217 nos. of fish fingerlings, 18198 kg of livestock and poultry feed, 4180 kg of feed supplements, 3000 kg of fish feed were also distributed among the tribal farmers for livelihood improvement. Vaccinated 200 poultry chicks and distributed medicines for the management of various animal diseases. A large number of minor agricultural tools and other implements like backpack sprayer, maize sheller, honey bee box, adjustable row markers, U-blade weeder, insect traps, hammer mill grinder, sealing machines were also distributed among tribal farmers. A total of 173 nos. of Training, 64 nos. of awareness and demonstration programmes (covering >330 ha) were organized for capacity development in various fields of agriculture.







# 1. INTRODUCTION

**I**CAR Research Complex for NEH Region has been serving the North Eastern Hill Region of India since 1975. The institute has been constantly endeavouring to develop location specific technologies through its ten divisions at the headquarters at Umiam, Meghalaya and its six regional centers at the six hill states of the NE region. Through its 15 KVKs distributed in different states, the institute is delivering its technologies to a large number of farmers in the remote localities.

Institute is also taking significant role in teaching and guiding students from Central Agricultural University, Assam Agricultural University and other central and state universities. The institute is working on three flagship programmes viz, improvement of *jhum* cultivation, temperate horticulture and trans-boundary diseases during the XII Five Yearly Plan. A multi institutional and multi-disciplinary project on medicinal plants has been initiated to tap the rich medicinal resources of the NE region. Some competitive projects such as DBT, DST, NICRA, NHB and NMSHE, TSP, KIRAN, etc. are operational 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. About 15 AICRPs, 5 network and 15 collaborative projects are in operation. 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

- To undertake basic and applied research for delivering technologies based on sustainable farming system for different agro climatic and socio-economic condition
- To improve the productivity of crops, livestock and fishery.
- To act as a repository of information on natural resources, different farming and land use systems.
- To impart training on research methodology and application of improved technologies for enhancing agricultural productivity.
- To collaborate with the state departments for agricultural development in the region and testing and promotion of improved farming and land use systems.
- To collaborate with national and international agencies.
- To provide consultancy.



## LABORATORIES

The institute's headquarters at Umiam, is well equipped with laboratory facilities in all the nine divisions. Besides, a centre of Biotechnology and central laboratory at headquarter also has the state of art instruments for catering of research needs in different agricultural and horticultural crops. A post-harvest processing unit is in operation in agricultural engineering division. A well-equipped workshop is also in place for research and development, fabrication and repair of agricultural implements and tools in the division of agricultural engineering. 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
<b>Institute</b>			
RMP	1	1	-
Scientific	181	130	51
Technical	252	197	55
Administrative	129	97	32
Skilled Support	114	93	21
<b>Total</b>	<b>677</b>	<b>518</b>	<b>159</b>
<b>Krishi Vigyan Kendra</b>			
Scientific	15	10	5
Technical	165	152	13
Administrative	30	15	15
Skilled Support	30	27	3
<b>Total</b>	<b>240</b>	<b>204</b>	<b>36</b>

## BUDGET

Actual expenditure for 2015-2016 (in lakh)

Head	Non-plan		Plan	
	RE	Expenditure	RE	Expenditure
<b>A. Recurring</b>				
Establishment charges	4210.38	4210.39	0	0
Wages	1065.00	1064.37	0	0
Travelling allowances	50.00	50.00	49.06	49.06
Recurring contingencies	1461.58	1457.50	628.88	627.60
<b>Total A</b>	<b>6786.96</b>	<b>6782.26</b>	<b>677.94</b>	<b>676.66</b>
<b>B. Non- recurring</b>				
Works	0	0	351.04	350.61
Equipments	40.00	39.79	234.00	233.86
Information technology	0	0	26.76	26.76
Furniture & Fixture	5.00	4.36	31.18	31.18
Books	0	0	25.00	24.46
Livestocks	0	0	0	0
Other items (HRD)	0	0	26.82	26.39
Repair & maintenance	0	0	0	0
Pension	586.02	584.74	0	0
Loans & Advances	50.00	46.53	0	0
<b>Total B</b>	<b>681.02</b>	<b>675.42</b>	<b>667.98</b>	<b>666.87</b>
<b>C.TSP</b>	<b>0</b>	<b>0</b>	<b>1004.92</b>	<b>585.76</b>
<b>Total C</b>	<b>0</b>	<b>0</b>	<b>1004.92</b>	<b>585.76</b>
<b>Grand total A+B+C</b>	<b>7467.98</b>	<b>7457.68</b>	<b>2354.62</b>	<b>1955.68</b>



## LIBRARY

Nature of publication	No. of copies available
Books & Reports	29795
Back volumes of journals	11066
Foreign journals	Nil
Indian journals	85
News papers	16
Hindi books	4478
Magazines	7

## IT FACILITIES

IT facility of the institute include computer Lab having SAS installed on 10 computers The institute has perpetual license for SAS, SPSS and STATISTICA. AARC GIS software with workstation is also in place to carry out work on GIS and remote sensing. Online ARS-NET examination facilities developed at the Umiam are functional since 2012. The 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 net connectivity.

## IMPORTANT MEETINGS

### ICAR Regional Committee Meeting

The XXII meeting of the ICAR Regional Committee (Zone III) was held at the Pragna Bhawan, Agartala, Tripura during 22<sup>nd</sup> -23<sup>rd</sup> May 2015. Dr. Arvind Kumar, Dy. Director General (Education), ICAR highlighted the role of ICAR Research Complex for NEH Region in improving the agricultural growth



Fig 1. Inauguration of RCM by Shri Manik Sarkar, Hon'ble Chief Minister, Tripura

in the region. The Hon'ble Secretary DARE and Director General, ICAR, Dr. S. Ayyappan discussed the progress in all sectors of agriculture in the north east. The deficit in food grain, milk, meat, fish and eggs has reduced over the past decade. Dr Ayyappan emphasized on the importance of indigenous food and medicinal plants of NE region. Special emphasis was laid on the rich biological resources of the region. He suggested to continuously update the knowledge portal, KIRAN, to transfer available technology to initiate entrepreneurship.



Fig 2. Dignitaries on dias during XXII ICAR Regional Committee (Zone III) meeting at Agartala

### RAC Meeting

The Research Advisory Committee (RAC) meeting of ICAR Research Complex for NEH Region was held on 7<sup>th</sup> – 8<sup>th</sup> July 2015 at Umiam under the chairmanship of Dr K. R. Dhiman. Dr Nawab Ali, Dr Lal Krishna, Dr V.K. Mishra, Dr. Pradhuman Kumar and Dr S.K. Dhyani were the other members present in the meeting. Dr S. V. Ngachan presented the achievements and future programmes of the Institute. He made a mention about the release of 56 crop varieties by the institute over the past four decades



Fig 3. Research Advisory Committee



and emphasized the need for improvement of pulse production which is 71% deficient in the region. He highlighted about the efforts of the institute to improve pulse production in the region through development and release of three high yielding varieties of pulse crop. The role played by the institute in supplying quality planting materials and improved breeds of livestock and poultry to the farmers as well as to the state governments of the region was highlighted. The Director highlighted the achievements of NICRA project in the context of developing climate smart agriculture. All completed projects of institute were reviewed and suggestions were made for future research work.

### IRC Meeting

The meeting of the IRC was held on 9<sup>th</sup> July 2015. The meeting was chaired by Dr S. V. Ngachan. RAC members also attended the IRC meeting and gave valuable suggestions. Dr S. V. Ngachan gave a brief account of the achievements and future thrust areas of the institute. He emphasized the need for production of breeder as well as truthfully labeled (TL) seeds of various crops. During his speech, Dr Ngachan made a mention about the initiatives taken by the institute for developing seed storage facilities at headquarters and at all the regional centers of the institute. The role of the institute in production of organic seeds for the states of Meghalaya and Sikkim was also highlighted. In the backdrop of low production and productivity of oil seeds and pulse crops in the region, he suggested the scientists to explore the possibilities for expanding the area under these crops. He gave importance on developing mechanism for popularizing cultivation of these crops among the farmers of the region.



**Fig 4. Institute Research Committee**

## DISTINGUISHED VISITORS

### Hon'ble Prime Minister visits ICAR stall at Sikkim organic festival at Gangtok

Hon'ble Prime Minister, Shri Narendra Modi visited ICAR stall at Gangtok, while inaugurating the organic festival in Gangtok and declaring Sikkim as the first organic state in the country on 18<sup>th</sup> Jan 2016. Prior to the organic festival, Hon'ble Union Minister of Agriculture and Farmers' Welfare Shri Radha Mohan Singh along with Shri. Somnath Poudyal, Minister for Agriculture, Horticulture and AH, Govt. of Sikkim visited ICAR Research Complex for NEH Region, Sikkim Centre, Tadong on 17<sup>th</sup> Jan, 2016 and inaugurated the Administrative Building of the Centre. He interacted with the scientists and progressive farmers from different parts of Sikkim. Dr. S. V. Ngachan, Director, ICAR Research Complex for NEH Region, Umiam, Meghalaya was also present on this



**Fig 5. Hon'ble Prime Minister of India Shri. Narendra Modi visiting ICAR Stall during Sikkim Organic festival**



**Fig 6. Hon'ble Union Minister of Agriculture and Farmers Welfare, Shri Radha Mohan Singh releasing publications**



occasion. Besides, during the Organic festival, ICAR Research Complex, Umiam participated in the agricultural exhibition, which was inaugurated by Hon'ble Prime Minister of India Sh. Narendra Modi.

### Intersession Consultative Meeting on “Horticultural Development in India” held at Umiam.

On 15<sup>th</sup> February 2016, Hon'ble Union Minister for Agriculture & Farmers' Welfare Shri Radha Mohan Singh along with Dr. Sanjeev Kumar Balyan and Shri Mohanbhai Kundariya Hon'ble Ministers of State for Agriculture and Farmers Welfare, visited the ICAR Research Complex for NEH Region, Umiam, Meghalaya. The Union Minister, Shri Radha Mohan Singh chaired the meeting on *Horticulture Development in India*. The meeting was also attended by committee members and Hon'ble members of Parliament (Lok Sabha and Rajya Sabha). The Hon'ble ministers inaugurated the FATE (Facility for Air Temperature Enhancement) and CTGC (Carbon dioxide Thermal Growth Chamber) facilities at the Research Complex and interacted with farmers at the Institute. The Deputy Director General (Horticulture) Dr. Krishna Kumar was also present during the meeting along with scientists from different institutes.



**Fig 7. Hon'ble Union Minister of Agriculture and Farmers Welfare, GoI Shri Radha Mohan Singh, inaugurated the FATE and CTGC facilities**

### Hon'ble Minister of State for Agriculture and Farmers Welfare, visited ICAR Tripura Centre

The Hon'ble State Union Minister for Agriculture, Govt. of India, Shri Mohanbhai Kalyanjibhai Kundariya visited ICAR Tripura Centre and laid the foundation stone of All India Coordinated Research



**Fig 8. Hon'ble Minister of State for Agriculture and Farmers Welfare Shri. Mohanbhai Kundariya laid the foundation stone of AICRP on Pigs in Agartala, Tripura**

Project (AICRP) on Pigs at ICAR Research Complex Livestock Farm, Tripura Centre, Lembucherra, West Tripura on 16<sup>th</sup> October 2015.

### Visit of NITI Aayog Member

The Hon'ble member of the NITI Aayog, Mr. Yogesh Suri visited the Institute on 13<sup>th</sup> August, 2015 to have a glimpse on the technological developments in the context of agricultural scenario of NEH Region. Welcoming the gatherings, Dr S. V. Ngachan, Director of the institute briefed about the significant accomplishments of the institute. Mr. Yogesh Suri in his address briefed about the basic functioning of the NITI Aayog in the context of agricultural planning and development and also interacted with the scientists of the Institute regarding different issues and constraints in the field of agriculture and allied sectors.



**Fig 9. Shri. Yogesh Suri addressing to the Scientists**



## IMPORTANT EVENTS

### 42<sup>nd</sup> Foundation day

The ICAR Research Complex for NEH Region celebrated its 42<sup>nd</sup> Foundation Day on 12<sup>th</sup> January, 2016. Shri. Bhaskar Baruah, Retd. IAS, Ex- Secretary (Agriculture), Govt. of India and Ex-Principal Advisor to National Planning Commission for Agriculture. Environment and Forests, GoI graced the occasion as chief guest. In his Foundation Day speech, he said that the institute is a boon for the NEH region and emphasized on conservation agriculture, *Jhum* improvement and climate change. He urged the scientists to launch the first brown revolution on priority basis. He told “Farmers should not be mere passive recipients rather the champions of innovative technologies”. The Director of the institute Dr. S.V. Ngachan highlighted the significant accomplishments of the institute during the last four decades. On the foundation day, farmer- scientist interaction and field visits by the farmers was organized. The senior staff members who were retiring in 2016 were also



Fig 10 Dr. S. V. Ngachan, Director welcoming the participants on 42<sup>nd</sup> Foundation Day



Fig 11 Shri. Bhaskar Baruah, Retd. IAS, GoI addressing to the gathering

felicitated for their long and dedicated service to the institute

### National Seminar on Sustaining Hill Agriculture

A National Seminar on “*Sustaining Hill Agriculture in Changing Climate*” was organized by Indian Association of Hill Farming (IAHF) jointly with ICAR Research Complex for NEH Region at Pragna Bhawan, Agartala during 5-7<sup>th</sup> December ‘2015. The programme was inaugurated by His Excellency, Hon’ble Governor of Tripura, Shri Tathagata Roy. The dignitaries present in the inaugural ceremony were Prof A. K. Ghosh, Hon’ble Vice Chancellor, Tripura Central University, Dr. G.S. G. Ayyangar, Principal Secretary, Finance, Agriculture and Rural Development, Govt. of Tripura, Dr. P. Das, Former DDG (Agri Extension), ICAR, New Delhi, Dr. K. R. Dhiman, Former VC, YSPUH&F, Solan, Himachal Pradesh, Dr. U.C. Sharma, Vice President, International Commission on Water Quality and Dr. S.V. Ngachan, Director, ICAR Research Complex for NEH Region, Meghalaya and Chairman of National



Fig 12 His Excellency, Hon’ble Governor of Tripura, Shri Tathagata Roy is lighting the lamp to inaugurate National Seminar on Sustaining Hill Agriculture in Changing Climate



Fig 13 Soil Health cards were distributed among the Farmers by His Excellency, Governor of Tripura



Seminar. More than 200 delegates participated in National Seminar and various awards such as IAHF Fellow, Best research paper, Best M.Sc. and Ph. D Thesis etc were conferred and soil health cards were also distributed among the farmers of Tripura and Meghalaya.

### National Seminar on Integrating Agri-Horticultural and Allied Research

A National Seminar on “Integrating Agri-Horticultural and Allied Research for Food and Nutritional Security in the Era of Global Climate Disruption” and Farmers Fair was organized by ICAR Research Complex for NEH Region, Manipur Centre, Imphal during 4-6<sup>th</sup> March, 2016 at Imphal.



Fig 14. Dignitaries on the dias during National Seminar on Integrated Agri-Horticulture & Allied Research

### National Workshop on Strengthening Horticultural Development

The 1<sup>st</sup> Manipur National Horti Expo and National Workshop on “*Strengthening Horticultural Development for Enhancing Productivity, Quality and Sustainable Livelihood*” in collaboration with Department of Horticulture and Soil Conservation,



Fig 15. Dr S. V. Ngachan, Director ICAR addressing the gathering during national workshop

Government of Manipur and ICAR Research Complex for NEH Region, Manipur Centre, Imphal was during 11-13<sup>th</sup>, June 2015.

### Awareness programme on Protection of Plant Varieties and Farmers Rights

An awareness programme on “Protection of Plant Varieties and Farmers Rights” was organized at ICAR Research Complex, Umiam in collaboration with PPV & FRA, Government of India, New Delhi on 10<sup>th</sup> April, 2015. On this occasion, Chief Guest Shri. R. K. Mishra, Additional Commissioner, Ministry of Agriculture, GOI, New Delhi, Dr R. C. Agrawal, Registrar General, PPV & FRA, Govt. of India, New Delhi, Dr S. V. Ngachan, Director, ICAR Research Complex for NEH Region, Umiam and Dr A. K. Tripathi, I/c Director, ATARI, Zone III, Umiam were present. During the programme a MoU was signed between *Ka Synjuk Ki Hima Arliang-Wah* Umiam, Mawphlang Welfare Society, Mawphlangm Meghalaya and ICAR Research Complex NEH Region for commercial production and marketing of the “*Pig Bristle Technology*” developed by this institute.



Fig 16. Dr R. K. Mishra, Additional Commissioner, MoA addressing the gathering



Fig 17. Dr S.V. Nagchan Director showing signed MoU



### North Eastern Agro-climatic Zone Workshop

A one day workshop on “Developing Roadmap for Agricultural Development in Eastern Himalayan Region” was organized by ICAR Research Complex for NEH Region, Meghalaya on 29<sup>th</sup> September, 2015 under the chairmanship of Dr N. S. Rathore, DDG (Education), ICAR to prioritize the issues of NEH agro-climatic zones for formulating strategies and developing futuristic roadmap for sustainable agricultural development in North Eastern Himalayan Region.



**Fig 18. Dr N. S. Rathore, DDG (Edu), ICAR addressing to the gathering**

### Vigilance Awareness Week

Vigilance Awareness Week was observed in the Institute during 26<sup>th</sup> - 31<sup>st</sup> October, 2015. The inaugural programme was chaired by the Director of the institute Dr S.V. Ngachan. Dr A. C. Phukan, Medical Superintendent, NEIGRIHMS, Shillong graced the occasion as the chief guest and Dr Rohit Dwivedi, Professor, IIM, Shillong was also present as Guest of Honour and he delivered a lecture on ‘Attitudinal Aspects on Vigilance’ followed by speeches of different delegates on dais regarding the importance of Vigilance in the work front so as to bring a transparency in our daily work.



**Fig 19. Dignitaries on the Dias during Inaugural programme of Vigilance Awareness Week**

### World Soil Day

In view of the growing emphasis on soil health by our Hon’ble Prime Minister Shri Narendra Modi, the World Soil Day- cum- Rabi Kishan Sammelan was organized at ICAR Research Complex for NEH Region, Umiam, 5<sup>th</sup> December, 2015. More than 350 farmers from across the state participated in the event, which was chaired by Dr. Satish Chandra, Director I/c, ICAR, Umiam and Dr P. L. N. Raju, Director, NESAC, Umiam was present as a Chief Guest on this occasion.



**Fig 20. Soil health card distributed to the farmers**

### Jai Kisan, Jai Vigyan Week

ICAR Research Complex for NEH Region, Umiam, Meghalaya celebrated “Jai Kisan Jai Vigyan Week” during 23<sup>rd</sup>-29<sup>th</sup> December, 2015 to commemorate the birth anniversaries of two former Prime Ministers of India, Shri Atal Behari Bajpayeeji and late Shri Choudhury Charan Singhji in view of their enormous and valuable contributions towards promoting the application of science and technology for the development of agriculture so as to bring a sustainable livelihood among the farming community of the country. The event celebrated by organizing various technology demonstrations-cum-training programmes and distribution of improved agricultural inputs among farmers along with famers- scientists’ interactions, etc.

### ICAR RC NEHR participated in Assam Krishi Unnyayan Mela at CPCRI, Guwahati

ICAR, Umiam participated in “Assam Krishi Unnyayan Mela” held at CPCRI Kahikuchi Guwahati during 13- 14<sup>th</sup> February, 2016. Hon’ble Union Minister of Agriculture and Farmers’ Welfare Shri Radha Mohan Singh inaugurated the Mela in the presence of Smt. Bijoya Chakraborty, Hon’ble MP,



Assam; Dr K. M. Bujarbaruah, VC, AAU, Jorhat; Dr Premjit Singh, VC, CAU, Imphal; Dr A.K. Singh, DDG (Agril. Extension); Dr S.V. Ngachan, Director, ICAR RC NEH, Umiam and Dr. A.K. Tripathi, I/C, Director, ATARI, Zone III, Umiam. On 14<sup>th</sup> February 2016, the Union Minister for Agriculture and Farmers' Welfare Shri Radha Mohan Singh laid the foundation stone for the new ATARI (Agriculture Technology Application Research Institute) at Kahikuchi Guwahati, Assam. About 10,000 farmers from various districts of Assam and Meghalaya visited the mela and got awareness about the improved technologies displayed by different institutes.



**Fig 21. Hon'ble Union Minister of Agriculture and Farmers Welfare, Shri. Radha Mohan Singh releasing publications**

#### **ICAR, Umiam participated in Krishi Unnati Mela at IARI Pusa New Delhi**

ICAR Research Complex for NEH Region participated in Krishi Unnati Mela held at IARI Pusa, New Delhi during 19<sup>th</sup> -21<sup>st</sup> March, 2016. A group of 25 selected farmers from different part of Meghalaya along with institute staffs were participated. The programme was inaugurated by Hon'ble Prime Minister Shri Narendra Modi in the presence of Hon'ble Union Minister of Agriculture and Farmers' Welfare Shri. Radha Mohan Singh. In this event Hon'ble Prime Minister Shri. Narendra Modi launched the latest special mobile app (*Kisan Subvidha*) to enable the farmers to get information about five critical



**Fig 22. Dr Trilochan Mohapatra, DG, ICAR visiting ICAR RC for NEH Region, Umiam stall**

parameters like weather, input dealer, market price, plant protection and expert advisory services on agriculture and allied sector relevant to the locality.

#### **Training Programme for All India Service Officers on PMKSY**

A 5 days capacity building programme on "Preparation of District Irrigation Plan (DIP) under Prime Minister Krishi Sinchayee Yojana (PMKSY)" for All India Service Officers ((IAS & IFS) of North East India has been organized at ICAR Research Complex for NEH Region, Umiam from 5<sup>th</sup> -9<sup>th</sup> October, 2015 under the sponsorship of Ministry of Agriculture & Farmers' Welfare, Govt. of India with an objective to enhance the technical capability of the officers to enable them to implement PMKSY.



**Fig 28. Training compendium released by dignitaries**



## 2. RESEARCH ACHIEVEMENT

### MEGHALAYA

#### WEATHER REPORT

The total annual rainfall of Umiam was 2551 mm with monsoon rainfall (June to September) of 1630 mm contributing 64% of the total annual rainfall. There were 129 rainy days (more than 2.5mm rain per day) in the whole year and monsoon season constituted 75 rainy days i.e. 58%. Also April, May and October months have contributed 42 rainy days and January and March got considerable amount of rain which is more than the long period average (LPA). During the year, the total rainfall was about 156 mm higher than normal and monsoon rain was also higher by about 6 percent. Monsoon was started slow similar to previous year which was evident from lesser than normal rainfall during June (-48%) and July (-45%), 2015. But later on, it was recovered with higher than normal rainfall in the months of August (99%) and September (39%) which ultimately culminated in about 6% higher than normal rainfall in the whole monsoon. The monthly rainfall of August, 2015 was 692.4 mm which was the highest monthly rainfall of August since data recording at Umiam. The August month had rain in 28 days. The highest rainfall in a single day was 72 mm on 24<sup>th</sup> September, 2015.

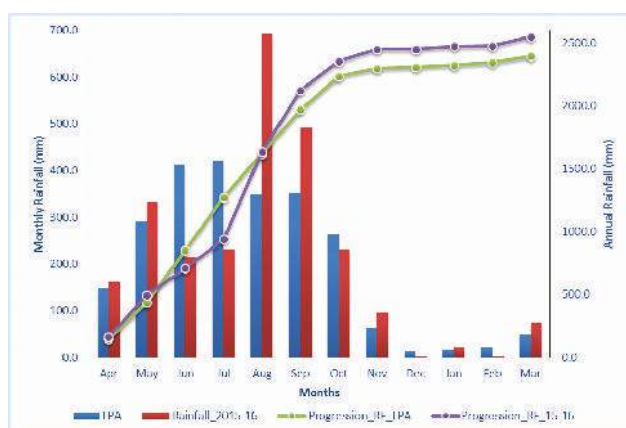
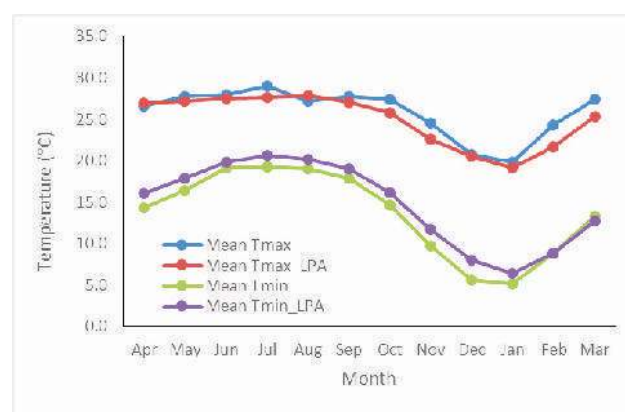


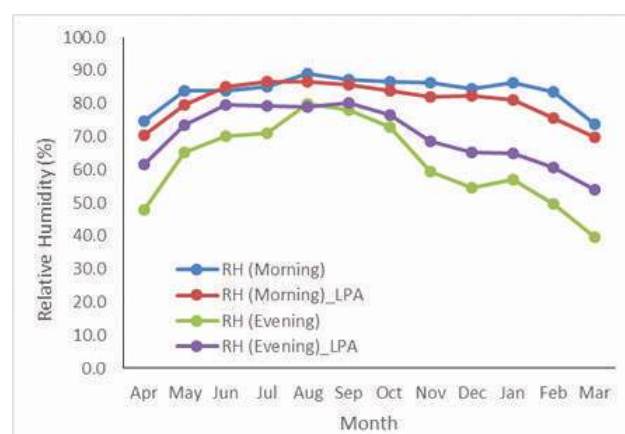
Fig 1. Monthly and annual rainfall pattern of Umiam

The Mean monthly maximum and mean monthly minimum temperature showed a similar pattern of change throughout the year [Fig 2a]. The mean  $T_{\max}$  varied between 29.0° C to 26.6° C for all the months

except November to February when it varied from between 24.5° C to 19.8° C. It is clear from the figure that for almost all the months the  $T_{\max}$  was either similar or more than its LPA value. The Mean  $T_{\min}$  was highest for the month of July with a value of 19.2° C and lowest for the month of January with a value of 5.1° C. It is clearly seen that the mean monthly minimum temperature increased after January to reach the maximum in July and thereafter decreased to the minimum in January again. It clearly showed that this year winter came early in the November evident from the mean  $T_{\min}$  value of 9.7° C which is about 2° C below LPA. But it is striking to note that for almost all the months the mean  $T_{\min}$  value was lower than its LPA value.



(a)



(b)

Fig 2. Monthly values of (a) mean maximum & minimum temperature and (b) mean relative humidity during 2015-16



The variation in the morning relative humidity ( $RH_{mor}$ ) is much less as compared to the evening relative humidity ( $RH_{eve}$ ) [Fig 2b]. The  $RH_{mor}$  varied from 73.96 % to 89.1% and  $RH_{eve}$  varied between 39.6% to 79.8% in March, 2016 and August, 2015 respectively. Due to heavy rainfall in the month of August the relative humidity also became high. The  $RH_{eve}$  was much lower than its LPA value throughout the year except for the month of August. The total annual pan evaporation was 857 mm. It was found that the pan evaporation was lower than the LPA in almost all the months except July, mainly due to higher than normal rainfall during the year. In August, it was much lower than LPA which may be due to the huge amount of rain and cloudiness associated with that. During 2015-16, the pattern of wind velocity almost matched with the LPA but it was 30% to 50% lower than the normal for all the months.

## CROP SCIENCES

### Rice improvement

#### Identification and molecular mapping of novel neck blast resistance gene(s) from local landraces and introgression lines of *Oryza*

Altogether, 7 landraces, 9 ILs and 5 local Meghalaya germplasm has been identified as resistant to neck blast. The neck blast resistant introgression lines have been crossed with ruling varieties of North East India at DRR, Hyderabad. The F<sub>1</sub> has been backcrossed with the parent to develop BC<sub>1</sub>F<sub>1</sub> progeny which was further advanced to BC<sub>2</sub>F<sub>1</sub> by backcrossing with the recurrent parent (Table 1)

**Table 1. Details of leaf and neck blast resistant landraces**

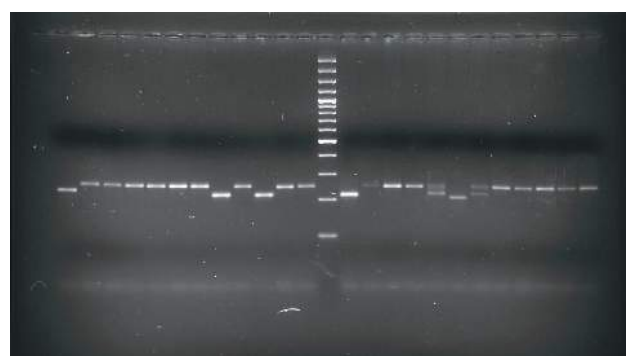
S. no	Name of Land race	Disease reaction scores for Neck blast		Leaf blast score
		1 <sup>st</sup> season	2 <sup>nd</sup> season	
1	Meghalaya lakang	0-0	0-0	3
2	Shangshak local	0-1	0-0	5
3	Wainem	0-0	0-0	0
4	Thekrulha	0-1	0-0	2
5	RCM-21	0-1	0-0	3
6	Chingchakhao	0-3	0-0	4
7	Daramphou	0-5	3-0	5

Scores: 0-3: Highly resistant; 3-5: Moderately resistant

Crossings were done for selected resistant ILs and landraces with three susceptible parents (BPT 5204, Swarna, Co-39 and RCM-9) for developing F<sub>2</sub> mapping populations. Polymorphic survey with 812 SSR markers which were spread uniformly on 12 chromosomes has been carried out for identification of introgression of regions of wild species genome in introgression lines. Similarly polymorphic survey with 192 SSR markers has been carried out for identification of polymorphism between the landraces and susceptible parents used for development of mapping populations. Phenotyping for blast disease was carried out in F<sub>2</sub> mapping populations of IL-3 (resistant donor) crossed with susceptible parents BPT-5204 (650 population) and Swarna (1100 population). Similarly F<sub>2</sub> mapping populations of landraces crossed with BPT-5204 were phenotyped for blast disease. The F<sub>2</sub> plants were maintained to develop F<sub>3</sub> seed. Selective genotyping was carried out using F<sub>2</sub> susceptible plants with polymorphic markers of IL-3. Introgression work has been carried out at DRR, Hyderabad.

#### Studies on biochemical dynamics of host pathogen interaction between rice and rice blast fungus for future development of durable resistance against rice blast disease

Field screening of 50 rice landraces for leaf and neck blast incidence was undertaken during kharif 2015. Genotyping of all these varieties was undertaken using panel of 50 standard SSR markers. Molecular screening for blast disease was also conducted using 10 SSR markers linked to blast resistance genes of rice (Fig 3).



**Fig 3. Genotyping of rice landraces using primer RM 19**

#### Study of rice yield under low light intensity

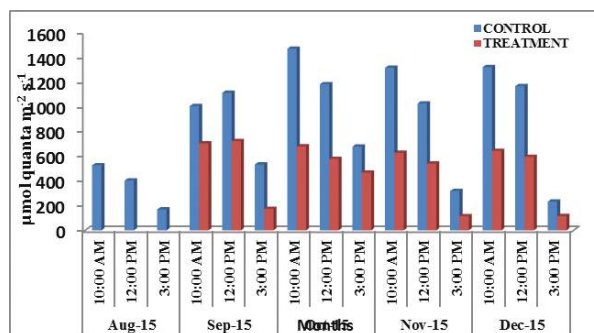
Three hundred genotypes pooled from NRRI, BCKV and ICAR, Umiam, were screened under ambient and 30% shading at Lowland Plant Breeding farm in kharif 2015 (Fig 4). Light and weather data



was recorded daily during the crop period (Fig 5). Chlorophyll b increased and a/b ratio reduced significantly, while plant height and crop duration increased under shade. Yield was significantly reduced under low light. Descriptive statistics of the characters studied under low light conditions is presented in Table 2.



**Fig 4. Low light experimental area**



**Fig 5. Light intensity during crop growth**

and 63.7% variance under ambient and low light conditions, respectively (Table 3). This project is funded by ICAR - Incentivizing Research in Agriculture.

### Phenomics of moisture deficit and cold tolerance in rice

In *kharif* 2015,  $F_2$ -derived  $F_3$  seeds of mapping populations of crosses (Kuki x Kuban 3, IRCTN 91-

**Table 2. Descriptive statistics of the main characters under low light intensity**

Statistic	Min	Max	Mean	Variance (n)	SD (n)	Variation coefficient	Skewness (Pearson)	Kurtosis (Pearson)
Plant height (cm)	44.20	116.00	78.63	153.800	12.41	0.158	0.443	0.050
Tiller no	5.80	42.20	18.80	32.770	5.73	0.304	0.975	2.150
Ear Bearing Tillers	3.60	30.50	12.61	17.340	4.05	0.332	0.721	1.730
Effective panicle no	1.00	18.50	7.76	15.260	3.92	0.496	0.541	0.256
Chl Index	31.50	73.80	43.39	17.300	4.16	0.096	1.590	13.210
Leaf Area (cm <sup>2</sup> )	3.59	142.90	33.08	751.700	27.05	0.818	2.020	4.090
SLW (mg dm <sup>-2</sup> )	51.80	1694.40	495.90	40802.400	199.80	0.404	3.230	12.980
Biol. yield (g plt <sup>-1</sup> )	1.08	79.60	21.73	200.500	14.16	0.652	1.290	1.580
Spikelet fertility (%)	3.03	100.00	71.59	543.300	23.99	0.321	-0.795	-0.447
Panicle wt (g plt <sup>-1</sup> )	1.25	33.00	7.68	27.170	5.19	0.678	2.090	6.110
Seed wt (g)	1.24	3.13	2.49	1.044	1.02	0.409	9.630	113.500
Grain yield (g plt <sup>-1</sup> )	0.08	39.40	5.70	25.840	5.08	0.879	2.990	13.200
Harvest Index	0.31	103.60	30.28	369.200	19.43	0.622	0.645	0.635

**Table 3. Principal component analysis of rice landrace populations for quantitative traits**

Characters	Ambient light			Low light		
	PC1	PC2	PC3	PC1	PC2	PC 3
Eigen value	03.98	02.76	2.085	03.67	03.25	01.35
Variability (%)	30.63	21.29	16.03	28.23	25.06	10.42
Cumulative %	30.63	51.92	67.96	28.23	53.30	<b>63.72</b>
Top traits contributing to PCA	Harvest index (0.431). Effective panicle no (0.430). Spikelet fertility (0.426) Chl index(0.363)	Biological Yield (0.555) Panicle Weight (0.472)	Tiller no (0.550) Ear bearing tiller no (0.428)	Panicle weight (0.468) Biological yield (0.412) Ear bearing Tillers (0.404)	Harvest index (0.472) Spikelet fertility(0.465) Effective panicle no (0.374)	Tiller no (0.613)



57 x Kuban 3, Kuki x IRCTN 91-57, and IRCTN 91-57 x Mujudo) were generated. Phenotyping data was subjected to Descriptive statistics (Table 4), and Distribution Fittings were plotted in  $F_2$  populations to indicate variations in the characters across the segregating populations (Fig 6).

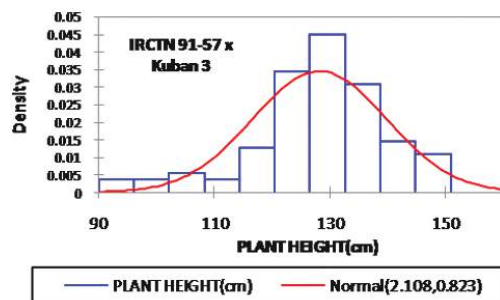


Fig 6. Distribution fitting for plant height in  $F_2$  population of IRCTN 91-57 x Kuban 3

Parental Polymorphism survey with 304 rice SSR markers was undertaken. 97 polymorphic markers between different bi-parental combinations have been identified (Fig 7).

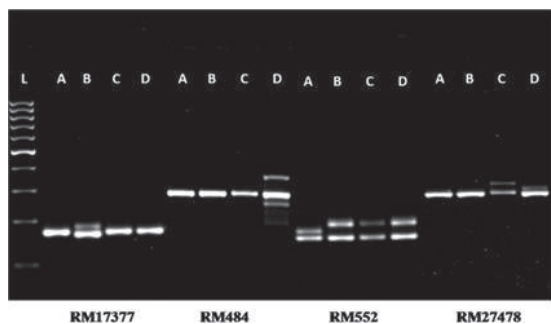


Fig 7. Parental polymorphism survey with 4 primers (A - IRCTN91-57, B - Kuban 3, C - Kuki, D - Mujudo, L - Ladder)

## Screening for Phosphorus (P) tolerance and validation of *Pup-1* linked markers in rice genotypes grown in acid soil of North Eastern India

Total of 172 rice varieties/genotypes/landraces grown in upland/lowland of NEH Region was phenotypically screened in hydroponics for identification of tolerance/sensitivity to P-deficiency. Systematic molecular analysis was done for validation of *Pup1* linked markers in all the rice varieties/genotypes/landraces identified to be tolerant or sensitive to low soil P. Many tolerant donor lines have been identified (*viz.*, Vandana, Sahbhagi Dhan, Rasi, Akshayadhan, Bhutmuri, Gobindabhog, Radhunipagol, RCPL 1-113, Dagardeshi, Pynthor, Paijong, Bhalum -3 etc.) and the presence of *Pup1* in these lines has been validated through marker analysis. While, varieties like Satabdi, Naveen, Anjali, Samba Mahsuri, Improved Samba Mahsuri, MTU 1010, NDR 359, Gomtidhan, Bhalum - 1, Bhalum - 2, Bhalum - 4 etc. have been observed to be highly susceptible to low soil P and also validated by markers. Interestingly, Swarna, a very popular rice of India, is found to be highly tolerant to P deficiency; and presence of *Pup1* QTL was also confirmed by *Pup 1* specific markers (Fig 8). It was

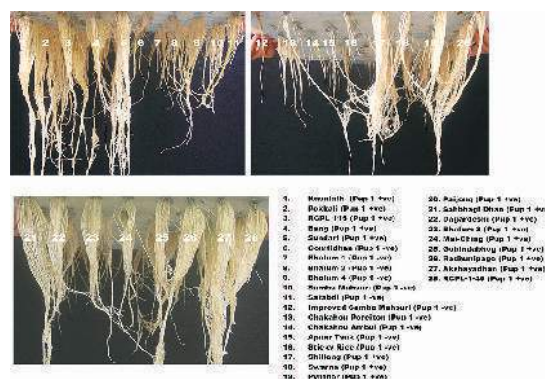


Fig 8. Root diversity of rice varieties/genotypes/ Landraces with and without *Pup 1* QTL (*Pup1* +ve/ *Pup1* -ve)

Table 4. Descriptive statistics of Kuki x Kuban 3

Statistic	Min	Max	Mean	Variance (n)	SD (n)	Variation coefficient	Skewness (Pearson)	Kurtosis (Pearson)
Per panicle weight (g)	1.40	4.50	2.59	0.746	0.86	0.333	0.755	-0.631
Biomass weight (g)	2.20	47.40	19.77	156.100	12.50	0.632	0.509	-0.737
Yield per plant (g)	2.80	38.20	17.99	126.100	11.23	0.624	0.596	-1.122
Spikelet fertility (%)	48.39	97.85	71.62	121.400	11.02	0.154	0.044	-0.213
Plant height (cm)	98.00	155.00	129.20	165.200	12.85	0.099	-0.443	-0.235
Tiller number	3.00	30.00	11.81	38.400	6.20	0.525	0.777	0.382
Seed weight (g)	1.80	2.80	2.39	0.064	0.25	0.106	-0.529	-0.261
No. of days to booting	84.00	94.00	88.72	7.640	2.76	0.031	0.000	-1.292
No. of days to flowering	89.00	98.00	93.22	6.920	2.63	0.028	-0.053	-1.125



also observed that, rice plants growing in hydroponics showed diverse root morphology which is directly correlated with presence of *Pup1* QTL. Based on the results obtained, Marker Assisted Backcross breeding program can be initiated for development of phosphorous efficient rice for NEH region.

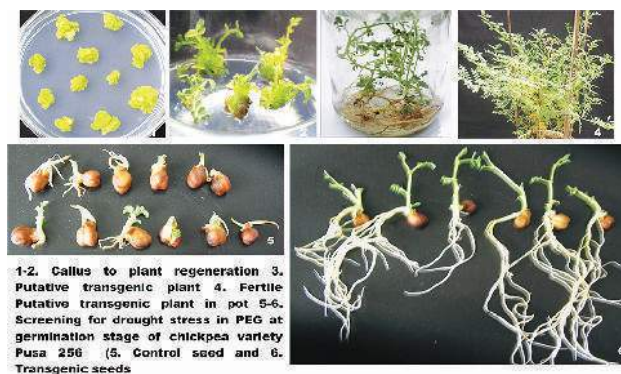
### Functional validation of Eukaryotic Translation Initiation Factor 4A (*eIF-4A*) isolated from *Pisum sativum* (*PS-eIF4A*) for abiotic stress tolerance in plants

The components of protein translational machinery including translation and elongation processes are very sensitive to environmental stresses. *eIF4A* is a prototype of a protein family termed the DEAD-box family of ATP dependent RNA Helicase. The full-length cDNAs of Pea (*Pisum sativum*) eukaryotic translation factor 4A (*PS-eIF4A*) was isolated and sequenced. *PS-eIF4A* found to get up-regulated when exposed to different type of abiotic stress treatments. *PS-eIF4A* was cloned in expression vector pCambia 1301 and over-expressed in rice and chickpea to study functional validation of *Pisum sativum eif4A* genes for reproductive stage abiotic stress tolerance in plants. It is expected that the transgenic plants with correct expression of the gene will be able to grow and set seed in an unfavorable environment (higher soil salinity, drought and cold).

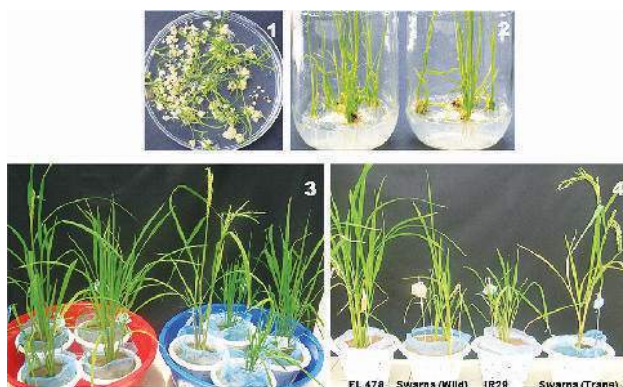
Seeds of chickpea variety Pusa 256 were screened for drought tolerance. For each of 10 transgenic lines, five replicates of 50-seed were screened with various concentration of PEG (MW 6000). Seed germination and root growth was very high in transgenic compared to control. However, *PS-eIF4A*, when over expressed in rice (Swarna) showed higher level of salinity tolerance at reproductive stage. On salinity screening, *PS-eIF4A* over expressed lines of transgenic Swarna, showed higher level of tolerance compare to salinity - tolerant control FL 478 and susceptible control IR29 (90 mM NACL STRESS at pH 5.6) at reproductive stage (Fig 9). Our results confirms that protein translational machinery especially, eukaryotic translation initiation factor 4A play a very important role in abiotic stress tolerance in plant (Fig 10). This finding will help in understanding the mechanism of abiotic stress tolerance in plant with special reference to protein translation machinery.

### AICRIP

Bhalum 5 (RCPL1-412, IET 22984) was identified for Meghalaya and Himachal Pradesh by the Varietal



**Fig 9. Functional validation of *PS-eIF4A* for drought tolerance in Chickpea (Pusa- 256)**



**Fig 10. Plant regeneration from putative transgenic calli 2. Putative transgenic plants of Swarna 3. Salinity screening at reproductive stage (90 mM NACL STRESS at pH 5.6) 4. Salinity screening at reproductive stage (90 mM NACL STRESS at pH 5.6)**

Identification Committee Meeting held at IIRR (Fig 11), Hyderabad on 11<sup>th</sup> April, 2015. Bhalum 5 matures in about 130 days, tolerant to leaf and neck blast, BPH and WBPH. Grains are long bold with acceptable quality.

Under upland conditions 2 AICRP trials were conducted. In AVT-1-UH, entry no. 2305 (2.99 t/ha) and in IVT-UH, entry no. 2407 (2.16 t/ha) were the top yielding genotypes. Under lowland conditions 2 AICRP trials were conducted. In AVT-1-MH, entry no. 2101 (2.13 t/ha) and in IVT-MH, entry no. 2209 (2.86 t/ha) were the top yielding genotypes. A set of 283 germplasm lines maintained in lowland conditions. Only basal dose of NPK (30:60:40) was applied so as to reveal the actual genotypic differences among the genotypes.



**Fig 11. Bhalum-5 (RCPL1-412, IET 22984)**



## Rice Pathology

Seven hundred forty four lines were screened against rice blast in uniform blast nursery pattern. One hundred and fifty seven entries were found to be resistant.

Screening trial	No. of Lines	Resistant lines
National Screening Nursery- 1	354	72
National Screening Nursery- Hills	77	20
National Hybrid Screening Nursery	131	26
Donor Screening Nursery	182	39
<b>Total</b>	<b>744</b>	<b>157</b>

## MAIZE

### Development of a highly efficient protocol for Transformation of maize (*Zea mays* L.) by *Agrobacterium*- mediated transformation.

Maize (*Zea mays* L.) is one of the most important commercial crops in the world because of its importance as food and feed. A highly efficient protocol for callus induction and plant regeneration protocol is developed from mature seeds maize.

After 3 - 5 days germinated seeds were split longitudinally to expose shoot meristem, scutellum and coleorhiza simultaneously, and cultured on callus induction media with the split side facing the media.

Two days later, growing radical and plumule was removed to encourage callus initiation and kept for 2 - 3 weeks of incubation. Embryogenic calli, on transfer to medium devoid of hormones at  $26 \pm 2^\circ \text{C}$  under 16/8 photoperiod regenerated and formed plantlets. Embryogenic calli was used as a source for *Agrobacterium*- mediated transformation (Fig 12).

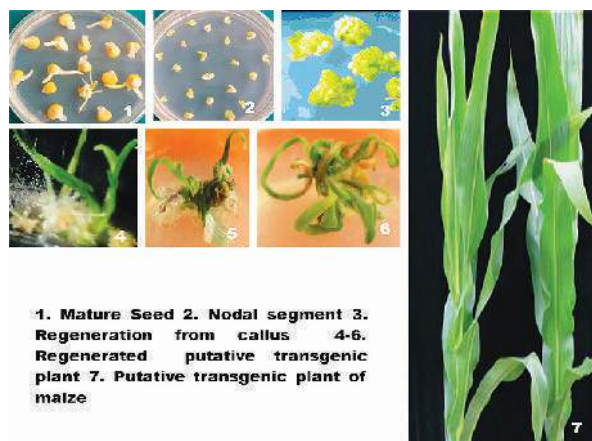


Fig 12. Development of a highly efficient protocol for Transformation of maize (*Zea mays* L.) by *Agrobacterium*- mediated transformation from mature seeds

## AICMIP

Twelve yield evaluation trials were conducted under the AICMIP. Promising lines identified from the trials are given in the Table 5.

Three Yield Evaluation Trials of CIMMYTS were also conducted the promising identified lines from the trials given in Table 6.

Table 5 Promising lines of Maize hybrids identified from AICMIP trials

Entry	Cob wt. (in kg)	Days to 50% Anthesis	Days to 50% dry husk	Plant height (in cms)	Ear height (in cms)
IMR-603	10.40	64.3	106.0	168.0	74.3
IMR-602	7.61	58.3	104.0	183.6	80.0
IMR-601	6.81	58.6	105.3	189.0	91.0
IMR-516	5.90	61.6	106.4	218.7	93.6
IMR-518	5.08	62.0	110.0	209.0	100.0

Table 6. Yield evaluation trials of CIMMYTS

Entry	Cob wt. (in kg)	Days to 50% Anthesis	Days to 50% dry husk	Plant height (in cms)	Ear height (in cms)
VH 141782	3.8	62	63	155.0	72.0
VH 141883	3.5	62	65	178.0	81.0
VH 141798	3.5	61	63	182.0	82.0
VH 141940	3.3	60	61	218.2	103.2
VH 133687	3.0	58	60	225.0	103.0



A set of 132 germplasm collected from different part of North East hill region and 242 germplasm of Mizoram maintained and characterized for different characters as per DUS guidelines. In addition to this 4 inbreds were advanced in S<sub>5</sub> generations. Above said germplasm were also planted at winter nursery center IIMR, Hyderabad for generation advance in offseason crop.

### Diseases

Ninety six lines in replicated trials (two) were evaluated for Turicum leaf blight resistance. Thirty lines were found to be resistant. RCM 1-2 (composite var.) and CM 202 (inbred line) were used as susceptible checks. RCM 1-2 was planted after every ten lines (Table 7).

**Table 7. Screening of maize lines for Turicum leaf blight resistance**

Screening trial	No. of Lines	No. of resistant lines	Reaction
Baby corn	18	2	resistant
Pop corn I-II-III	10	1	moderately resistant
Sweet corn	13	10	moderately resistant
QPM I-II-III	39	26	moderately resistant
AVT I-II (Extra Early)	16	8	moderately resistant

### Insect Pest

#### Screening of maize varieties against stem borer (*Chilo partellus* Swinhoe)

A total of 12 varieties were evaluated for stem borer infestation in lowland field of agronomy division for consecutive two years (2014 and 2015). Infestation was recorded in terms of per cent plant infestation and dead heart. Maximum per cent plant infestation and dead heart was observed in Local yellow with 60.6 and 62.08% plant infestation and 8.22 and 8.43% dead heart in year the 2014 and 2015, respectively. Least damage was observed in RCM-1-2 with 10.4 and 10.10% plant infestation and 0.62 and 0.83 per cent dead heart in year 2014 and 2015, respectively. Five varieties RCM1-3, DA-61-A, Hybrid, Sweet corn and Hemant were found to be moderately susceptible.

## OILSEEDS AND PULSES

Under upland conditions, coordinated yield trial (IVT, AVT-1 and AVT-2) was conducted. Code 1, Code 37 and Code 40 were found superior in IVT trial whereas entry Dsb-28-3 was found promising from AVT-1 trial. In AVT-2 trial Dsb-23-2 was found as most promising.

### Diseases

#### Evaluation of breeding materials for resistant donor(s)

Under AICRP, total 75 soybean genotypes were evaluated in IVT, AVT 1 and AVT 2 for resistance against rust disease caused by *Phakopsora pachyrhizi*. The genotypes showing no infection were categorized as absolute resistant (AR), 0.01-11.11 percent disease index (PDI) as highly resistant (HR), 12.22 - 33.33 PDI as moderately resistant (MR), 34.44 -55.55 PDI as moderately susceptible (MS), 56.66 - 77.77 PDI as susceptible (S) and 78.88- 100.00 as highly susceptible (HS). The results are shown in table 1. In IVT genotype code nos. 19 and 29 were AR and 1, 3, 9, 14, 23, 27, 28, and 32 were HR. In AVT I, only three varieties viz., DS 3101, KDS 869 and PS 1556 were found HR and in AVT II, one variety JS 20-53 showed HR reaction. Two resistant check genotypes (EC 241778 and EC 241780) continued to maintain their resistance level for the 3<sup>rd</sup> year (Table 8).

**Table 8. Reaction of soybean genotypes to rust disease**

Trial	No. of genotypes tested	Resistance or susceptibility category					
		AR	HR	MR	MS	S	HS
IVT	40	2	9	5	15	8	1
AVT 1	21	0	3	10	7	1	0
AVT 2	14	0	1	5	4	3	1

#### Trap nursery trial for monitoring soybean diseases

A set of 16 varieties susceptible to one or more diseases was planted (DOS=12/6/15) in two replications. Maximum rust severity (PDI 71.11) was recorded in var. VLS 58. Bacterial leaf blight and *Rhizoctonia* aerial blight were maximum i.e. PDI 10.72 and 8.17 respectively in var. PK 272. *Colletotrichum* pod blight and Frog eye leaf spot diseases were maximum PDI 28.89 and 6.33 respectively in var. NRC 7.



### Integrated management of pod blight complex of soybean

Two sprays of thiophanate methyl fungicide @ 0.1% at 55 and 75 DAS significantly reduced disease as compared to untreated control. Seed treatment alone with carbendazim + thiram or carbendazim +mancozeb each @ 2g/kg seed or *Trichoderma viridae* @ 5g/kg seed failed to control disease. PDI in different treatments ranged 12.21 to 36.38 and there was no significant increase in yield due to treatments.

### Rapeseed and mustard

150 Germplasm (mustard 50 samples, Yellow Sarson 50 samples and Toria 50 samples) received from NBPGR, New Delhi were evaluated in Rabi 2015 -16. Seed production of mustard variety namely PM - 25, 26, 27 have been done. Seed production of Toria variety TS -67 have also been done and it is found that this variety performed well under Meghalaya conditions. Two trials of rapeseed and mustard namely IVT MCNR (E) rain fed and AVT -I (Rain fed Zone V) have been conducted. In IVT MCNR (E) rain fed MCNR 15 -21, MCNR 15 -5 and MCNR 15-9 were found promising. In AVT -I (Rain fed Zone V) MCNR 15 -29, MCNR 15 -30 and MCNR 15 -33 were found promising.

### Screening of mustard varieties/germplasm against mustard aphid (*Lipaphis erysimi*)

Total 20 varieties/germplasms were screened for infestation of mustard aphid (*Lipaphis erysimi*). On the basis of aphid index 2, IC-94090 and IC 121719 was found to be highly susceptible against mustard aphid. IC- 73236, IC- 76773, IC- 121667, IC- 121676, IC- 121689, IC- 121706, IC- 121717, IC- 121724, IC- 122026 and IC- 121726 were found to be moderate, while IC- 94448, IC- 121657, IC- 121697, IC- 122030,

Pusa mustard- 25, Pusa mustard- 26, Pusa mustard- 27 and Pusa mutard- 28 were found to be susceptible to *L. erysimi*.

### Effect of different botanicals and imidacloprid on non-target organism (Honeybee and *Coccinella septempunctata*) in mustard

Botanicals like lantana @ 5%, adhatoda @ 5% and chemical pesticide imidacloprid @0.025% were evaluated against non-target insect like honeybee and *Coccinella septempunctata*. Imidacloprid was found to be harmful to both honeybee and *C. septempunctata* at 0.025%,. However, lantana and adhatoda at 5% concetration were found to be the safest to both the non target insect pests harboured in mustard ecosystem.

### Perilla

### Assessment of nutritional quality and genotypic variations in *Perilla frutescens*

Second field trial of 88 *Perilla* landraces collected from North eastern India was undertaken for morphological diversity at Upland Plant Breeding farm, Umiam. Descriptive statistics of the main characters studied is presented in Table 8. Genotyping of 52 genotypes is undertaken with 15 primers (Fig 13).

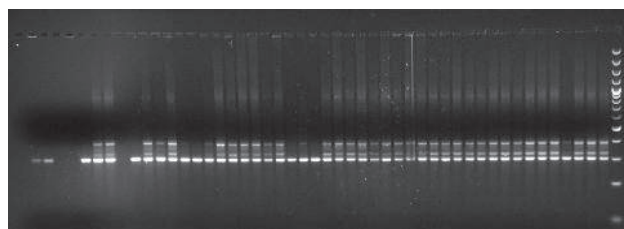


Fig 13. Genotyping of 52 *Perilla* landraces using primer KWPE 56

Table 8. Range of variation for different quantitative traits of *Perilla* landraces

Statistic	Minimum	Maximum	Mean	S.D. (n)	Variance(n)	Skewness (Pearson)	Kurtosis (Pearson)
Leaf area (cm <sup>2</sup> )	42.800	165.00	77.56	17.51	306.70	6.438	1.611
Plant height (cm)	56.000	186.40	128.80	26.91	724.10	-0.311	-0.084
Largest inflorescence(cm)	4.800	13.30	8.07	1.94	3.77	-0.071	0.656
No of internodes	10.800	20.40	15.12	2.03	4.14	-0.363	0.016
No of branches	8.000	25.00	15.46	3.21	10.29	0.707	0.453
Inflorescence per plant	15.400	241.00	89.19	36.21	1311.20	2.437	0.955
Plant yield	36.000	89.60	60.09	11.73	137.50	-0.118	0.393
1000 seed wt	0.013	10.38	3.97	2.26	5.09	0.174	0.728



## UNDERUTILIZED CROPS

### Job's Tears

A set of 65 Job's Tears was characterized by using different qualitative and quantitative traits. Wide variations for various morphological traits were recorded among the job's tears germplasm (Table 9). Significant correlations with grain yield per plant were observed in inflorescence length, brace roots/tiller, girth of tiller, no. of leaves/tiller and 100 seed weight. Based on grain yield per plant two promising lines JTN-11 and IC - 89392 were identified. The accessions were also characterized for total seed storage proteins using sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE). A total of 14 (all polymorphic) bands were scored among the 65 accessions of Job's Tears. In cluster analysis based on protein fragments all Job's Tears accessions were grouped in 6 clusters.

## FRUITS

### MANDARIN

#### Maturity indices of Khasi mandarin

Khasi mandarin orchards were selected from two different altitudes *viz.*, 600-800 msl and 1200-1400 msl of Meghalaya to study the effect of altitudinal variations on fruit maturity. During spring blossom fruit were sampled at 180, 210, 230, 250 and 260 days after fruit set (DAFS) to record the changes during maturation. At an altitude of 600-800m rapid increase in juice content was recorded up to 250 DAFS (47.88 %) followed by drop in juice content at 260 DAFS. Fruit rind developed yellow orange (230 DAFS) to

orange (260 DAFS) colour during maturity *i.e.* in Oct-Nov when mean minimum temperature was 21.5-19.6° C with significant ( $P = 0.05$ ) drop in chlorophyll content. The rise in TSS (10.18° Brix), TSS:acid ratio (12.89) and drop in titratable acidity (0.79 %) were significant ( $P = 0.05$ ) up to 230 DAFS with desired sensorial attributes *viz.*, sweetness (3.93), flavour (8.00) and appearance score (8.07). While at an altitude of 1200-1400 msl, juice content was recorded highest at 260 DAFS (51.03 %) followed by 250 DAFS (50.73 %) and fruit rind developed orange (230 DAFS) to deep orange (260 DAFS) colour during maturity *i.e.* in Nov-Dec when minimum temperature was 11.1-7.5° C with significant ( $P = 0.05$ ) drop in chlorophyll content. At 260 DAFS highest TSS (10.14° Brix), TSS: acid ratio (12.52) and drop in titratable acidity (0.81 %) with sweetness (4.27), flavour (8.07) and appearance score (8.20) were recorded followed by 250 DAFS. The results revealed that at 600-800 msl, 230-250 DAFS, juice content ( $\geq 47.0$  %), TSS ( $\geq 10.0$ ° Brix) and TSS: acid ratio ( $\geq 12.0$ ) and at 1200-1400 msl, 250-260 DAFS, juice content ( $\geq 50.0$  %), TSS ( $\geq 10.0$ ° Brix) and TSS: acid ratio ( $\geq 12.0$ ) can be considered as maturity indices.

#### Comparative performance of wedge grafting and 'T' budding techniques

In order to find out most suitable propagation technique in Khasi mandarin the comparative evaluation between 'T' budding (conventional) and wedge grafting were done under polyhouse condition. From the results, highest graft success (74.63%), plant survival (78.32%) with minimum days to first sprouting (14.11) was recorded in wedge grafting compared with 'T' budding (50.33%, 58.60% and 19.31 days, respectively). Further in *Khasi mandarin*,

**Table 9. Morphological variations among Job's Tears accessions**

Statistic	Minimum	Maximum	Mean	SD	CV	Skewness	Kurtosis
Plant height (cm)	76.6	179.0	113.046	23.343	0.206	0.822	-0.100
Inflo. Length (mm)	17.1	166.0	85.083	23.968	0.282	0.301	1.510
No. of tillers/plant	1.0	28.0	4.062	4.468	1.100	4.151	17.682
No. of nodes/tiller	6.0	13.0	8.508	1.360	0.160	0.938	1.942
Internode/tiller	15.4	33.7	22.933	3.992	0.174	0.291	-0.203
Brace roots/tiller	1.0	22.0	5.969	3.337	0.559	2.401	7.691
Girth of tiller (cm)	4.1	14.0	8.514	2.007	0.236	0.718	0.353
No. of leaves/tiller	6.0	14.0	9.000	1.403	0.156	0.601	1.126
No. of Spikelet/tiller	9.0	125.0	52.877	25.348	0.479	0.787	0.215
No. of Spike/spikelet	2.0	7.0	3.877	0.920	0.237	0.720	1.057
No. of grains/plant	51.0	3485.0	592.169	550.736	0.930	3.007	11.151
100 seed wt	3.0	15.1	8.912	3.628	0.407	-0.167	-0.648
Grain wt./plant (gm)	3.2	492.0	54.993	88.944	1.617	3.946	15.562



wedge grafting is done on 6-7 month old rootstock and 'T' budding is done on 12-13 month old rootstock, thus wedge grafting reduces the production period.

#### **Fruit and soil nutritional status in decline citrus orchards at varying altitudes**

Declined Khasi mandarin orchards were identified at varying altitudes viz., >1000 msl (Ryngab, Pynursla, Mawryngkneng and Mawphu); 600-1000 msl (Lumsohpieng, Saitama, Sohbar and Wahkhen); <600 msl (Pohriat, Dawki and Muktapur). Fruit acidity (0.86-1.72%) and ascorbic acid (25.26-57.33%) increased in declined orchards. Soil pH of declined orchards was very low (3.83-4.80). Similarly, soil Ca + Mg content was ranging from 2.25 meq/100 g to 7.00 eq/100 g. The Ca content was less in declined orchards ranging from 1.59-1.85 Meq/100 g at varying with altitude.

#### **Fruit and seed characteristics of rough lemon (*Citrus jambhiri* Lush.)**

Eleven genotypes of rough lemon were evaluated for their fruit and seed characteristics for their utilization as rootstock. Observations on fruit weight (81.58-180.33 g), fruit length (50.2 – 84.33 mm), fruit diameter (55.15 – 73.60 mm), fruit volume (84.16 – 185.36 cc), rind weight (21.33 – 61.78 g), rind thickness (2.65 – 7.13 mm), seed weight (0.11-1.33 g) and number of seed (8.33 – 24.37 per fruit) was recorded. Mawphu genotype recorded highest fruit weight (180.33 g), fruit volume (185.36 cc), juice content (45.0 ml) and rind weight (61.78 g) and minimum seed weight (0.11 g). Maximum seed weight was recorded in Wahkhen-2 genotype (1.48) and Jatah genotype recorded maximum number of seeds per fruit (24.37).

#### **Khasi mandarin and chow-chow blended beverage**

The Khasi mandarin juice was blended with chow-chow pulp to prepare ready to serve (RTS) in the ratios of 9:1, 8:2 and 7:3. The different ratios of blended juice were adjusted to 15° B TSS with 0.5% acidity. On the basis of organoleptic test the pulp blend ratio of 9:1 was observed best (Fig 14).



**Fig 14. Chow chow blended mandarin**

#### **Insect Pest**

##### **Citrus trunk borer (*Pseudonemophas versteegi*) from India appeared to be a cryptic species?**

Citrus trunk borer is an important pest of citrus crops in north eastern India. Various synonyms have been widely used for citrus trunk borer i.e., *Monohammus versteegi*, *Anoplophora versteegi* and *Pseudonemophas versteegi*. However,

*Pseudonemophas versteegi* has been widely used in current literature (Fig 15). The genetic diversity of citrus trunk borer was studied by sequencing partial COI gene of mtDNA.



**Fig 15. Citrus trunk borer (*Pseudonemophas versteegi*)**

Samples were collected from four different states namely Arunachal Pradesh,, Sikkim, West Bengal, and Meghalaya. From a limited sample size (n=12), a total of twelve mtDNA haplotypes were detected. Genetic

divergence between citrus trunk borer populations from the four states ranged from 0 to 5%. The higher pairwise genetic distance detected within Indian populations of citrus trunk borers was mainly due to the significant variation detected in sequences of citrus trunk borer collected from Sikkim and West Bengal. Moreover, the pairwise genetic distance in between Indian citrus trunk borer (*P. versteegi*) and the *P. versteegi* reported from Japan was highly significant (9%). The genetic distance of 9% is generally considered to be the genetic distance between two separate species or even in some cases it has been considered to be the genetic distance between two different genus/genera. Therefore, preliminary results suggested that, *P. versteegi* reported from India appeared to be the cryptic species.

#### **GUAVA**

##### **Performance of guava varieties/lines**

At 12<sup>th</sup> year (Table 10), among the seven guava varieties/lines (5 m x 5 m) RCGH-1 recorded highest fruit yield (16.88 t/ha) followed by RCGH-7, Allahabad Safeda and RCGH-4 during rainy season. The fruit weight was recorded highest in RCGH-4 (223.09 g). In fruit quality, highest TSS (11.0 °B), TSS:



**Table 10. Yield and quality of rainy season grown guava varieties/lines (12 year old)**

Varieties	Yield (t/ha)	Fruit weight (g)	No. of seeds /100 g fruit weight	TSS (%)	Acidity (%)	Ascorbic acid (mg/100g)	Total sugar (%)
RCGH-1	16.88	159.44	144.33	10.8	0.55	225.75	7.93
RCGH-7	16.04	148.14	121.40	10.9	0.57	205.86	7.07
RCGH-4	14.58	223.09	182.00	9.6	0.62	174.60	6.18
RCG-11	9.72	131.41	61.23	11.0	0.52	213.95	8.00
Allahabad Safeda	14.98	184.50	160.34	10.6	0.59	189.35	7.77
L-49	13.52	193.08	152.64	10.5	0.55	205.10	7.50
Lalit	10.10	158.77	189.56	9.5	0.65	180.00	6.13
CD (P=0.05)	2.58	9.00	11.12	0.21	0.09	25.06	0.17

acid ratio (21.15) and lowest number of seeds/100 g fruit weight (61.23 No.) were recorded in RCG-11. However, ascorbic acid content was recorded highest in RCGH-1 (225.75 mg/100g), while total sugar was recorded highest in RCG-11 (8.00%).

### Value added products

Value added products such as nectar (Fig 16), spread (Fig 17) and cheese (Fig 18) were prepared from guava fruits. In guava nectar, 20% guava fruit pulp was adjusted to 10, 15 and 20°B. On basis of sensory evaluation, nectar with 15°B was liked most. In case of guava spread preparation, firm ripe fruits pulp was adjusted to 70° B and cooked to smooth and creamy consistency. For guava cheese preparation, every kilogram of mature fruits was cooked to a thick paste with sugar (1.25-1.5 kg), acid (3 g) and butter (56 g). Hot cheese is spread on tray to set overnight and cut in to desired shapes and sizes.

**Fig 16. Guava nectar****Fig 17. Guava spread****Fig 18. Guava cheese**

## PEACH

### Evaluation of rejuvenated peach varieties

Three low chilling peach varieties viz., Partap, Flordasun and Shan-e-Punjab were rejuvenated by primary branch pruning (50 cm) during 2011. At 4<sup>th</sup> year Partap recorded highest fruit yield (36.5 kg/tree) followed by Flordasun (32.2 kg/tree), while lowest was recorded in Shan-e-Punjab (25.0 kg/tree). The fruit weight, fruit length and diameter were recorded maximum in Partap (65.1 g, 5.77 cm and 5.13 cm), respectively, followed by Flordasun (59.0g, 4.60 cm and 4.32 cm), respectively. In quality, highest TSS and lowest acidity were recorded Flordasun (9.8°B and 0.63%) while ascorbic acid content was recorded maximum in Partap (6.12 mg/100g).

### Insect Pest

#### Population dynamics of fruit fly and their natural enemies in guava

Trap catches of fruit fly *Bactrocera* spp. was observed to be higher during mid of September (34.17 flies/trap) in guava orchard and found to be decreasing till the end of the season. Numbers of maggots per fruit were higher during September and were decreased during October and November. Moreover, numbers of maggots per fruit were significantly reduced in the field with traps than control. About six natural enemies were observed parasitizing fruit fly, *Bactrocera* species in guava orchards in Meghalaya. Amongst, braconid and cynipid wasps were the most dominant larval pupal parasitoids of fruit fly. Natural parasitism by braconid wasp was found to be higher (48.39%) during mid of October

#### Management of fruit flies in Guava

Module consisting of male trapping by parapheromone traps @ 15 traps/ha, four sprays of



neem oil @ 2ml/lit of water during fruit setting at 15 days interval and soil application of *Metarhizium anisopliae* ( $1 \times 10^9$  cfu/gm) @ 15 kg/ha during early September (i.e. 15 days before fruit maturity) was found to reduce 39.66% fruit damage over control. Although, replacement of deltamethrin @ 0.5 ml/lit and malathion @ 1 ml/lit of water in place of neem oil in this module have provided 45.33% and 41.66% reduction in fruit fly damage, respectively over control.

## MANGO

### Survey and evaluation of mango cultivation in north east India

Among different mango cultivars surveyed in Manipur, Tripura and Arunachal Pradesh, Mallika recorded maximum fruit weight (352.67 g) and pulp (70.51%). TSS was recorded maximum in Dashehari (20.15%), while acidity was recorded maximum in Totapuri (0.34%).

## UNDER UTILIZED FRUITS

### Physico-chemical characteristics of *Sohjhur* (*Pyrus pashia* Buch. & Ham.)

Physico-chemical characteristics of six genotypes of *Pyrus pashia* Buch. & Ham. were studied. Result revealed that the fruit peel is russet and the taste of the fruit varies from highly astringent at maturity to sweet taste when ripe. Fruits are edible at maturity stage, however, emit greater aroma when it is decaying slightly which make it taste better. Genotype-3 recorded maximum weight (42.96 g), length (45.02 mm), diameter (52.89 mm) and volume (66.40 cc). Maximum fruit stalk length (4.91 cm), stalk thickness (2.76 mm), depth of stalk cavity (3.34 mm) and depth of fruit eye basin (4.96 mm) was observed in Genotype-3. However, maximum TSS (14.68%) and acidity (0.40%) was recorded in Genotype- 4 and Genotype- 2, respectively.

### Genetic variability in Aonla (*Emblica officinalis* L) genotypes

Ten genotypes of aonla collected from Jaintia and Khasi Hills of Meghalaya were evaluated for physicochemical characteristics. Results showed that Genotype-6 had highest fruit weight (5.26 g), fruit length (16.37 mm), fruit diameter (20.57 mm), fruit volume (4.61 cc) and juice content (37.42%). Seed weight was recorded highest in Genotype-1 (0.62 g). Maximum TSS (15.63%), acidity (2.60%) and

ascorbic acid (452.36 mg/100 g) was recorded in Genotypes -2, 1 and 7, respectively. The pigmentation of the fruit revealed that Genotype-1 had highest *L*\* value (41.66) and *b*\*value (15.42) while, Genotype-3 had highest *a*\* value (6.82), indicated its red peel colour.

## VEGETABLES

### Effect of lime + mulch on cucumber and King-chilli grown under low-cost polyhouse

The experiment on cucumber was conducted during March - July, 2015 under low cost polyhouse with two hybrids, Indame Swadisht and NS-404. Treatment lime + mulch have shown significant effect on growth and yield of the cucumber. The earliest flowering (36 days), highest number of fruits (8.0) and yield (2.48kg) per plant was recorded from the hybrid Indam Swadist in treatment comprising of lime (2.5q/ha) + polymulch. Similarly, in King-chilli with Red type (local genotype) the maximum number of branches (6.3), leaf area (146.80cm<sup>2</sup>), plant height (162cm), number of pods per plant (138.56), average pod weight (4.67g) and yield (647g) per plant was recorded in treatment lime (2.5 q/ha) + polymulch under the low cost polyhouse.

## BROCCOLI

### Effect of mulching and different doses of N and P on growth and yield

Experiment was conducted for three years (September to February, 2012-2016) on broccoli hybrid Puspa using mulches viz., paddy straw, live seasonal weeds, dry seasonal weeds and poly mulch. Among the treatments, the highest gross plant weight (803g), marketable head weight (410g) and yield (163q/ha) was recorded from the treatment comprises of mulching with seasonal weeds and NPK at the rate of 120:80:60 kg/ha.

### Insect Pest

### DNA barcoding of insect pests and natural enemies of cole crops ecosystem of Meghalaya

In order to have comprehensive taxonomical and molecular information of insect fauna of cole crop ecosystem of Meghalaya, insect pests and natural enemies of cole crops were collected either from different cole crops. A total of 29 insect species were collected and documented which belonging to different insect order viz., Diptera (10), Lepidoptera (6), Coleoptera (6), Hymenoptera (5) and Hemiptera (2).



Out of 29 species, 12 species were insect pests and 17 species were of natural enemies. The DNA barcodes based on partial COI gene were developed for all the species and subsequently their molecular identity at species level were also established. All the barcoding sequences were submitted to international GenBank (NCBI) vide Accession Number KT175576 to KY175607. The comprehensive morphological and molecular data developed for a total of 29 species observed in cole crops could be used as diagnostic guide at both morphological and molecular levels.

## KAKROL

### Morphological variability

Total thirty two germplasm of Kakrol (*Momordica subangulata*) were collected from Assam, Nagaland, Manipur, and Tripura. The wider variability was observed for the fruit traits like leaf margin, size of flower, distribution of spine on fruits, seed and fruit size and colour (Fig 5). The average fruit length, width and weight ranged from 6.2-10.5 cm, 3.7-4.8 cm and 45.5 g – 105.0 g, respectively.



Fig 5. Variability in Kakrol

## CHOW-CHOW

### Collection, evaluation and genetic characterization of germplasm

Total seventy four germplasm of chow-chow were collected and evaluated for the fruits and quality traits. Among the land races, wide range of variations were

recorded for fruit traits such fruit length (6.5 cm-21.5 cm), fruit diameter (4.2-10.7 cm), average fruit weight (60-560 g) and quality traits like vitamin-C (2.6-13.8), reducing sugar (0.18-2.77%), total sugar (1.09-2.94%) and phenol content (0.17-3.85mg/g). Summary diversity of different group based on RAPD (28) and ISSR markers (5) are given in Table 10. The highest percentage of polymorphic fragments observed in light green group. Eight fragments found specific to landraces with light green fruits. Three fragments found specific to RCSC-21 (dark green fruit) and another three found specific to a RCSC 29 (yellow fruit).

### Dehydrated chow-chow shreds

Mature chow-chow fruits were collected for making dehydrated shreds (Fig 19). The fruits were peeled manually, core removed and cut into slices. The slice thickness and length were kept at 0.5, 1, 1.5 cm and 6, 7, 8 cm, respectively. The slices were dehydrated on trays in cabinet drier oven at  $55 \pm 5^\circ \text{C}$ . On the basis of uniformity in drying and visual quality, slice thickness of 0.5 cm gave the best result.



Fig 19. Dehydrated chow-chow shreds

## DOLICHOS BEAN

### Genetic variability

Total sixty eight germplasm were collected and evaluated during for the yield and related traits. The wider variability was observed for the traits like seed and pod colour, shape and size of the leaves and pods and days to flowering (Fig 20). The average pod length

Table 10. Diversity of different group based on RAPD and ISSR markers

Group	na*	ne*	h*	I*	Polymorphic loci	Polymorphic (%)
Light Green	1.78±0.41	1.46±0.37	0.27±0.19	0.40±0.27	181	78.70
Yellow	1.53±0.50	1.36±0.39	0.20±0.21	0.30±0.17	121	52.61
Green	1.25±0.43	1.19±0.35	0.18±0.10	0.26±0.15	59	25.65
Dark Green	1.49±0.44	1.35±0.41	0.26±0.17	0.38±0.26	113	49.13

\* na = Observed number of alleles \* ne = Effective number of alleles [Kimura and Crow (1964)] \* h = Nei's (1973) gene diversity \* I = Shannon's Information index [Lewontin (1972)]





**Fig 20. Genetic variability in Dolichos bean**

and pod weight varied from 6.2 cm to 24.5 cm and 4 - 25 g, respectively. Similarly, number of seeds, pods and yield per plant varied from 3 - 7/pod, 22-95pods/plant and 0.26-2.23 kg/plant, respectively.

## CHILLI

Total 106 germplasm of chilli including cultivars (hot and sweet pepper) and popular land races (Fig 21) like King-chilli, Cherry chilli, Dalle chilli and Bird Eye chilli were evaluated for yield traits and also



**Fig 21. Genetic variability in Capsicum spp.**

characterized using 47 SSR loci. The fruit length ranged from 0.29 g in Bird eye chilli to 68 g in Capsicum. The yield per plant ranged from 70 g in bird eye chilli to 680 g in chilli. The number of seeds/pod ranged from 4.0 (Bird eye chilli) to 142 (Capsicum). By molecular analyses a total of 205 alleles were observed with an average of 4.36 alleles per locus. The number of alleles ranged from two (in HPMSE 7) to 8 (in HPMSE 72 and CAMS 91). Based on the value of Shannon's Information index CAMS 91 (1.956) was identified as the most informative marker in this study. Out of 205 alleles only 10 alleles were common in all different *Capsicum* spp. under study. Nine alleles were found specific to Dale chilli (*Capsicum chinense*) and five to Bird eye chilli (*C. frutescens*). Two alleles were also found specific to King chilli (*Capsicum chinense*) and 21 alleles were specific to chilli (*C. annum*). The results of cluster analysis revealed that the king chilli is closer to Bird eye chilli than the Dalle chilli.

## Insect Pest

### First report of invasive mealybug, *Phenacoccus parvus* Morrison infesting Naga King chili and its colonization potential on major host plants of the NE region

The lantana mealybug, *Phenacoccus parvus* Morrison: (Hemiptera: Pseudococcidae) is an invasive species and recently found damaging Naga King chili (*Capsicum chinense* Jacquin) plants in Meghalaya (India). During survey, nymphs and adults of *P. parvus* were observed infesting leaves and stems of King chili plants (Fig 22) at Umiam and adjoining villages. Infested plants were found stunted, withered and did not bear flowers as did the healthy plants of the same age. In case of severe infestation, 100% mortality of young plants and seedlings was observed (Fig 23). Basic biological attributes of *P. parvus* was studied on some potential host crops to understand its



**Fig 22. Mealybug colonies on leaves and stems of *C. chinense***



**Fig 23. *C. chinense* seedlings died due to severe infestations of *P. parvus***



establishment fate in the region. The results revealed that, *P. parvus* has a potential to cause significant damage to Naga king chilli, potato, tomato, China aster and *Lantana camera* etc.

## TOMATO

Fifty germplasm including wild relatives were evaluated for yield and quality attributes and also characterized using 34 SSR markers. The number of fruits ranged from 20 (TMC-1) to 185 (cherry tomato). Yield per plant ranged from 0.28 kg (TMC-1) to 2.6 kg (MT-3). The highest TSS, Vitamin C and lycopene content was recorded as 5.4 (MT-3), 25 mg (*S. peruvianum*) and 10.77 mg (MCTR-4B), respectively. In molecular analysis, total 130 alleles were detected with average number of 4.48 alleles per locus. The polymorphic information content (PIC) were range from 0.743 (LEat015 primer) to 0.181 (LEta003 primer). The cluster analyses generated total five cluster and gene diversity ranged from 0.777 to 0.186. Among the studied genotypes maximum Nei genetic distance was found between *S. peruvianum*-1 and DMT-5 (0.931) followed by *S. peruvianum* -1 and BWT-3 (0.929). Further 10 alleles were found unique to indeterminate tomato group whereas 5 alleles were unique to determinate tomato group. The genetic structure of the populations was also studied by using the Bayesian Model-based approach proposed by Pritchard *et al.* (2000) to assign the genotypes into genetically structured groups. In present study the most appropriate number of groups (K) was identified at K = 5 (Fig 24).

## Insect Pest

### Eco-friendly management of tomato fruit borer

Five chemical insecticides (flubendiamide 480SC, indoxacarb 14.5 SC, novaluron 10 EC, plethora (novaluron 5.25% SC + indoxacarb 4.5% SC) and cypermethrin 10 EC) and four bio-pesticides (*Bacillus thuringiensis*, neem, *Metarhizium anisoplae* and *Beauveria bassiana*) were evaluated against tomato fruit borer (*Helicoverpa armigera*) along with control

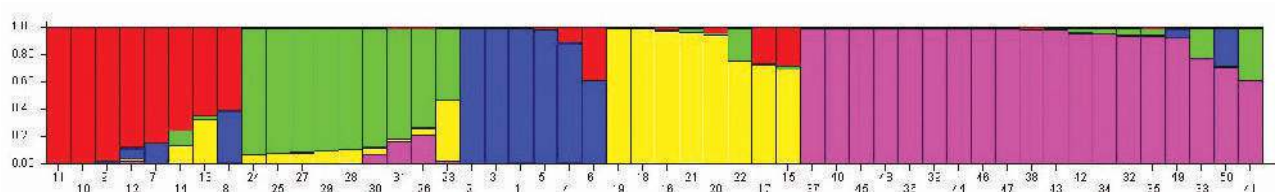
treatment. Flubendiamide and plethora were most effective treatments in reducing fruit damage as well as more than 80% reduction of fruit damage over untreated control plots. Among bio-pesticides, *Bt* was effective treatment against tomato fruit borer followed by neem but all treatments were superior over untreated control plots.

### Evaluation of tomato cultivars against serpentine leaf miner, (*Liriomyza trifolii* Burgess) in mid-hills of Meghalaya

The field incidence of leaf miner was severe during fruiting stage of the crop. On the basis of susceptibility index for tomato cultivars for leaf miner 24 varieties were evaluated in low land field of Agronomy section, ICAR Research Complex of NEH Region, Umiam. Out of the 24 total 18 varieties MT-3, Set-2, Avinash-3, MCTR-413, DMT-5, MCTR-4, MT-2, MT-11, MT-9, Set-3, MCTR-7B, RCM-T-8, Rocky, Pant T-10, VL-4, Set-1, H-86 and arka vikash were found to be least susceptible against serpentine leaf miner. Only six test cultivars viz., RCT-3, TMC-2, DVRT-2, Set-9A, VAR-801 and MCTR-5 were found to be moderately susceptible. No cultivar was found highly susceptible against leaf miner.

## BRINJAL

Twenty six germplasm including wild relatives of brinjal were characterized using 34SSR markers. Total 136 alleles were observed from the markers and the number of alleles ranged from 2 to 7. Among the *Solanum* spp. the maximum genetic distance (18.9) was recorded between *S. torvum* and *S. melongena* (Local Purple). However, *S. torvum* was closer to *S. khasianum* followed by *S. gilo*. *S. indicum* and *S. macrocarpon* was closer to each other over other species. Among the wild species *Solanum torvum* was found highly resistant to bacterial wilt while *S. gilo* (25-66%) was susceptible to wilt under field condition. However in cultivated species Punjab Sadabahar and Kasi Taru were highly susceptible (100%) to bacterial wilt.



**Fig 24. Assignment of fifty tomato genotypes to five clusters by Structure version 2.0. Each individual bar represents a genotype of tomato**



## **Insect Pest**

### **Evaluation of bio-rational pesticides against brinjal shoot and fruit borer**

Some bio-rational pesticides were evaluated against brinjal shoot and fruit borer (*Leucinodes orbonalis*) under field condition during kharif season, 2015. Treatments viz. chlorantraniliprole 18.5% SC, spinosad 45% SC, chlorfenapyr 10% SC, indoxacarb 14.5% SC, *Bacillus thuringiensis* (Bt), neem 0.03% EC, *Metarigium anisoplae* (Ma) and *Beauveria bassiana* (Bb) and chlorpyrifos 20 EC and control. Among the treatments, chlorantraniliprole and spinosad were very effective treatments against target pest with 79% and 76% reduction over untreated control plots. Next best treatments were indoxacarb, chlorfenapyr, Bt and chlorpyrifos.

## **TUBER CROPS**

### **Molecular characterization of Aroid germplasm**

To study the genetic diversity of tuber crops (*Colocasia* and *Xanthosoma*) under CIP funded project, 66 germplasm were characterized using SSR markers. The wider genetic diversity was observed among the germplasm and all the germplasm were grouped into five major clusters. Tajiting Purple and Tajiting White germplasm of *Xanthosoma* spp. cultivated for their peduncle were grouped together with the Chigi a species (Unidentified) cultivated in kitchen garden for their leaves and peduncle and were most diverse from the other species. However, minimum genetic distance (0.69) was observed between Takangki and Tamiting land races collected from Garo Hills.

## **SWEET POTATO**

Ten sweet potato varieties were evaluated for yield and other parameters. The variety TSp12-8 recorded the highest tuber yield of (6.8 t/ha). Maximum tuber length (18.94 cm) was found in TSp12-12 and tuber diameter in variety TSp12-6 (6.33 cm). Dry matter content was found highest in TSp12-7 (36.96 %) whereas  $\beta$ -carotene in TSp12-11 (3.87 mg/100 gm).

## **COLOCASIA**

Twenty nine varieties of colocasia were evaluated for their physical parameters viz., plant height (cm), number of side shoots per plant, number of cormels per plant, cormel yield (t/ha), total yield (t/ha) and disease incidence percentage. The plants were

harvested at six months maturity. Maximum plant height was recorded in Tamiting (155.7 cm) whereas ML-2 (5.50) has the most number of side shoots/plant. Number of cormels/plant and cormel yield t/ha were found highest in Tajiting purple (33) and (23.10 t/ha), Tajiting purple also recorded the maximum total yield t/ha (28 t/ha). Leaf blight incidence was found to be lowest in BCC-1 (6.25%).

## **SPICES**

### **Source sink relationship in turmeric and ginger**

Six genotypes of turmeric and three ginger were evaluated to study the response of a variety to changing climate which may be helpful in understanding rhizome bulking process and the partitioning efficiency under climatic influence and also to provide information on quality by climate. The observations were recorded at 60, 120, 180 DAP and at harvest stage and the dried samples were sent to IISR for further analysis. In turmeric, Mydkur variety recorded highest fresh rhizome weight (542.76 g/plant) followed by Rajendra Sonia (454.24 g/plant). Amongst ginger, Nadia variety produced the highest fresh rhizome weight of 562.88 g/plant followed by Himgiri (433.54 g/plant).

### **Optimization of blanching time in black pepper**

Four blanching time viz., 30, 60, 90, 120 seconds was tried in black pepper (collected from farm) by dipping the fruits in 100° C water. After complete drying, they were packed in PE packets. It was found that on the basis of visual and textural quality, 60 seconds blanching time gave the best result and kept well for up to eight months at room temperature.

## **FLOWERS**

### **GERBERA**

#### **Evaluation of gerbera hybrids**

The performance four gerbera hybrids developed by the Institute were depicted in Table 11.

## **ORCHIDS**

### **Growth and flowering of orchids species**

Thirty two species of orchids were evaluated for growth and flowering under net house. Growth characteristics showed wide variation with plant height (17.5-105.2 cm), internodal length (1.6-4.3 cm), number of leaves (1-92) and number of pseudobulbs



**Table 11. Performance of gerbera hybrid under open condition**

Hybrids/ variety	Stalk length (cm)	Diameter		Days to full flower opening	Durability of flower (days)	No. of flowers /plant/ month	Vase life (days)
		Stalk(mm)	Flower (cm)				
RCGH-12	32.41	4.08	9.01	5.33	7.24	7.09	6.84
RCGH-22	31.31	4.20	10.31	5.74	7.65	4.94	6.78
RCGH-114	34.65	4.40	8.88	5.43	6.34	5.37	5.76
RCGH-117	33.70	4.49	10.85	4.79	6.76	6.94	6.50
Alesmera	41.14	5.24	9.36	7.40	7.69	5.36	7.20
SEm±	0.72	0.12	0.15	1.07	0.16	0.09	0.26
CD (0.05)	1.96	0.36	0.46	2.95	0.47	1.07	0.67

(16-87). Regarding flowering, 17 species have started flowering having wide range of colour with spike length (8.2-35.7 cm), flower diameter (3-9.5 cm), flower length (3-10.1 cm), number of flowers (1-13.5 per spike).

## TRANSFER OF TECHNOLOGY

### Training Programmes

One day training on “Improving Livelihood of Tribal farmers through Horticultural Interventions” was organized on 29<sup>th</sup> January, 2016 at Maskut village, West Jaintia Hills District, Meghalaya where 53 farmers were participated. As rehabilitation preparedness for army personnel from Umroi Cantt. Umiam a six days training on “Horticultural Crops” was organized during 22<sup>nd</sup>-27<sup>th</sup> February, 2016. Similarly four days training cum demonstration on “Organic ginger cultivation” was organized during 29<sup>th</sup> March to 1<sup>st</sup> April, 2016 where a total of 236 farmers participated from 100 SHGs of the Ri-Bhoi district, Meghalaya (Fig 25).



**Fig 25. Glimpse of capacity building programme organized during 2015-16**

### Field demonstration

Gerbera cultivation under open field was demonstrated to resources poor farmers on 11<sup>th</sup> February, 2016 and gerbera hybrids viz., RCGH-12, RCGH-22, RCGH-114 and RCGH-117 were distributed.

## ENTOMOLOGY

### Diversity of mealybugs and scales in northeast (NE) India

About 12 species of invasive mealybugs and scale insects were collected and identified from the NE region infesting different agricultural and horticultural plants viz., Cotton mealybug (*Phenacoccus solenopsis*), Lantana mealybug (*Phenacoccus parvus*), Root mealybug (*Formicococcus polysperes*), Common mealybug (*Planacoccus citri*), Papaya mealybug (*Paracoccus marginatus*), Mango mealybug (*Rastrococcus invadens*), Pink mealybug (*Maconellicoccus hirsutus*), Stripped mealybug (*Ferissia virgata*), Groundnut mealybug (*Planacoccus bendovi*), Cryptic mealybug (*Pseudococcus cryptus*), Banana scale (*Icerya seychellarum*) (Fig 26) and Fluted scale (*Icerya purchasi*) (Fig 27) etc. Many of them have potential to cause significant damage to different crops in NE region. Interestingly, all the species were found to have a relationship with specific ants, as observed from the studies.



**Fig 26 *Icerya seychellarum***



**Fig 27. *Icerya purchasi***

### Survey and identification of aphids on economically important crops in Meghalaya

During the survey, four major species of aphids (Aphididae: Hemiptera) viz., *Brevicoryne brassicae* (Fig 28), *Aphis gossypii*, *Myzus persicae* and *Lipaphis erysimi* were found attacking cruciferous and





**Fig 28. Cabbage aphid**

solanaceous crops in different locations of northeast India. Some other species of aphid were found in the region viz., *Sitobion avenae* on Onion, *Cinara* spp. on *Thuja orientalis*, *Pentalonia calidii* on turmeric, *Rhopalosiphum maidis* on maize, *Smynthuroides betae* on groundnut roots and *Tetraneura nigriabdomenalis* on rice roots.

#### **Incidence of root mealybug, *F. polysperes* on turmeric, *Curcuma longa*: A new host record**

Nymphs and adults of root mealybug, *F. polysperes* (Fig 29) were observed in some turmeric samples collected at the time of harvesting from the farmer's field in Ri-bhoi district. Similar species were also observed in different farms of the institute at Umiam during harvesting. However, the infestation was very less in all the cases. Visual symptoms of mealybug damage were not clearly observed in above ground turmeric plants under field conditions, although mealybug colonies were observed in fewer rhizomes during harvesting.



**Fig 29. *Formicococcus polysperes***

#### **Pest complex of onion and screening of onion genotypes against insect pests**

The cutworm, *Agrotis* spp. (Fig 30), leaf miner, aphids and semilooper were recorded feeding on onion

in mid hills of Meghalaya. Among 49 genotypes evaluated, cutworm (*Agrotis* spp.) was found to be a major pest of onion. In IET, cutworm infestation varied from 26.44 to 55.83% in different genotypes, being highest in genotype ON-15-42 ( $55.83 \pm 15.95\%$ ) and lowest in genotype ON-15-04 ( $26.44 \pm 9.78\%$ ). In AVT I, cutworm infestation ranged from 24.22 to 64.44% in different genotypes. The cutworm damage was maximum in genotype ON-14-11 ( $64.44 \pm 5.30\%$ ) and lowest in genotype ON-14-25 ( $24.22 \pm 4.16\%$ ). In AVT II (varietal trial), cutworm infestation varied from 13.33 to 59.11% in different genotypes, being highest in genotype OLR-1341 ( $59.11 \pm 13.72\%$ ) and lowest in genotype OLR-1352 ( $13.33 \pm 4.81\%$ ). In AVT II (Hybrid trials), cutworm infestation ranged from 16.11 to 51% in different genotypes. The cutworm damage was maximum in genotype OLR-1381 ( $51 \pm 10.44\%$ ) and lowest in genotype ON-14-25 ( $16.11 \pm 7.84\%$ ).



**Fig 30. Cutworm damage in onion**

#### **New species of Zygaenid moth from Meghalaya**

A new species of the zygaenid procridine genus *Artona* (Amuria) Walker (Fig 31) has been discovered



**Fig 31. *Artona* (Amuria) sp.**

infesting banana plants in Meghalaya. Studies on its basic biological aspects and taxonomic description are being undertaken. The larvae of this species were found feeding on leaves of banana and the infested leaves ultimately dried. In several cases, entire plants were found defoliated in the locality.

#### **Eco-friendly management of major pest of cauliflower**

Different bio-pesticides were evaluated against major pests of cauliflower under field conditions. Amongst entomopathogenic fungi, *Beauveria bassiana* ( $1 \times 10^6$  cfu/ml) @ 5 ml/litre of water was found most effective treatment against pierid butterfly followed by neem oil 1500 ppm @ 2 ml/litre of water,



which reduced 48.33% and 39.66% damage of *Pieris* spp., respectively than control. Foliar spraying of neem oil @ 2ml/litre of water along with Silicon adjuvant @ 0.5 ml/litre of water at 15 days interval was found the best treatment against aphids in cauliflower with 73.66% reduction in damage over control. In another experiment, flubendamide and Spinosad @ 0.5 ml/lit of water each were found very effective against cabbage defoliators, with a 68.33% reduction in damage over control

## POLLINATORS

### Pollinator diversity and pollination biology of native bees in cucurbits at mid-hills of Meghalaya

*Bombus* spp., *Apis cerana himalaya*, *Xylocopa* spp., *Trigona* spp., *Peponapis* spp., *Syrphus* spp., *Sphinx* spp., *Apis florea*, *Anthophora* spp. and squash bee were found to be an important pollinators in cucurbits (Fig. 32). Bumble bee was the most abundant pollinator in pumpkin with higher foraging speed (24.56 /m<sup>2</sup>/ 5 min) followed by little honey bee (13.22), Indian honey bee (1.72), and Digger bee (1.06). Also, bumble bee (*Bombus* spp.) was found a sole pollinator in ash gourd with foraging speed 6.00 secs/flower and the foraging rate 7.33 flowers/min. Indian honey bee was the most dominant pollinator in chow chow with 19.00 /m<sup>2</sup>/ 5 min foraging speed and 84.19 % mean relative abundance.



Fig 32. Diversity of insect pollinators in cucurbits' at mid-hills of Meghalaya

### Native bee as a pollinator: A need based conservation methodology for cucurbits growers of Meghalaya

To exploit the use of native bee as a pollinator a need based methodology was developed for the growers. This methodology comprises growing of flowering crops like golden rod, sunflower, rose near cucurbits crops which generally attracts the Indian honey bee, bumble bees and other native bees. To provide the support to the cucurbits crop, staking with hollow bamboo (native plant of Meghalaya) was recommended as the native bee pollinator prefers

hollow structure for making its nest and also for shelter. This methodology strongly recommends removal of any foreign insect like blister beetles from the cucurbits crops as these insects significantly affect the foraging behaviour of native bee.

### Diversity of insect pollinators in radish crop at mid hills of Meghalaya

The diversity and abundance of different insect pollinators on radish crops were studied during 2015-16. A total of 5 insect pollinators belonging to order Hymenoptera (Indian honey bee) Lepidoptera (Cabbage butterfly and Diptera (*Syrphid* flies *Episyrphus* sp. and *Syrphus* sp.) and drone fly were found to pollinate the radish crops (Fig 33). Relative abundance of Indian honey bee was maximum (33.33%) followed by *Episyrphus* sp. (26.66%), Cabbage butterfly (22.22%), drone fly (11.11%) and *Syrphid* fly (6.66%).



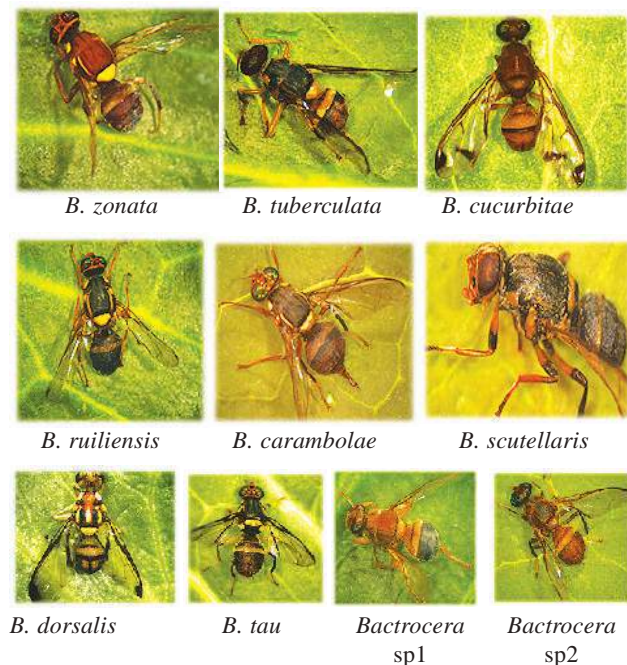
Fig 33. Diversity of insect pollinators in radish

### Molecular characterization of fruit fly species infesting fruits and vegetables in mid hills of Meghalaya

Fruit fly species were collected from fruits and vegetables field by using ME lure and cue lure based fruit fly traps and also from the infested fruits and vegetables in the year 2014 and 2015. The collected fruit fly species were separated and identified first based on the established diagnostic keys and subsequently the molecular characterization was undertaken by sequencing of partial (>700bp) mitochondrial COI gene. A total of ten different species of fruit flies viz., *B. zonata*, *B. tuberculata*, *B. cucurbitae*, *B. ruiliensis*, *B. carambolae*, *B. scutellaris*, *B. dorsalis*, *B. tau*, *Bactrocera* spp. 1 and *Bactrocera* spp. 2 (Fig 34) were successfully identified and characterized at molecular level. *Bactrocera* spp.1 which resembles similarities with *B. aethriobasis* and *B. ruiliensis* has been reported first time from India. *B. scutellaris* has been reported first time from the North East India. Across the ten *Bactrocera* species,



no INDELs (Insertion and Deletions) were observed at nucleotide sequences of partial COI gene. All the sequences were submitted to NCBI vide accession number KT151114 to KT151123.



**Fig 34. Ten different species of fruit fly of the genus *Bactrocera* characterized at molecular level**

## PLANT PATHOLOGY

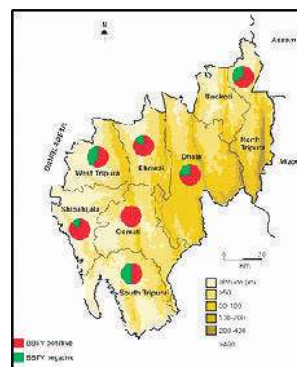
### Biodiversity of plant pathogens in northeast India

Powdery mildew is a serious problem on Khasi mandarin (*Citrus reticulata*) and is considered as one of the factors responsible for citrus decline in this region. Molecular identification was done for powdery mildew pathogen (anamorph) on *Citrus reticulata* based on nrDNA ITS region (ITS 1-5.8s and ITS2). Maximum likelihood analysis clearly clustered the sequences from this study (KP797974 and KR131403) with *Erysiphe quercicola*. Based on these results, it is clear that the anamorph of the powdery mildew pathogen on *Citrus reticulata* belongs to *E. quercicola*. Molecular identification was also done for powdery mildew pathogens on cucurbits. The ITS sequences obtained (KP242025, KM036210, KM036211, KM036212, JX403722 and KM036213) from powdery mildew pathogens of *Cucurbita maxima*, *C. moschata*, *Sechium edule* and *Cucumis sativus*, respectively were highly similar to *Podosphaera xanthii* sequences in nBlast searches. Maximum

likelihood analysis clearly clustered our sequences within main *Podosphaera xanthii* clade which indicated presence of anamorph of *P. xanthii* on these hosts. Morphological and molecular characterization was done for ascertaining the accurate identity of the powdery mildew pathogen (anamorph) on soybean (*Glycine max*). Light and scanning electron microscopy revealed it to be a *Pseudoidium* anamorph. Type of wrinkling pattern on conidia was examined using scanning electron microscopy. Molecular analysis was also used for confirmation using ITS (ITS1-5.8s-ITS2) region. Morphological and molecular evidence based on sequences proved it to be an anamorph of *Erysiphe diffusa*.

### Genetic structure of *Banana bunchy top virus* (BBTV) in Tripura: Indication of trans-boundary exchange of planting materials

Diagnostic surveys were conducted in seven districts of Tripura and polymerase chain reaction based detection established that BBTV is widely prevalent in all parts of Tripura (Fig 35) showing an average incidence of 22.02% (Table 12). A representative population (31 isolates) of BBTV from Tripura was characterized based on DNA R and DNA S. The clustering pattern and genetic diversity of BBTV population from Tripura suggested monophyletic origin of majority of representative isolates from a common ancestor of Pacific-Indian Oceans (PIO) group. The exchange of vegetative propagules within and in between countries could have contributed to the geographical expansion of PIO isolates in Tripura. However, four variant BBTV isolates has been identified from North Tripura and Khowai districts possessing somewhat unique variability than that of distinct isolate (BBTV-Umiam) reported from NE India (Meghalaya). This further strengthened the differential evolution of BBTV in NE India.



**Fig 35. District wise occurrence of BBTV in Tripura**



**Table 12. District wise occurrence and incidence of BBTV in Tripura**

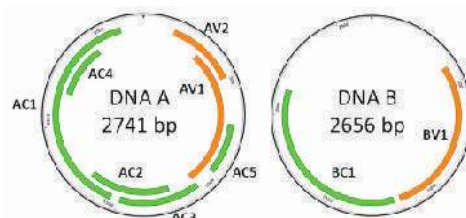
Districts	Occurrence		Incidence		Percent
	Location Surveyed		Samples tested for BBTV		
	Total	BBTV occurrence found	Total	Positive to BBTV	
North Tripura	6	4	32	13	40.63
Dhalai	8	6	26	10	38.46
Khowai	6	5	45	9	20.00
West Tripura	7	4	34	6	17.65
Shipahijala	7	6	52	13	25.00
Gomati	6	6	70	13	18.57
South Tripura	8	4	68	8	11.76
Total	48	35	327	72	22.02

### Identification and characterization of yellow mosaic virus species associated with yellow mosaic disease in Meghalaya

During 2014-15, symptoms like yellowing of inter-veinal tissue and bright yellow spots in the leaves were observed in mungbean, black gram, soybean and ricebean growing in mid-hills of Meghalaya (Fig 36). The polymerase chain reaction assay showed specific amplicon for MYMIV DNA A, MYMIV DNA B and MYMV DNA B from the symptomatic leaf samples. The whole genome characterization following rolling circle amplification confirmed identical features in DNA A (2741 bp) and DNA B (2656 bp) as of *Begomovirus*. The BLAST analysis of DNA A from Meghalaya showed 95-97% identity with MYMIV DNA A, while DNA B showed 90-96% identity with both MYMIV DNA B and MYMV DNA B. Moreover, the highest identity of 96% was with MYMV DNA B from Tamil Nadu having a recombinant DNA B (Fig 37). One recombination event was identified in DNA B spanning the nucleotide region 2462-2729 nt (possessing the common region). Recombination signals detected by five different methods coupled with phylogenetic evidence confirmed MYMV DNA B as the major parent and MYMIV DNA B as the minor parent. Therefore, yellow mosaic disease in Meghalaya is an association of MYMIV DNA A with a recombinant MYMV DNA B.



**Fig 36. Symptom of yellow mosaic disease**



**Fig 37. Genome organization of yellow mosaic virus isolate from Meghalaya**

### Antagonistic potential of fluorescent *Pseudomonas* species against bacterial wilt pathogen

A total of 14 fluorescent *Pseudomonas* isolates were evaluated against virulent strain of *R. solanacearum* (RsRC-S<sub>9</sub>R<sub>1</sub>). During in-vitro bio-efficacy test, 13 isolates showed inhibition by volatile metabolites. However, only 6 isolates showed inhibition by non-volatile metabolites. In case of volatile metabolites, maximum inhibition zone (19.33 mm) was shown by fluorescent *Pseudomonas* isolate RCPs-4; while in case of non-volatile metabolite, maximum inhibition zone (11.0 mm) was shown by isolate RCPs-34. However, isolate RCPs-26 and RCPs-34 showed antagonism by both volatile and non-volatile compounds.

## FARMING SYSTEM RESEARCH

### Farming System Research Project

Micro watersheds comprising of 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) is being evaluated on long term basis at ICAR Research Complex for NEH Region, Umiam, Meghalaya.

### 1. 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 falls under annual fodder crops and the remaining under broom and guinea grass production. Three numbers of milch cow along with their calves were maintained 0.50 ha area in the system. An analysis of fodder production and requirement revealed that total green fodder from forage crops and slopping land was 35.4 t, while the requirement for dairy animals was 29.70 t, showing a surplus of (+) 7.81 t/annum. The feed concentrate, paddy straw and medicine were arranged from nearby market costing to Rs. 97,047. The milk yield obtained from the system was 3,980 litres amounting to Rs.1,19,400. Besides, 29.60 tonnes of FYM produced from cow dung, urine, crop residues and weed biomass in the system. The net annual income from the system was calculated as Rs. 28,039.

### 2. Mixed Forest Block (FSW-2)

Mixed forest block had been 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 auriculiformis*, *Michelia oblonga* and *Symingtonia populnea* for timber and fuel purpose. The plant height and Dead Breast Height (DBH) of the trees were 1.31 m and 1.18 m for *Acacia auriculiformis*, 1.16 m and 1.08 m for *Michelia oblonga* and 1.35 m and 1.20 m for *Symingtonia populnea* respectively.

### 3. 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%. Twenty seven goats (9 males, 18 females) were maintained in this system by demarcating 0.5 ha area in the system which resulted a net income of Rs. 9,750.00. The system was not generating profit and hence, poultry (427 no. broilers) chicks were also integrated in four cycles on the dyke of fish pond of 500 m<sup>2</sup> of area as a subsidiary source of income. The fish weight of 35 kg was recorded, which together with

broiler poultry increased income of the system. The gross income from this system was Rs. 1,03,710 with input cost of Rs. 88,374 on feed, concentrate and procurement for day old chicks resulting into a net profit of Rs. 15,536 from the watershed. The lower half portion of the watershed was planted with fodder trees species *Symingtonia populnea*, *Bauhinia purpurea*, *Ficus* spp, *Schima wallichii*, *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.

### 4. Agro –pastoral system (FSW-4)

Agro-pastoral system established in 0.64 ha area having an average slope of 32.42 %. The hill slopes is having 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 which resulted a production of 15204.3 kg of rice equivalent yield (REY) excluding guinea grass from the system.

An integrated approach with crops and livestock showed that maximum income was obtained from cow milk (Rs.1,05,000). This system could generate 240 man-days employment amounting to Rs. 48,000 adding the cost of other inputs amounting to Rs. 1,53,397. The gross and net income of Rs. 3,33,636 and Rs. 1,80,238 was obtained, respectively giving an input–output ratio 0.45. Production of guinea grass on terrace risers in the lower and middle part of the watershed and broom on the top portion of the watershed provided green fodder sufficient for 8 months for the dairy unit without any extra input/management cost.

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

The area of Agri-horti-silvi-pastoral system was developed 1.58 ha for *jhum* improvement in NEH Region. Out of which, 0.55 ha was under forest while 1.03 ha under planned land use system. 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 use and 0.44 ha for silvi-pastoral crops. The Agri-horti-silvi-pastoral system produced 8344 kg REY. The highest REY of 3000 kg was estimated with cow milk followed by Capsicum-Turmeric (2006.5 kg REY).

Cost of cultivation analysis indicated gross return of Rs. 94,781 from the system while net return of Rs. 45,092 was obtained from one cow dairy unit.



Vegetable component registered a net income of Rs.18365 while fruit orchard (guava and pineapple) gave a net income of Rs. 5071 amounting to a total net income of Rs. 45,092 from the system.



Fig 1. Agri-horti-silvi-pastoral system

## 6. 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 of which 0.50 ha area was kept for system study. The average slope of the area was 53.18%. Lower terraces covering an area of 490 m<sup>2</sup> was utilized for growing spices and vegetables like turmeric + bottle gourd, turmeric + pumpkin and turmeric alone. 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. 34,400.00 was recorded from this system.

## 7. 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 use (0.95 ha). The average slope was 45.87 %. The watershed area was dominated by common weed flora viz. *Fumaria parvifolia*, *Ciprus irri*, *Eupatorium adenophorum*, *Arundinella bengallensis*, *Solanum khasianum* and *Ageratum* spp. Two tree species were commonly grown on the natural forest in the watershed area. The growth and development attributes of these tree species revealed that *Pinus kesiya* (1.6 m) attained more plant height and other developmental attributes as compared to *Schima wallichii* (1.25 m).

## 8. Timber –based farming system (FSW-8)

The area of 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 height of 1.03 m and 1.01, respectively.

## Effect of integrated farming systems (IFS) on fractions and stocks of organic carbon in acid soils of Meghalaya

The status of total and other fractions of organic carbon (SOC) in soils under different integrated farming systems (IFS) viz. Alder based IFS (with turmeric, Elephant foot yam, ginger, maize and ginger+turmeric) and Melina based IFS (with turmeric, Elephant foot yam, ginger, maize and colocasia+elephant foot yam) in Meghalaya was assessed. The results revealed that the TOC varied from 2.81 to 3.17 g per 100g under Melina based IFS and from 2.92 to 3.18 g per 100g under Alder based IFS. On an average, alder based IFS recorded higher TOC than Melina based IFS (Fig 2). With respect to the crop combinations in the IFS, soils under melina+elephant foot yam (EFY) and alder + colocasia + EFY contained maximum amount of TOC in melina and alder based IFS, respectively. Irrespective of the IFS, the very labile and labile fractions of SOC constituted more than 50% of the total organic carbon (TOC) while the less labile and non-labile fractions constituted less than 50%. Similarly, soils under melina + elephant foot yam (EFY) and alder + colocasia + EFY had the maximum values of all the fractions of organic carbon as compared to that under other crop combinations of melina and alder based IFS (Fig 2). With regard to SOC stocks, the total SOC stocks was found to be the highest under alder based IFS (37.5 t/ha). In melina based IFS it was found to be 35.2 t/ha. In melina based IFS, melina+ginger+turmeric recorded the maximum SOC stocks (40.7 t/ha) while under alder based IFS, alder+colocasia+EFY recorded the maximum value of SOC stocks (42.8 t/ha) (Fig 3). Amongst several IFS studied, alder based IFS, alder+colocasia+EFY in particular performed better in sequestering organic carbon as well as other fractions of organic carbon as compared to other crop combinations under both the IFS.

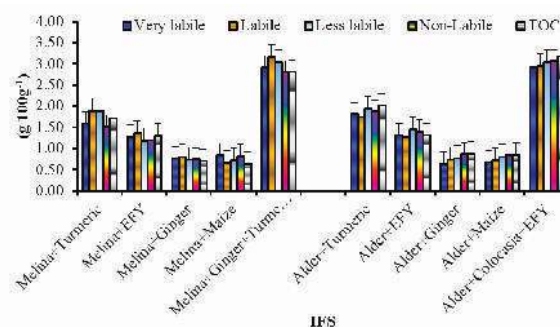
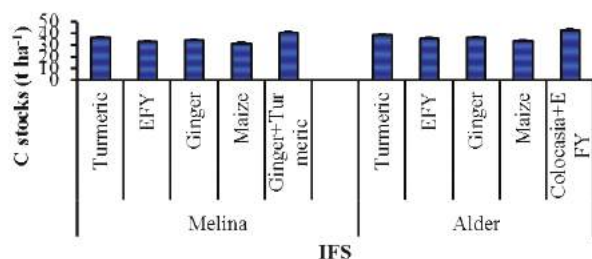


Fig 2. Soil organic carbon fractions and TOC under different IFS in Meghalaya



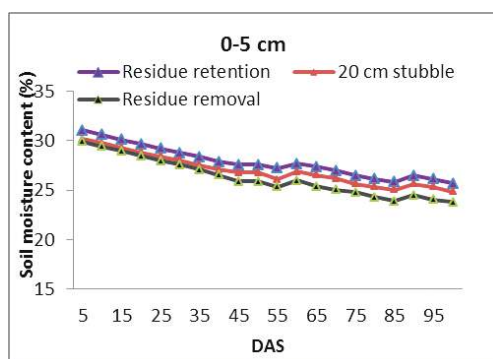


**Fig 3. Soil organic carbon stocks under different IFS in Meghalaya**

## CONSERVATION AGRICULTURE

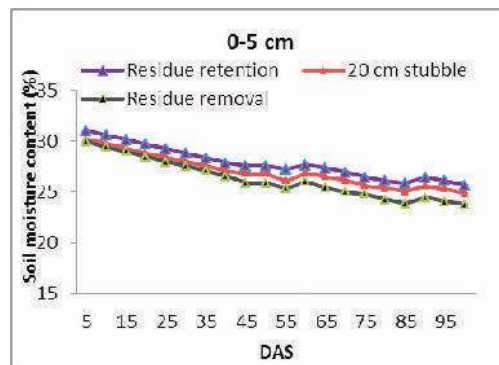
### Mitigating abiotic stresses and enhancing resource use efficiency in pulses in rice fallows through innovative resource conservation practices

Rice-lentil cropping system was evaluated in upland and lowland farm of Agronomy under different tillage and residue management options. The no-till (NT) recorded higher rice yield (3.75 t/ha) as compared to conventional tillage (CT) (3.69 t/ha). The tillage practice and water management had significant effect on leaf relative water content (LRWC). Residue retention under life-saving irrigation (LSI) recorded maximum LRWC (78.75, 73.27 and 71.74%) followed by 20 cm standing stubble (66.84%) at 90 DAS. About 38.5 and 13.5% higher water potential was recorded with residue retention and 20 cm standing stubble, respectively as compared to residue removal. The highest soil moisture content was observed under mulching followed by 20 cm standing stubbles which were significantly higher than residue removal (Fig 4). Irrespective of tillage / irrigation / stubble management practices and depth, less soil resistance was observed under mulching and 20 cm standing stubbles (Fig 5). Bulk density was the lowest under



**Fig 4. Rice stubble management practices on soil moisture content under no-till (Lifesaving irrigation) at 0-15 cm depth in upland condition**

NT (1.02 Mg/m<sup>3</sup>) as compared to CT (1.06 Mg/m<sup>3</sup>) at 0-15 cm soil depth. It was the lowest under residue retention (1.00 Mg/m<sup>3</sup>) followed by 20 cm standing stubble (1.05 Mg/m<sup>3</sup>) and maximum under residue removal (1.07 Mg/m<sup>3</sup>).



**Fig 5. Soil resistance as influenced by rice stubble management (no-till) in rainfed condition (upland)**

In Lowland, two establishment techniques for rice (puddled and un-puddled transplanting), three residue management practices (rice residue retention @ 5 t/ha, 20 cm standing rice stubble and residue removal) for *rabi* lentil and two nutrient management options i.e. recommended doses of fertilizer (RDF) and improved management practices (2% DAP and micronutrient along with RDF) (Fig 6 and Fig 7). The grain yield of rice under un-puddled transplanting (5.17 t/ha) was relatively higher than puddled transplanting (5 t/ha). Transplanting, nutrient and residue management practices have significant effect on LRWC. Un-puddled transplanting registered higher LRWC (81.00, 84.40 and 79.82%) at 30, 60 and 90 DAS, respectively as compared to puddled transplanting. Higher leaf water potential was recorded with residue retention (9.21%) as compared to 20 cm standing stubble (5.65%) and residue retention.



**Fig 6. Lentil (DPL 62) in upland field**

**Fig 7. Lentil (IPL 81) in lowland field**

### Standardization of nutrient requirement under different resource conservation technologies for rice based cropping systems

Field experiments were conducted on rice- pea and rice-rapeseed cropping system under lowland and



upland condition, respectively to evaluate of nutrient requirement under different resource conservation technologies during 2012 to 2016. In rice-pea sequence, treatments for rice comprised of three tillage practice i.e., no-till (NT), minimum tillage (MT) and conventional tillage (CT) and five nutrient management (NM) practices. After harvest of rice (cv. Shahsarang 1), pea varieties Prakash (field pea) and Arkel (Garden pea) was sown under NT with 20 cm standing rice stubble and grown with recommended package of practices (20:40:30 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg/ha). The maximum grain yield of rice was recorded under NT (4.85 t/ha) followed by MT (4.56 t/ha) and CT (4.25 t/ha). Among NM practices, the highest grain yield of rice was recorded under 50 % NPK + weed biomass (WB) of *Ambrosia artemisiifolia* @ 10 t/ha on fresh weight basis (4.82 t/ha) followed by 50% NPK + GLM (4.77 t/ha). The grain yield of rice under 50% NPK + WB was 9.10% and 16.7% higher than that under 100 % NPK and 50 % NPK, respectively. Green pod yield of pea cultivated under zero tillage with residual effect of MT was the highest (7.52 t/ha) followed by NT (6.40 t/ha) and lowest in CT (7.15 t/ha) for Prakash. Similarly, Arkel had the highest green pod yield under residual effect of MT (4.61 t/ha) followed by NT (4.20 t/ha) and lowest in CT (4.00 t/ha). The green pods of pea variety Prakash was significantly higher under 50% NPK + WB (7.45 t/ha) and were statistically at par with 50% NPK + green leaf manure (GLM) of *Tephrosia purpurea* @ 10 t/ha on fresh weight basis (7.38 t/ha). SOC stock was found to be not influenced by tillage practices at soil depth (0-15 cm) but significantly influenced by NM practices, (Fig 8).

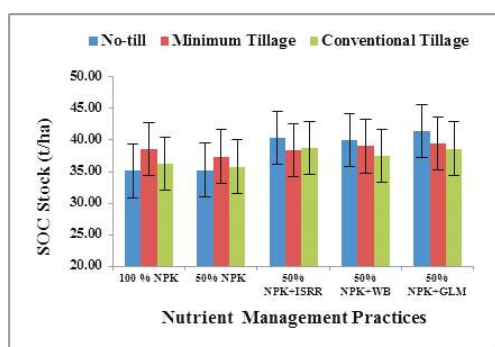


Fig 8. SOC stock (t/ha) at 0-15 cm soil depths seed

For rice-rapeseed system in upland, treatments comprised of two tillage for rice (variety IURON-514) i.e., conservation tillage (CsT) and conventional tillage (CT) and five NM practices. After harvesting of rice,

rapeseed (var. TS-46) was sown with recommended dose of fertilizer (60:60:40 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg/ha) under zero tillage in rice fallow maintained with 30 cm standing stubble in CsT plots and complete removal of stubbles in CT plots (Fig 9). Grain yield was significantly higher under CsT compared to CT. Among the different NM practices, 50% NPK + WB recorded the highest yield. The residual effect of rice on seed yield of rapeseed is also varied with tillage and NM practices. Seed yield of rapeseed was significantly higher under CsT compared to CT. Residual effect of 50 % NPK + WB (525 kg/ha) was recorded significantly higher seed yield of rapeseed as compared to 50 % NPK (475 kg/ha).



Fig 9. Rapeseed (TS-46) in upland condition as influenced by tillage and NM practices

## ORGANIC FARMING

### Evaluation of maize cultivars for their suitability under organic production system

Maize is the most potential and predominant rainy season crop in the upland ecosystem of North Eastern Region of India. For getting optimum yield in maize from organic farming, organic input responsive varieties are to be identified. Eleven varieties/ lines of maize comprising eight composites, one hybrid and two local lines were evaluated in Agronomy farm of ICAR Research Complex for NEH Region, Umiam under organic production system. Significantly, the highest chlorophyll index at 60 days after sowing (DAS) was recorded in the variety DA 61A followed by RCM 1-3. Cob weight was maximum in variety DA 61 A. The highest grain yield was recorded in variety DA 61 A (3.77 t/ha) followed by RCM- 76 (3.58 t/ha). For green cob production, RCM-75 and RCM-76 (75-80 days) recorded the shortest crop period followed by DA 61A (80 days) and RCM 1-2



(85 days). However, for seed production, DA 61A took 110 days duration followed by RCM 1-2 (115 days). Local lines took 125-130 days for seed production. Thus, DA 61A and RCM-76 varieties of maize are most suitable for growing in NEH Region under organic production system.

### Evaluation of different varieties of French bean crop under organic farming

Yield was recorded by taking both green pod and seed yield as presented in the Fig 10. Highest green pod yield was recorded in Naga local (8.70 t/ha) followed by RCM-FB-18 (7.81 t/ha) and RCM-FB-80 (5.64 t/ha). Lowest green yield was recorded in Maram (0.98 t/ha) followed by Director 1 (2.09 t/ha) and RCM-FB-61 (3.50 t/ha). Recorded seed yield also showed similar trend as in green pod wherein Naga local (4.17 t/ha) was found highest and Maram (0.63 t/ha) was the lowest.

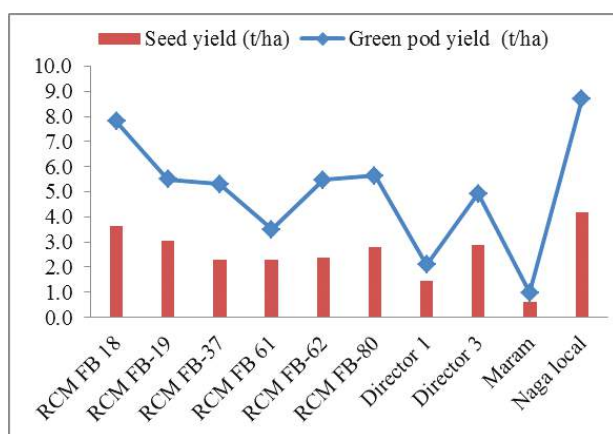


Fig 10. Yield of different varieties of French bean under organic production system

### Field evaluation of fungicides, fungal biocontrol agents and bioorganic for management of rhizome rot in ginger

Ginger variety Nadia was selected for the experiment and planted during the 3<sup>rd</sup> week of April 2015. The number of leaves per plant and plant height were not affected significantly with any treatments. Number of pseudostems and dry matter accumulation were also non-significant for all other treatments except GF1 formulation, which resulted in 51.14% more pseudo stems 23.75% higher dry matter accumulation over control.. All the treatments significantly affected the disease incidence percent in ginger crop and the best result was recorded with Ridomil MZ 72 WP treatment with over 88.7% of plants were free from disease. The rhizome yield

recorded highest with GF<sub>1</sub> (T<sub>6</sub>) and it was 27.7 percent more over control whereas, in case of Ridomil MZ 72 WP (T<sub>2</sub>) it was 19.09 percent more over control.

## JHUM IMPROVEMENT

### Participatory production technology development in maize

An experiment was conducted in *jhum* field of Sonidan village of Meghalaya to identify efficient varieties and improved agronomic management practices (IAMP) for maize production (line sowing of seeds across the slope, low doses of manure (2 t/ha) and fertilizer application @ 40:30:20 kg N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O/ha, Lime @ 500 kg/ha, two hand weeding, need based insect and disease management etc.) Table 1. Nine varieties of maize (Hemant, Vijay Composite, DA 61A, RCM 1-1, RCM 1-3, RCM 75, RCM 76, Saru Tangring, and Saru Bhoi) were evaluated under IAMP and compared with farmers' practice (seeds are randomly dibbled, no manure/fertilizer application, no proper weed management, no pesticide application etc.). Results revealed that, chlorophyll index (43.88), number of grain per cob (301.5), seed weight per cob (72.4 g), test weight (240.3) and grain yield (3.41 t/ha) were significantly higher in IAMP compared to farmers' practice (grain yield 1.25 t/ha). Among varieties, DA 61 A (2.92 t/ha) and RCM 75 (2.60 t/ha) have performed better over other varieties in terms of grain yield, test weight and seed weight per cob.

### Sustainable production of *jhum* rice through improved agronomic management practice

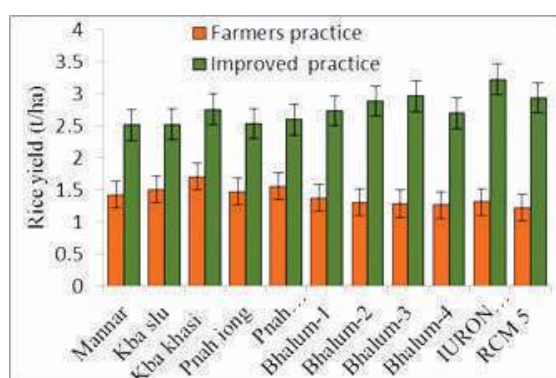
A three years (2013-2015) participatory research was conducted in the farmers' *jhum* field of Sonidan village, Ri-Bhoi District, Meghalaya to identify suitable rice varieties/lines and improved agronomic management practices for improving productivity and sustainable soil health. Five local rice varieties and six improved varieties were evaluated under both local and improved management practices. Soybean and groundnut were successfully grown as intercrops with rice. Tephrosia were grown along the contour at suitable intervals for checking soil loss and improving soil fertility.

The highest rice yield was obtained under IURON 514 (3.13 t/ha) followed by Bhalum -3 (2.89 t/ha) and RCM -5 (2.88 t/ha) Fig 11. On an average, 64% and 113% yield enhancement was recorded with local and high yielding rice varieties, respectively, when grown



**Table 1. Effect of cultivation practices and varieties on chlorophyll index, yields attributes and yield of maize**

Treatment	Chlorophyll Index	No. of seeds /cob	Seed weight /cob (g)	Test weight (g)	Grain yield (t/ha)
Cultivation practice					
Improved Practice	43.88	301.50	72.40	240.30	3.41
Farmers' practice	37.39	235.20	50.20	220.90	1.25
S.Em±	0.17	1.51	0.47	1.12	0.01
C.D. (P=0.05)	0.48	4.34	1.35	3.21	0.03
Variety					
Hemant	37.63	225.20	51.30	235.80	2.32
Vijay Composite	38.35	274.50	63.40	212.80	2.04
DA 61 A	41.27	303.50	76.00	238.50	2.92
Saru Tangring	39.78	241.70	52.40	249.30	2.00
Saru Bhoi	40.50	270.80	52.60	215.30	2.27
RCM 1-1	44.19	278.60	62.80	197.00	2.12
RCM 1-3	40.65	255.70	61.20	218.20	2.30
RCM 75	41.42	300.60	75.40	257.30	2.60
RCM 76	41.93	264.90	56.50	251.00	2.40
S.Em±	0.75	6.79	2.11	5.03	0.05
C.D. (P=0.05)	2.17	19.51	6.06	14.45	0.14



**Fig 11. Effect of different organic practices on production of *jhum* rice**

under improved agronomic management practices as compared to farmers' practice (control). The highest yield of Mannar and IURON 514 was recorded with line sowing (2.49 and 2.99 t/ha, respectively) as compared to dibbling (2.02 and 2.28 t/ha) and

broadcasting (1.77 and 1.61 t/ha). Application of 50% recommended dose of nutrients (RDN) (30:30:20 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O/ha) either through fertilizer or fertilizer + FYM both recorded 40 to 60% enhancement in rice yield in *jhum* field. Foliar spray of DAP (2%) twice at 30 and 60 days after sowing resulted in 25 to 39% yield enhancement in rice across the varieties as compared to farmers' practice (Fig 12 and Fig 13)

#### Evaluation of sea weed sap on performance of tomato

Field experiment was conducted during the 2015 to study the effects of foliar applications of different concentrations (5 and 10%) of seaweed extracts viz., *Kappaphycus sp* (K sap) and *Gracilaria sp* (G sap), GA<sub>3</sub> free sap as well as vermiwash on growth, yield and quality of tomato. Significantly higher number of fruits/plants, fruit weight and tomato yield were recorded with seaweed sap and vermiwash spray as



**Fig 12. Rice+soybean intercropping in *jhum* land**



**Fig 13. Bhalum-1 sowing**



compared to control (water spray). The highest numbers of fruits/plant were recorded with 10% K sap followed by 10% G sap and 10% vermiwash. The average weight of tomato/fruit was highest under 10% K sap, however it was at par with 10% vermiwash spray and 10% G sap and 10% GA<sub>3</sub> free spray. Significantly highest tomato yield (13.06 t/ha) was recorded with 10% K sap followed by 10% vermiwash spray (13.0 t/ha) and 10% G sap (12.64 t/ha) as compared to control (9.27 t/ha) Table 2.

The quality attributes like ascorbic acid and lycopene content in tomato also significantly influenced by different concentrations of sea weed sap and vermiwash spray. Significantly the highest ascorbic acid content was recorded under GA<sub>3</sub> free sap (25.41 mg/100g) followed by 10% G sap (24.23 mg/1000g) as compared to control (19.77 mg/100g). The lycopene content was highest under 10% GA<sub>3</sub> free sap followed by 10% K sap and 10% G sap.

## PLANT PHYSIOLOGY

### Physiological aspects of phosphorus efficiency in Maize for acid soils of NEH region

Different nutrient sources of phosphorus were evaluated in acid soil of Meghalaya. Results indicated

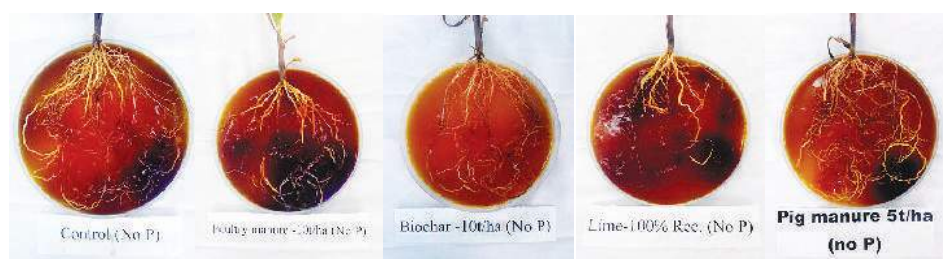
the content of chlorophyll increased in plants provided with pig manure @ 5 t/ha and biochar @ 10 t/ha. Anthocyanin accumulation in the leaves of the plant grown with biochar applied @ 5 t/ha was significantly higher compare to other nutrient sources. Root exudation showed that the organic acids were synthesized and excreted more in control and in the roots provided with pig manure @ 5 t/ha (Fig 14). Plants grown with FYM @ 10 t/ha and poultry manure accumulated more nutrient uptake especially phosphorus compare to other treatments. Root size was higher in FYM than poultry manure. These results reveal that maize plants grown with poultry manure, pig manure and biochar @ 10t/ha has shown better growth and nutrient accumulation in acidic soils of Meghalaya

### Physiological response of buckwheat for nutrient management practices in acid soils

Buckwheat is a crop with multi stress tolerance ability suited for the region. In this study, the morpho-physiological response of buckwheat for various nutrient management (NM) practices has been evaluated. Among various NM practices, T2 (RDF), T6 (PLM@5t/ha) and T8 (RDF+VC @ 2.5t/ha) have shown significantly altered chlorophyll pigmentation,

**Table 2. Yield attributes, yield and quality parameters of tomato as influenced by different concentrations of sea weed sap and vermiwash spray**

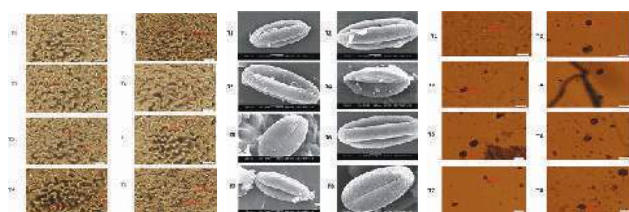
Treatments	Fruits/plant	Weight/fruit (g)	Yield (t/ha)	Ascorbic acid (mg/100g)	Lycopene (mg/1000g)
T1. Control (water spray)	8.0	40.0	9.27	19.77	10.68
T2. K sap @ 5%	10.7	45.7	11.94	22.43	12.12
T3. K sap @ 10 %	12.6	47.3	13.06	23.33	13.14
T4. G sap @ 5%	10.3	44.3	11.47	22.33	12.07
T5. G sap @ 10%	12.5	45.3	12.64	24.23	13.10
T6. GA <sub>3</sub> free sap @ 5%	10.3	44.0	11.83	23.27	12.57
T7. GA <sub>3</sub> free sap @10%	11.2	46.0	12.08	25.41	13.74
T8. Vermiwash @ 5%	10.3	43.3	12.36	21.50	11.29
T9. Vermiwash @10%	11.7	46.7	13.00	21.83	11.80
SEm+	0.6	1.5	0.48	0.67	0.40
LSD (P=0.05)	1.7	4.5	1.45	2.01	1.20



**Fig 14. Differential Root exudation of maize plants grown different nutrient sources in pot culture**



improved root architecture, increased stomatal distribution and size, increased pollen morphology and pollen viability (Fig 14). The pollen morphology data recorded through SEM indicate altered pollen size and structure under different NM practices. Bigger and turgid pollens were noticed in T2, T3, T6 and T8. Under above treatments, pollens were germinated better with longer pollen tube growth. The changes in pollen morphology reflected in altered pollen viability depicted in Fig.15 under different NM practices. The yield components recorded indicate higher grain as well as straw yield under T2 with RDF, T6 with PLM @ 5t/ha and T8 (RDF+ VC @ 2.5t/ha).



**Fig 15. Stomatal distribution, Pollen morphology and pollen viability of buckwheat**

## SOIL SCIENCE

### Evaluation of organic manures as a substitute of lime for amelioration of acid soils

The ash alkalinity of organic manures viz. poultry manure, pig manure, compost and FYM was determined and calcium carbonate equivalent (CCE) of these manures estimated. The CCE of poultry manure was found to be the highest ( $8981 \text{ kmol H}^+/\text{kg} \times 10^{-6}$ ) followed by FYM, pig manure and the compost (Table 3). Because of high ash alkalinity, the liming potential of poultry manure was maximum (CCE  $449 \text{ kg/t}$  of the product) as compared to the other organic manures tested. The liming potential of these manures was evaluated against recommended liming materials (agricultural lime and lime sludge of paper mill) under field conditions during 2014-15 using mustard as test crop (cv. M-27) grown in acid soil having pH 4.55. Mustard grain yield under 50% of recommended dose of fertilizer (50% RDF as control) was recorded to be  $4.81 \text{ q/ha}$ . Application of agricultural lime (@  $4 \text{ q/ha} + 50\%$  of RDF) in furrows increased the grain yield by 38.7% over control. Application of lime sludge in furrows (@  $4 \text{ q/ha} + 50\%$  RDF) increased the yield by 88% over the control treatment (50% RDF). The grain yield of the crop ranged between 6.64 to  $16.4 \text{ q/ha}$  under different

organic manure treatments when applied @  $2.5 \text{ t/ha}$  as a substitute of lime. The grain yield increased further ( $9.3$  to  $21.9 \text{ q/ha}$ ) when the same manures were applied @  $5 \text{ t/ha}$  (+50% RDF) Fig 16a & b. Among the organic manures, the performance of poultry manure (as substitute of lime) at both the rates of application was superior over other tested organic manures in increasing the yield of the crop. Lime can be substituted with the tested organic manures without affecting the yield of mustard crop.

**Table 3. Ash alkalinity of organic manures**

Product	Ash Alkalinity ( $\text{kmol H}^+/\text{kg} \times 10^{-6}$ )	$\text{CaCO}_3$ Equivalent ( $\text{kg/t product}$ )
Poultry Manure	8981 (7707-10896)	449 (385-545)
Pig Manure	2876 (2312-3171)	144 (116-159)
Compost	2778 (1145-3966)	139 (57-198)
FYM	4018 (4014-4371)	201 (184-219)

(Values in brackets indicated the range)



**Fig 16a. General View of the Experiment**



**Fig 16b. Poultry manure@ 5 t/ha+50% RDF**

### Maize rhizosphere effect on soil organic carbon pools and enzymes activity

Studies on rhizosphere effect of maize on organic carbon pools revealed that rhizosphere soil contained significantly higher quantity of different fractions of soil organic carbon than that of non-rhizosphere soil (Table 4). Proportion of soil organic carbon (SOC) and microbial biomass carbon (MBC) over total organic carbon (TOC) and MBC over SOC was significantly higher in the rhizosphere soil as compared to that of non-rhizosphere soil. Soil enzymes (dehydrogenase, acid phosphatase and glucosidase) activity was also found to be significantly higher in the rhizosphere soil as compared to that of non-rhizosphere soil. Correlation study revealed that there is significant correlation between the organic carbon fractions and enzyme activities in soil.



**Table 4. Soil biochemical properties in rhizosphere and non-rhizosphere soils**

Parameters	Rhizosphere soil	Non-Rhizosphere soil
SOC(%)	1.67 <sup>A</sup>	1.40 <sup>B</sup>
MBC(mg/kg)	542 <sup>A</sup>	418 <sup>B</sup>
SOC/TOC(%)	41.0 <sup>A</sup>	34.4 <sup>B</sup>
MBC/TOC(%)	1.33 <sup>A</sup>	1.02 <sup>B</sup>
MBC/SOC(%)	3.25 <sup>A</sup>	2.95 <sup>B</sup>
DHA (ug TPF/g/h)	13.9 <sup>A</sup>	11.3 <sup>B</sup>
PHA (mg phenol/kg/hr)	385 <sup>A</sup>	286 <sup>B</sup>
GSA (mg phenol kg/hr)	83.2 <sup>A</sup>	74.5 <sup>B</sup>

\* values in a row followed by different letter are significantly differ at  $P=0.05$  by DMRT

DHA: Dehydrogenase activity; PHA: Acid Phosphatase activity; GSA: Glucosidase activity

#### Root inhibition test of pesticides viz. Carbendazim and Carbofuranin

This study evaluated the inhibition effects of pesticide formulations of carbendazim (Crosstin 50% W.P.), a systemic fungicide and carbofuran (Furasac 3% G Encapsulated), a nematicide as well as an insecticide on root of *Allium cepa*. The evaluation was made based on  $EC_{50}$  value. Dose dependent reduction in *A. cepa* root length was observed for the two pesticides. Significant reduction in root length was observed at 80 ppm for both the pesticides compared to the control. The  $EC_{50}$  values showed growth inhibition at 81 ppm and 83 pmm for carbendazim and carbofuran, respectively.

#### Survey on identification of coal mine affected areas in Jaintia Hills District of Meghalaya

Mining in Jaintia hills district of Meghalaya tends to make a notable impact on environment, its impact varying in severity depending upon whether the mining is continuing or abandoned. Acid mine drainage (AMD) associated therewith is one of the major environmental concerns in the region. To identify the coal mine affected areas, a survey was conducted during the pre-monsoon season (2016) in East and West Jaintia Hills district, Meghalaya. Geo-referenced soil and water samples were collected from both affected and unaffected areas in the districts for assessment of heavy metal and trace elements contamination. The precipitates of iron hydroxides and oxides which occur on streambeds as yellow–orange jelly-like coatings, called ochre are commonly observed in AMD-affected areas near the mining sites and the stockpiles (Fig 17c).

During the survey, it was observed that coalfields in the district are small and highly dispersed. However stockpiles are a common sight in most of the areas in Jaintia Hills specially near the road sides. Mining activities in West Jaintia Hills are almost abandoned while extensive mining activities are continuing in East Jaintia Hills. Large areas near Jowai and adjoining areas in West Jaintia Hills still remain unaffected though very few stockpiles could be seen. Identified coal mining areas include Lad Rymbai, Sutgna, Jarain-Shkentalang, Rymbai, Lumshong, Iongnoh. It was observed that the tribal population in the district (having complete ownership of their land including the underground resources as per the prevailing land-holding system in Meghalaya) is engaged in coal extraction using an unscientific, vulnerable, artisanal method of underground mining, called as ‘rat-hole’ mining which involves felling tree, digging a pit of 5 to 100 m<sup>2</sup> till coal seam is reached, making a side way tunnel, and finally extraction of coal from the pit by wheel-barrow. Mine shafts have been dug almost everywhere, forests, agricultural fields and grasslands (Fig 17a). The exhausted mines are never backfilled which not only causes environmental degradation but also poses a big threat to humans and livestock as well.



**Fig 17 (a). Rat-hole mining- a crude mining technique (b) Mine shaft filled with rain water (c) Stockpiles of Coals (d) Corrosive layer seen on rocks at the river side (e) Drainage from stockpiles to nearby agricultural fields (f) Rat-hole mines at the river side**



## Refinement of soil test methods for acidic soils of Northeast India

Utility of mehlich-3 as multi-nutrient extractant (universal extractant) was established for the acidic soils of northeast India using both cereal (Maize) as well as pulse (Pea) crops. It could simultaneously extract at least 9 essential elements (P, K, Ca, Zn, Cu, Fe, Mn, B etc) from the acidic soils of the region with satisfactory correlations (usually >0.75) between the soil test values obtained using conventional soil test methods and the Mehlich 3 extractant. Critical limits of P, Zn and B availability in soils and their concentrations in plants were also established using Mehlich-3 extractants. Application of this universal extractant can therefore save time and resources involved in soil testing.

## Effect of Hydrogel Based Phosphate Formulations on Maize in Acid Soil

A field experiment was conducted in 2015 (June-October) to evaluate the effect of new hydrogel based phosphate formulations on soil phosphorus availability, and growth and yield of maize in acidic soils of Meghalaya. The Maize crop (Variety-DA 61-A) was grown with 9 treatments laid out in Randomized Block Design, with each treatment replicated three times. Crop yield could be improved by 0.3-0.4 t/ha by applying 50% of recommended P through ZP and KP based formulations along with full doses of N and K. Application of Citric acid and PSB formulations, either alone or in combinations, resulted in still better crop yield, with the highest yield (0.74 t/ha higher than in control) obtained by combined application of PSB and CA along with full doses of N and K. On the whole, applications of CA and PSB, and 50% P application through KP and ZP formulations were found to improve soil P availability, as well as crop growth and yield on the acid Alfisol of Meghalaya.

## WATER MANAGEMENT

### Residue management and conservation tillage in Rice-based cropping system

Field experiment was conducted to evaluate the effect of tillage and residue management in rice based system for increased production and resource conservation. Zero tillage with residue retention resulted in significantly higher yield of rice (17.2%) and succeeding *rabi* crops, Mustard (34.6%), Pea

(16.4%) and Buckwheat (27.4%) (Table1) compared to that of conventional tillage with residue removal. The water use efficiency (WUE) of succeeding *rabi* crops was greatly influenced by tillage practices. The highest WUE for mustard and pea were 8.6 kg/ha/mm and 20.8 kg/ha/mm, respectively, recorded under zero tillage for *rabi* crops (residue retention), which were 35.9 and 16.3% higher, in the same order, as compared to conventional tillage.

### Resource conservation practices in rice lowland cropping system.

The field experiment was conducted to assess different tillage practices and planting methods on growth and yield of rice and to study the influence of different tillage practices on the succeeding *rabi* crops. Highest grain yield was recorded under puddled transplanted rice (6015 kg/ha) followed by unpuddled transplanted rice (5715 kg/ha). There was 29.2% increase in grain yield recorded under puddled transplanted condition compared to unpuddled wet seeding. The lowest yield was recorded under unpuddled wet seeding (4260 kg/ha).

### Evaluation of resources conserving option on productivity and water use efficiency (WUE) of maize - toria cropping system under terrace condition

Results showed that the highest yield of both *kharif* and *rabi* crops were recorded under zero tillage. Among the intercropping systems, the yield of both crops was significantly higher under Maize+Groundnut (Fig 19) intercropping system (paired row). The practices resulted in significant increase in yield by 20.4% in mustard and 35.2% in maize. The WUE of mustard was highest under zero tillage (5.8 kg/ha/mm) as compared to conventional tillage. Among the intercrop/residue management practices, the highest WUE was recorded under Maize + Groundnut Paired (Residue Removal) which was 20.8% higher as compared to sole maize.



Maize + Soybean

Maize + Groundnut

**Fig 19. Crop performance under different intercropping practices**



### Effect of in-situ residue management on carry over soil moisture conservation and crop growth under hill agriculture

Among the residue management practices, the yield of maize (32.2 %) and mustard (15.8 %) were highest under “Maize Stalk Cover (MSC) + Poultry manure + Ambrosia” @ 5 t/ha as compared to control. The WUE of succeeding mustard was found higher under zero tillage (4.7 kg/ha/mm). Among the residue management practices “MSC + Poultry manure + Ambrosia” @ 5t/ha recorded the highest WUE (15.1%) as compared to control (Table 5).

**Table 5. Yield of maize and succeeding mustard as influenced by tillage and residue management practices**

Treatments	Maize	Mustard	
Tillage	Grain yield (kg/ha)	Seed yield (kg/ha)	WUE (kg/ha/mm)
Conventional Tillage	5618a	765.2a	4.8
Zero Tillage	5193b	747.9b	4.7
Residue management			
Control	4582b	714.1c	4.5
MSC + Ambrosia @ 5 t/ha	4950b	734.3bc	4.6
MSC + Ambrosia @10 t/ha	5310ab	795.5ab	5.0
MSC + Poultry manure + Amb. @5 t/ha	6758a	848.3a	5.3

### Effect of mulching and drip irrigation on growth and yield of tomato under terrace condition

Field experiment was conducted to find out the effect of drip irrigation and mulching on growth and yield of tomato. The result revealed that the fruit yield of tomato was significantly higher under drip irrigation+black polythene mulching (17.6 t/ha) and the lowest fruit yield of tomato was recorded under farmers’ practice (11.5 t/ha). There was an increase of up to 34.6% in fruit yield between farmers’ practice and drip irrigation+black polythene mulching (Fig 20).



**Fig 20. Tomato under different mulching treatments**

### Integrated weed management for enhanced productivity and water use efficiency in upland rice

Evaluated effect of weed management practices in upland rice for higher productivity and water use efficiency. The results revealed significant differences in grain yield of upland rice. Weedy check/control plot resulted in complete crop failure, whereas application of Butachlor 1.5 kg/ha @ 3 DAS fb 2, 4-D @ 0.75 kg/ha @ 25 DAS resulted in higher grain yield of rice (4815 kg/ha) as compared to other treatments (Fig 21).



Weedy check

Butachlor 1.5 kg/ha @  
3 DAS fb 2, 4D @  
0.75 kg/ha @ 25 DAS

**Fig 21. Upland rice under different weed control treatments**

### Effect of manures and straw mulching on turmeric under terrace condition

Significant differences in seed yield of turmeric were observed under various organic matter and mulching treatments. The seed yield of turmeric was highest under Farm Yard Manure @ 5 t/ha + Mulching @ 5 t/ha followed by Pig manure @ 5 t/ha + Mulching @ 5 t/ha. There was an increase of 55.6% of yield under Farm Yard Manure @ 5 t/ha + Mulching @ 5 t/ha compared to control.

### Effect of herbicides for enhancing productivity of maize under terrace conditions

Field experiment was conducted to evaluate the effects of herbicides for higher productivity of maize and water use efficiency (WUE) under terrace condition. The results revealed that the grain yield of maize was significantly higher under Atrazin @ 1.5 kg/ha at 3 DAS followed by 2, 4-D @ 0.75 kg/ha at 25 DAS followed by Atrazin @ 1.5 kg/ha at 3 DAS. There was an increase of 42.3% in grain yield of maize compare to weedy check plot.

### Demonstration on pea and capsicum cultivation in rice fallow for enhancing water productivity and livelihood of hill farmers

A demonstration on zero tillage pea and capsicum cultivation in rice fallow was conducted in two villages



(Umeit and Mawlasnai) of Ri-Bhoi district of Meghalaya with the objective to improve and enhance the water productivity through utilization of residual soil moisture in lowland after the harvest of rice and thereby increasing the cropping intensity by growing the second crop i.e. high value crops such as capsicum, pea, broccoli, cauliflower etc. Such demonstration can contribute to improve the farmers livelihood as compared to their earlier traditional practices i.e. monocropping. Farmers from two villages including women were selected and awareness programme was also organized both at the ICAR campus and farmers field. Inputs such as seeds of pea and capsicum, FYM, vermicompost etc were distributed to the selected farmers (Fig 22).



**Fig 22. Demonstration on zero tillage at ICAR farm and farmers' field**

After the demonstration programme, the farmers from two villages started preparing their land for zero tillage pea cultivation by the first week of December by using a simple implement i.e. furrow opener. The seeds were immediately sown after application of manures/vermicompost as per recommended practices and few intercultural operations like weeding, hoeing etc. were done by the farmers for better crop

performance. Harvesting of green pods was done mostly in the month of March and first week of April. It also differs from one farmer to another and the product was immediately transported for selling in the market. Two to three pickings were required for harvesting green pods. In general, higher yield was obtained from the first two pickings and lower yield in third picking compared to the first two (Fig 23).



**Fig 23. A farmer in the zero tillage pea demonstration plot**

Capsicum cultivation was also demonstrated in rice fallow land and each selected farmers prepared two plots i.e. pit system and their traditional practice bun system for comparison. Capsicum seed was then sown in a nursery bed as per recommended practices during the month of December (Fig 24a & b). In raised bed system, minimum ploughing was done in the soil and planking was also done to make friable soil bed before transplanting. In pit system, the soil was not ploughed but pits of appropriate depth were being dugged by the farmers. Manures/FYM/vermicompost was also applied as per recommended practices before transplanting. Transplanting was done after one month or so from the date of sowing the seeds in both the plots. Two to three weeding and hoeing was done at the initial stage of plant growth.

### **Impact of the demonstration**

The introduction of such technologies after rice has given the farmers on average an extra income of Rs.38564 from 4600 m<sup>2</sup> area (zero tillage pea) and Rs.43755 from 2110 m<sup>2</sup> area./-(capsicum cultivation in pit method) and 52,388 from 3575 m<sup>2</sup> area (capsicum cultivation in bun method) to improve their livelihood. The average WUE of capsicum was 17.78 kg/ha/mm; however capsicum grown under pit system





**Fig 24a. Capsicum plants in pit and raised bed plots**



**Fig 24b. A women farmer harvesting capsicum fruits**

recorded a higher WUE (18.13 kg/ha/mm) as compared to bun system (17.43 kg/ha/mm).

#### **Zero energy based water harvesting (*Jalkund*) and its recycling for high value crop under hilly condition.**

To popularize zero energy-based water harvesting technology - *Jalkund* and recycling of stored water under hilly condition to improve livelihood of hill farmers. The demonstration on low cost micro rain water harvesting structure and their efficient utilization undertaken at different farmer's field of the village Mawpun and Umeit of Ri-Bhoi District (Fig 25a & b). The harvested water is being used for growing vegetable crops; rearing livestock and poultry etc. the technology is getting immense popularity in different states of N.E. hill region.



**Fig 25a. Jalkund at Mawpun village**

**Fig 25b. Jalkund at Umeit village**

#### **Improving *jhum* sustainability through micro-climate guided interventions**

This study was conducted in Umeit village of Ri-Bhoi district of Meghalaya during 2014-2015. The experimental plot has average elevation of 914, 913 and 912 m above msl at top, middle and bottom, respectively, with average slopes of 23.6, 23.4 and 34.6%, in the same order. The field has an exposure to the south west (SW) direction. Upland high yielding rice cultivar Bhalum-3 was direct seeded in lines in the 2<sup>nd</sup> week of June and harvested in the 3<sup>rd</sup> week of October. Results obtained from the study indicated that different altitude and slopes have influenced the soil nutrient status, maximum LAI, Absorbed PAR (%) and yield of rice. With respect to influence of different altitude and slopes, the soil moisture content was found significantly higher in the middle level (30.6 %/v) compared the top (25.4 %/v), but at par with the bottom level (28.8 %/v). PAR absorption was found highest in middle portion (84.3%), followed by bottom (74.2%) and top (66.8%) Table 6. Higher availability of soil moisture might have led to higher LAI in the middle and bottom portions of the field that resulted

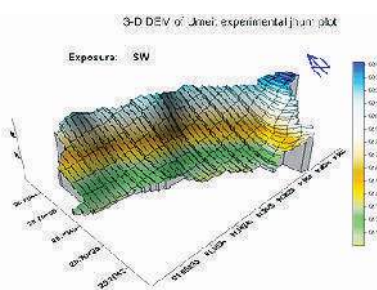


**Table 6. Regression equations to estimate grain yield based on maximum LAI and absorbed PAR in the flowering stage of rice at different levels of altitude and slope**

Altitude (m), Slope (%)	Relationships	R <sup>2</sup> (d.f = n-2=7)
Top (914, 23.6)	Grain yield = -0.411 + 1.118 LAI I+0.225APAR	0.96**
Middle (913, 23.4)	Grain yield = -0.68 + 1.784 LAI +0.221APAR	0.65
Bottom (912, 34.6)	Grain yield = -1.923 + 1.223 LAI+ 0.614APAR	0.86**

APAR: Absorbed PAR (%); d.f.: degree of freedom; \*\*: Significant at 1% levels of probability

in higher PAR absorption by the plants. Though LAI did not differ significantly, irrespective of slope and altitudes, but the radiation absorption was significantly influenced by the LAI at 5% level of significance (Fig 26).



**Fig 26. 3-D DEM of Umeit experimental jhum**

## AGROFORESTRY

### Evaluation of agro-forestry system under hill ecosystem

Groundnut was grown in agri-horticulture system under Assam lemon, guava, Khasi mandarin, peach, plum pear and open space (without trees as control).

**Table 7. Performance of groundnut in different agri-horticulture system**

	Plant Height (cm)		Number of tillers		No of groundnut /Plant		Yield t/ ha (DW)		Chlorophyll A		Chlorophyll B	
	T	WT	T	WT	T	WT	T	WT	T	WT	T	WT
Assam lemon	46.05	49.15	12.40	10.88	30.05	35.56	1.24	1.82	1.97	1.90	0.76	0.78
Guava	48.10	52.84	9.18	10.38	37.50	31.90	1.31	1.43	1.90	1.85	0.81	0.73
Khasi mandarin	49.08	51.94	13.12	10.11	36.15	35.95	0.95	1.04	2.05	1.87	0.74	0.78
Peach	48.66	49.04	8.99	8.57	29.00	25.05	0.90	1.38	1.85	1.95	0.81	0.75
Plum	46.25	50.24	10.00	9.51	27.90	23.30	0.63	0.88	1.83	1.96	0.67	0.65
Pear	52.45	50.95	6.22	7.61	20.40	21.25	0.77	0.89	2.08	2.16	0.88	0.88
Control	42.73		13.62		33.48		2.00		1.64		0.61	

T : Terrace with tree, WT : Terrace without tree

Growth and yield attributes of groundnut was evaluated and results are presented in table 1 & 2. Groundnut yield ranged between 0.63 t/ha to 1.31 t/ha on the terraces with trees and 0.89 to 1.97 t/ha on the terraces without trees (Table-7).

Highest chlorophyll A and chlorophyll B was found in pear based system which may be attributed to heavy shade due to dense canopy of pear based system. The total fruit yield was found to be 4.98 t/ha, 0.84, 4.67 t/ha and 6.23 t/ha respectively, for peach, Assam lemon, guava and pear, Table 8.

**Table 8. Productivity of agri-horticulture system on slopping land**

Fruit trees	Yield (t/ha)		REY*
	Fruit	Groundnut	
Assam lemon	0.84	1.53	4.46
Guava	4.67	1.37	7.41
Peach	4.98	1.14	7.26
Pear	6.23	0.83	7.89

\* For calculating Rice Equivalent Yield (REY) the cost of Groundnut, Assam lemon, guava, peach, pear and rice was assumed as Rs. 30/kg, Rs. 25/kg, Rs. 15/kg, Rs. 15/kg and Rs. 15/kg respectively.

### Evaluation resin production potential of *Pinus kesiya*

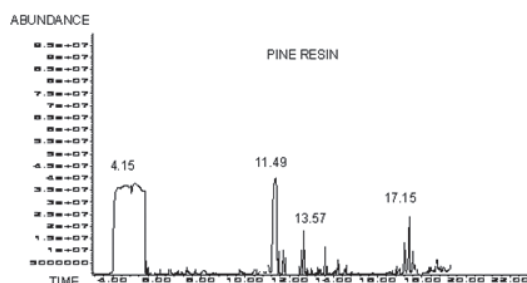
*Pinus kesiya* (khasi pine) resin was tapped from trees of three different diameter classes viz., 30-40 cm, 40-50 cm and > 50 cm. Resin was processed by steam distillation and rosin and turpentine percentage was estimated. Mean turpentine yield was 14.97%, 15.07% and 16.36% respectively, in 30-40, 40-50 and > 50 diameter class. The extract from resin was analyzed in a GC-MS. The HP-5 MS phenyl methyl siloxane



non polar capillary column (0.25 mm x 30 m x 0.25  $\mu$ m) max 350 $^{\circ}$ C (Agilent part No 190915 – 433) was used for the separation of fractions. The mobile phase was Helium 99.99% purity (Praxair India Ltd). The split inlet was used with split ratio of 50:1 and inlet temperature of 280 $^{\circ}$ C. The oven temperature program was set at 70 $^{\circ}$ C min $^{-2}$  with two minutes hold and a ramp of 10 $^{\circ}$ C min $^{-1}$  till 260 $^{\circ}$ C and held for 5 minutes with column flow of 1 mL/min. The mass spectral detector was maintained at a temperature of 280 $^{\circ}$ C with the interface temperature of 230 $^{\circ}$ C. The mass spectra created using the MS was compared with the Wiley mass spectral library (Wiley 2012 and NIST 2012 version). Alpha pinene, gemacrene, longiborneol and phenanthrene 7 ethenyl was identified and chromatogram of pine resin is presented in Fig 27 and Table 9.

**Table 9. Compounds identified through GC-MS**

Retention time	Compounds	Mol weight	% match
4.15	Alpha pinene	136	95
11.49	Gemacrene	204	98
13.57	longiborneol	222	96
17.15	Phenanthrene 7 ethenyl	272	83



**Fig 27. GC-MS chromatogram of *Pinus kesiya* resin**

**Table 10. Growth and development traits of *Parkia roxburghii* at Umiam, Meghalaya after 9 years of evaluation**

Seed Source	Plant height (m)	D.B.H (cm)	Collar diameter (cm)	Canopy (m)	Primary branch (nos)
Bilkhawthlir	8.31	10.84	14.15	4.78	6.75
Kawnpui	9.11	10.48	14.53	3.11	5.22
Thingkhangphai	9.00	13.25	15.93	5.75	7.00
Kanpokpi	8.61	8.62	12.47	4.33	5.33
Kezanglwa	10.25	13.05	16.95	4.38	7.75
Khaibung	8.00	9.83	14.30	3.83	10.00
Mawkiang	6.50	7.28	8.93	2.67	5.00

## Progeny evaluation of plus trees of Tree bean (*Parkia roxburghii*)

*Parkia roxburghii* is a multipurpose nitrogen fixing tree species, locally known as Yunchak in Manipur, the pods of the species are in high demand in north eastern hill states. To develop genetically superior planting materials of the species, progenies of plus trees from seven of its natural range of distribution were evaluated in uniform environment in replicated trial. For the biomass and growth traits (Table 10), Kezanglwa (height 10.25 m and diameter 13.05 cm) was found to be the best seed source. In case of canopy spread, Thingkhangphai had the most spreading crown. The pod productivity shall be evaluated once the trees come to optimum flowering and fruiting.

## Performance of selected germplasm lines of *Mucuna pruriens*, a medicinal plant useful to treat Parkinson's disease.

*Mucuna pruriens*, a self pollinated leguminous plant, is commonly known for its nitrogen fixing nature, ability to colonize recently exposed sites. It is used to treat *Parkinson's* disease because of presence of L-DOPA (L-3,4-dihydroxyphenylalanine) in its seeds. The crop has also potential in fallow management of shifting cultivation. One hundred eighty four germplasm lines were collected from different north eastern states and other states like Rajasthan, Uttarakhand, Odisha, West Bengal, and Uttar Pradesh. After a series of elimination trials, 184 lines were reduced to 11 promising lines. Evaluation of these lines is presented in Table 5. Maximum seed yield was obtained from WBNMP-03 (1.96 t/ha) followed by WBNMP-07 (1.83 t/ha) and UPMP-06 (1.58 t/ha), Table 11.



**Table 11. Growth and yield attributes of eleven lines of *Mucuna pruriens***

Genotype	Inflorescence length (cm)	Flowers/ inflorescence	Pod length (mm)	Pod width (mm)	Seeds /pod	Pods / cluster	Days to flower initiation	No .of clusters / plant	100 seed weight (g)	Seed yield (t/ha)
IC-83195	14.37	10.07	94.65	15.22	5.70	5.27	71.67	43.56	38.75	1.10
MGHMP-06	23.37	19.70	77.86	13.22	5.43	10.53	98.67	38.33	21.25	0.86
MZRMP-16	39.77	46.30	60.72	12.03	3.83	9.47	149.67	16.89	17.05	0.16
NGLMP-25	25.07	34.83	75.77	13.37	4.53	11.87	109.00	66.00	22.13	0.53
NGLMP-41	13.53	19.23	69.99	11.37	5.33	8.33	105.00	32.33	19.55	0.49
SKMMP-02	16.33	18.23	71.00	12.54	4.97	9.47	87.67	41.22	22.51	0.81
UKDMP-11	7.90	9.77	71.04	11.43	5.00	4.40	69.33	44.22	22.04	0.44
UPMP-04	6.30	6.57	89.37	15.38	4.97	4.33	68.33	13.56	67.11	0.45
UPMP-06	14.60	20.67	45.16	14.38	4.97	6.33	76.67	39.44	55.49	1.58
WBNMP-03	32.17	40.30	67.77	11.89	4.80	9.93	107.33	65.44	20.70	1.96
WBNMP-07	29.47	30.93	69.13	13.17	4.67	11.73	103.33	66.11	19.78	1.83
CD (5%)	6.18	6.76	14.46	1.51	NS	4.18	6.23	12.17	4.13	0.22
SE (m)	2.10	2.29	4.90	12.39	0.29	1.42	2.11	4.13	1.40	0.08

## AGRICULTURAL ENGINEERING

### Evaluation of Conservation Efficiency of grasses on hill slopes of Meghalaya region

A project on assessing the conservation efficiency of grasses was initiated during 2014 -15 with the aim of studying the hydrological behaviors of degraded lands under selected grass covers with their conservation efficiencies and production potentials. During 1<sup>st</sup> year 16 numbers of runoff producing events were received. During 2<sup>nd</sup> year (201 -16) eight numbers of experimental runoff plots were cleared up of natural vegetation. All the plots were renovated for maintaining uniform soil depth and slope. 8 gauging stations equipped with H-flumes were renovated and installed with automatic stage level recorders. During the period under report the area received 2565.3 mm annual rainfall in 132 events with runoff producing storms of 2162 mm in 72 events. All the runoff plots were brought under calibration. The hydrological behavior of runoff plot no.1 was considered as control plot for comparison of runoff and sediment yield. Calibrated statistics for runoff and sediment is presented in Table 12.

### Estimation of water budget components for predominant farming systems of Meghalaya

Adequate and timely supply of soil moisture is the most critical input for ensuring sustainable crop production in the mid hills of Meghalaya region. Land use and cropping systems have been drastically changed to cope with changing climatic aberrations. There is also a need to evaluate the available models/

**Table 12. Calibrated statistics of runoff and sediment yield of runoff plots (2015) ( $Y = mx + c$ )**

Control : Plot No.1 Runoff plot (ROP) No.	Slope	Intercept	Coefficient of determination (R <sup>2</sup> )
ROP-II	0.999 (0.924)	0.620 (0.587)	0.957 (0.958)
ROP-III	0.989 (0.968)	0.614 (0.583)	0.917 (0.945)
ROP-IV	1.04 (1.09)	0.644 (0.594)	0.945 (0.956)
ROP-V	0.982 (0.992)	0.609 (0.875)	0.928 (0.956)
ROP-VI	0.850 (0.837)	0.725 (0.865)	0.936 (0.905)
ROP-VII	0.928 (0.978)	0.596 (0.864)	0.954 (0.946)
ROP-VIII	0.977 (0.985)	1.027 (0.956)	0.935 (0.924)

NB: Figure in parenthesis indicated statistics for sediment yields

methods to quantify water budget components (runoff, evapotranspiration and soil moisture) for prominent farming systems and their management options on water budget components under climate change scenarios. Therefore, water budget studies for predominant farming systems were initiated during 2014-15. Five farming system micro-watersheds were delineated and demarcated for taking up the study. These 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 class VIIe. The average slope of micro-watersheds lies in the range of 32.02 to 45.87% with relief of 89-110 m. The maximum length and width varies from 250-320 m and 65-230 m respectively. 5 gauging stations equipped with H-flumes were renovated and installed



with automatic stage level recorders. During the period under report the area received 2565.3 mm annual rainfall in 132 events with runoff producing storms of 1528.9 mm in 35 events. The hydrological behavior of W5 was considered as control for comparison of runoff of other four FSR micro-watersheds. Calibrated statistics for runoff is presented in Table 13.

**Table 13. Calibrated statistics of runoff and sediment yield from runoff plots ( $Y = mx + c$ )**

Control : W5FSR Micro- watershed No.	Slope	Intercept	Coefficient of determination (R <sup>2</sup> )
W <sub>1</sub>	0.601	-0.826	0.948
W <sub>2</sub>	0.599	-1.326	0.953
W <sub>3</sub>	0.595	-0.818	0.945
W <sub>4</sub>	0.625	-0.005	0.893

Runoff was estimated using SCS-CN method and Actual evapotranspiration by FAO-56 Penman-Monteith method. Using the water balance approach, recharge contribution was estimated. Estimated water budget components are presented in the Table 14.

**Table 14. Estimated contributions of water budget components during 2015**

Land uses	Contribution		
	Runoff (%)	AET (%)	Recharge (%)
Agri(W <sub>1</sub> )	13.70	37.7	48.60
Agri-Horti-Silvi-Pasture (W <sub>2</sub> )	12.98	60.1	26.92
Agro forestry(W <sub>3</sub> )	13.57	48.5	37.93
Forestry(W <sub>4</sub> )	15.42	52.3	32.28
Natural fallow (W <sub>5</sub> )	24.67	31.3	44.03

### Flagship Programme on *jhum* improvement

During the period under report 78 rainfall events occurred with annual rainfall of 2146.3 mm. 22 runoff producing storms were recorded with 29.28% runoff and 54.69 ton/ha/yr of sediment yield from a gauged *jhum* cultivated area at KVK, Tura, West Garo hills of Meghalaya.

### Analysis of historical weather variables and accuracy assessment of the weather forecast

Monthly temperature and rainfall data of seven north eastern states recorded at the agromet

observatories of the respective centres of ICAR-NEH were used for analysis. The analysis showed that the changes followed dissimilar pattern among the states. The mean temperature ( $T_{avg}$ ) showed increasing trend across all the states (Table 15). The mean annual temperature has increased significantly for all the states except Nagaland. The monthly values for Basar showed increase of 0.5° C to 1.6° C per decade during the study period. In case of Gangtok it varied from 0.2° C to 0.6° C per decade, whereas for Umiam and Kolasib the winter months had witnessed significant increase in the  $T_{avg}$  at a varying rate from 0.4° C to 0.9° C. The IMD weather data of Kailashnagar, Tripura depicted significant trend during monsoon months, while it increased in July & September and decreased in June. Pettit's test was implemented for the detection of change point in the time series temperature data. Significant changes were seen in almost all the places with higher number of changes in Imphal, Gangtok, Basar, Umiam and Kolasib. The monthly pattern of changes also varied from place to place. The changes mostly occurred during the mid-1990s to early years of 2000s. Most of the changes in Imphal (11), Gangtok (9) and Basar (7) occurred during 1990s while for Umiam (6) and Kolasib (4) it was in early 2000s.  $T_{avg}$  for Nagaland has not shown any change due to large and significant trend of maximum and minimum temperature in reverse direction. Rainfall values also showed changes but it was significant in a few occasions only. It can be broadly said that the winter rainfall is reducing in these places with significant decrease in Basar, Gangtok, Umiam and Kolasib. Rainfall in the month of May had significantly increased for Umiam, Basar and Imphal, which may be linked to the heavy pre-monsoon showers or early monsoon in these areas. Contrary to others Kolasib had witnessed a significant increase in the annual rainfall along with the monthly rainfall during August and September.

The weather forecast of 2015 -16 provided by the IMD for Ri-Bhoi district was evaluated with the weather data recorded at Umiam. The analysis confirms that when rain is more the error is also more. The occurrence of rainfall events may well be forecasted but the quantity of rainfall still remains a matter of challenge. In case of Max and Min temperature the mean bias error (MBE) is always negative, signifying that the forecast value is always more than the recorded value, which is also similar to the previous year's observation.



**Table 15. Trend and Change Point of Mean Temp at different places of Northeast India**

Place	Basar, Arunachal Pradesh		Imphal, Manipur		Jhamapani, Nagaland		Gangtok, Sikkim		Umiam, Meghalaya		Kolasib, Mizoram		Kailashnagar, Tripura	
Month	Trend	Change	Trend	Change	Trend	Change	Trend	Change	Trend	Change	Trend	Change	Trend	Change
Jan	3.3*** (0.7)	262*** (1993)	3.5*** (0.2)	418*** (1997)	0.6 (0.3)	25 (NO)	1.3 (0.3)	81 (NO)	1.3 (0.3)	97 (NO)	2.0** (0.4)	196*** (2001)	0.9 (0.1)	88 (NO)
Feb	3.0*** (0.9)	182*** (1997)	3.2*** (0.3)	432*** (1997)	-0.2 (-0.2)	28 (NO)	2.3*** (0.6)	175*** (1997)	2.2** (0.8)	106* (1998)	3.0*** (0.9)	193*** (2000)	1.1 (0.1)	116 (NO)
Mar	4.1*** (1.1)	210*** (1997)	2.1** (0.2)	270* (1998)	1.1 (0.4)	20 (NO)	3.0*** (0.6)	158*** (1998)	2.2** (0.5)	119** (2003)	2.2** (0.6)	164* (2005)	1.6* (0.2)	102 (NO)
Apr	1.9** (0.5)	127 (NO)	0.3 (0.0)	211 (NO)	-0.7 (-0.2)	30 (NO)	1.6* (0.3)	136** (1994)	0.3 (0.1)	63 (NO)	0.6 (0.2)	87 (NO)	0.6 (0.1)	53 (NO)
May	3.2*** (1.0)	188*** (1992)	1.1 (0.1)	344** (1993)	0.5 (0.2)	22 (NO)	4.0*** (0.6)	195*** (1993)	2.2** (0.4)	129** (2003)	0.0 (NO)	70 (NO)	1.1 (0.2)	90 (NO)
Jun	3.8*** (1.0)	136* (1983)	3.2*** (0.2)	412*** (1987)	-1.1 (-0.5)	37 (NO)	2.4*** (0.3)	129** (2007)	0.3 (0.0)	80 (NO)	1.3 (0.3)	108 (NO)	-1.7* (-0.1)	124* (1996)
Jul	2.8*** (1.0)	130 (NO)	3.4*** (0.2)	475*** (1990)	0.7 (0.2)	28 (NO)	3.9*** (0.4)	172*** (1992)	1.1 (0.2)	122** (2004)	0.9 (0.2)	89 (NO)	1.6* (0.1)	97 (NO)
Aug	3.0*** (0.8)	113 (NO)	3.8*** (0.2)	551*** (1996)	-0.20 (0.0)	22 (NO)	2.5*** (0.2)	148*** (2000)	1.4 (0.1)	128** (2002)	-0.1 (0.0)	119 (NO)	1.2 (0.1)	116 (NO)
Sep	3.7*** (1.6)	192*** (1992)	2.5*** (0.2)	430*** (1997)	0.5 (0.2)	36 (NO)	3.6*** (0.5)	169*** (1993)	2.7*** (0.4)	130** (2002)	-0.6 (-0.1)	111 (NO)	2.2** (0.1)	119 (NO)
Oct	3.6*** (1.0)	157** (1994)	3.1*** (0.3)	474*** (1994)	0.1 (0.1)	34 (NO)	2.3** (0.3)	121* (1997)	0.9 (0.1)	67 (NO)	0.4 (0.1)	107 (NO)	2** (0.1)	115 (NO)
Nov	3.1*** (0.9)	188*** (1992)	3.5*** (0.3)	455*** (1993)	-1.0 (-0.3)	32 (NO)	1.8* (0.3)	142** (1994)	0.5 (0.2)	52 (NO)	-0.2 (-0.1)	111 (NO)	0.3 (0.0)	76 (NO)
Dec	1.6* (0.5)	155** (2003)	3.6*** (0.2)	554*** (1994)	0.0 (0.0)	20 (NO)	0.1 (0.0)	60 (NO)	0.9 (0.2)	73 (NO)	1.6 (0.4)	147 (NO)	1.7* (0.2)	105 (NO)
Annual	4.0*** (1.0)	169** (2003)	4.2*** (0.2)	594*** (1994)	0.2 (0.0)	29 (NO)	3.8*** (0.4)	185*** (1997)	2.3*** (0.2)	154*** (2004)	1.7* (0.2)	167* (2004)	2.6*** (0.1)	150** (2000)

\*\*\*, \*\* and \* denote trends at 1%, 5% and 10% significance level, respectively

Trend values indicate Mann Kendall's Z statistics and in the parentheses Sen's Slope represents the rate of change ( $^{\circ}\text{C}$  per decade). Change values indicate Pettit's test statistics and in the parentheses the year of change in the series if the test was significant.

## AICRP on Farm Implements and Machinery

### Modification of power paddy thresher cum cleaner

The designed lightweight paddy thresher cum cleaner was modified to reduce the vibration and shattering losses. The overall height of the thresher was reduced to 1310 mm to make it convenient for feeding. A cover was fitted to the belt and pulley for safety purpose. The speed of threshing drum and sieve was reduced to minimize the grain shattering losses by adjusting the transmission system. The thresher was tested for its performance and found that the threshing efficiency has increased to 99.2% and losses due to shattering were reduced to 2% at the average grain output of about 143 kg/h.

### Design and development of manual pineapple harvester

Irregular flowering of pineapple results in the harvesting spread over a long period hence selective

harvesting is required. With this objective the design of manual harvester (Fig 28) was conceptualized to harvest pineapple on sloppy lands. Components of pineapple harvester includes fruit stem cutting blade, lever for operating blade, fruit holder and handle. It has a sharp blade operated with a lever fitted on the handle (Fig 29). Above the blade is fitted a fruit holder for holding the cut fruit. It can achieve the harvesting



**Fig 28. Modified power paddy thresher**



**Fig 29. Design of manual pineapple harvester**



of fruits in the radius of 1 m by standing in one position.

### Prototype feasibility testing of farm machinery

The PFT was conducted on power tiller drawn seed drill (Palampur design) and light weight power tiller with different attachments. For adoption the length of hitch link of seed drill was increased and overall height was reduced to 765 mm. Three row seed drill equipped with fluted roller seed metering mechanism was tested for sowing of lentil. It was found suitable for sowing in terraces and valley lands with effective field capacity of 0.08 ha/h. PFT of light weight power tiller (69 kg weight and 4.1 kW engine) was conducted with rotavator, cultivator and ridger/furrower attachment. Due to light weight the whole unit could easily be shifted from one terrace to another and easily operated in narrow terraces due to small turning radius. Rotavator having L-shaped blades in 4 rows resulted in 450 mm width of coverage and 80 mm average depth of operation. The cultivator having 3 tynes was able to cover 400 mm width. The ridger attachment was tested for potato planting. It reduces the drudgery of making ridges manually with spade and the operation becomes faster (Fig 30).



**Fig 30. PFT of Power tiller seed drill and light weight power tiller**

### Frontline demonstration of farm tools and machinery

Front line demonstrations of paddy drum seeder, self propelled vertical conveyor reaper, cono weeder, posthole digger, hand operated winnower, brush cutter with paddy harvester attachment and power weeder



**Fig 31. Frontline demonstration of farm tools and machinery**

were conducted in the farmers field. The paddy drum seeder is of plastic body having 9.50 kg weight and fitted with 2 drums for sowing 4 rows at 20 cm spacing. The equipment is easy to operate due to light weight and can be used in narrow terraces. Self propelled VCR having 1000 mm cutter bar length, 4 Nos. of crop divider and 3.8 KW diesel engine was demonstrated for harvesting paddy in terraces and valley lands. Manually operated cono weeder having two rotors, float and handle was demonstrated for weeding in low land paddy fields. Engine operated posthole digger having augur of 635 mm length and 150 mm diameter was demonstrated for digging holes. Hand operated winnower was demonstrated for cleaning threshed paddy. Grass/brush cutter fitted with 1.3 KW petrol engine and paddy harvester attachment was demonstrated for harvesting of paddy in small and undulating fields (Fig 31).

### Prototype Manufacturing

Prototypes of farm tools and equipments (1939 numbers) worth Rs. 10,30,700/- were fabricated during 2015-16 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. Fabricated tools and equipments includes mainly maize sheller, long handle weeders, wheel hoe, cono weeder, briquette mould and chulha, groundnut decorticator, dibbler, winnower and paddy thresher.

### AICRP on plasticulture engineering and technology

A sub project “Feasibility and economic evaluation of heating and cooling of polyhouse using earth heat exchanger” was initiated to evaluate the performance of closed loop geothermal cooling of poly house and to work out the techno-economic feasibility of the geothermal cooling system in poly house for high value crop production. Designed and installed heat Exchanger consists of eight 75 mm dia and 6 m long MS pipes connected by elbows and nipples. Two pipes



form one grid of 12 m length. After each grid a butterfly valve has been placed to divert air from rest of the grids to change the length of the path of air travel. The heat exchanger was installed at a depth of 1.5 m below ground level. The blower is backward curved centrifugal pump of diameter 300 mm and operated by a three phase motor at 3000 rpm. Polyhouse ground area is 8 m × 4 m with height of 2.5 m at the centre and 1.5 m at the sides covered by 200 µ LDPE sheet. Temperature and humidity inside the polyhouse has been recorded continuously at an interval of 30 min by a data-logger. It is heating the polyhouse when outside temp is below 25° C and cooling when outside temperature is above 25° C. During day time from 8 AM to 6 PM outlet air temperature was almost constant at 26° C and during night it was almost at 24° C. The heat exchanger cooled the polyhouse from maximum temperature of 48° C to 41° C and heated the polyhouse from 15° C to 20° C during night time. However, the maximum difference between blower inlet and outlet air temperature was 14° C.

In a sub project “Modeling the micro climate of vegetable based cropping system under poly house in mid hills of Meghalaya”, planted offseason vegetable crops (capsicum, brinjal and tomato) were monitored for yield. Under polyhouse yield of capsicum, brinjal and tomato were observed as 28, 58, and 34 t/ha whereas the same were 22, 41.5 and 30.2 t/ha in net house and 19.2, 30.1 and 26.5 t/ha respectively in farmers practice. The rise in temperature by 2.6° C and decrease in RH (1.6%) in poly house helped in more yield as compared to net house and farmers practice. Bamboo frame materials were procured for fabrication of low cost storage bins of 50 kg capacity wrapped with plastic under sub-project “Development of low cost seed storage system using plastics”.

### **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 in 2015-16. Rainfall during maize growing period (April-July, 2015) was 940.7 mm against water requirement of 750 mm with 63 nos. of rainy days, whereas, during rice growing period (June-October), amount of rainfall was 1859.6 mm against requirement of 1000 mm with 84 nos. of rainy days. The crops did not suffer from any water stress during its growth periods. Maize and rice took 103 and 117

days respectively to attain physiological maturity. DSSAT (Ceres-Maize) simulated maize yield was 2565 kg/ha against observed yield of 2109 kg/ha with over estimation of 21.6%. In case of rice, simulated yield was 2816 kg/ha against observed yield of 2603 kg/ha with over estimation of 8.2%. Considering acreage of maize and rice in Meghalaya as 18,025 and 63,539 ha, respectively, expected (simulated) production of *kharif* maize and rice in Meghalaya in 2015 may be 46.2 and 178.9 thousand tonnes, in the same order.

### **Agri-consortia research platform on water**

The project “Development and Management of Integrated Water Resources in different Agro-ecological Regions of India” under “Agri Consortia Research Platform on Water” was approved on 11-11-2015. The Institute is one of the consortia partner and is working in the theme “Conservation and augmentation of Water resources” with sub theme on “Development & management of integrated water resources”. During the period under report hydrological data of Farming System Research (FSR) Micro-Watersheds having land uses of Agril, Agri-horti-silvi-pasture, Agro-forestry, Forestry and natural fallow were collected for the duration of 1991-2006. Based on the historical data compilation design of soil and water conservation measures with construction in micro-watershed basis will be undertaken in the year 2016-17.

### **Gramin Krishi Mausam Sewa (GKMS)**

Agro-advisory bulletin was started from May 1996 at AMFU, Barapani with the objectives of preparing AAS bulletin based on weather forecast after consultation with the Agro-Advisory bulletin board and weather forecast received from IMD, Guwahati (medium range of 3-5 days) every Tuesday and Friday, providing 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 for improvement of weather forecast. Agromet advisories are prepared by expert groups based on the weather forecast received from Regional Meteorological Centre, Guwahati along with tools and techniques like Normalized Difference Vegetation Index (NDVI) and the Standardized Precipitation Index (SPI) for 11 districts of Meghalaya



received from Agromet Pune. Agro-advisories are disseminated to media through e-mail, SMS, Fax and telephonic conversation. The agro-advisory bulletin prepared are uploaded in IMD Agromet website ([www.imd.agrimet.gov.in](http://www.imd.agrimet.gov.in)), ([www.farmer.gov.in](http://www.farmer.gov.in)) and ([www.kiran.nic.in](http://www.kiran.nic.in)) for dissemination. This AMFU is sending the advisory bulletin as well as SMS to all the KVKs of the state, State Agril/Horti officers for forwarding the SMS to farmers. During the period under report 102 numbers of weather forecasts were received by the AMFU and 96 numbers of AAS Bulletins were prepared and disseminated to the farmers.

## TRANSFER OF TECHNOLOGY

### Technology and machinery demonstration Mela organized

A “Technology and Machinery demonstration Mela” for the farmers of NEH Region was organized at the Division of Agricultural Engineering on 18<sup>th</sup> March, 2016 under AICRP on FIM and AICRP on PET schemes (Fig 32-33). About 150 farmers from different villages of Meghalaya participated in the mela. The events of Mela included exhibition on improved farm tools and machinery for hill agriculture, field demonstration of implements and machinery, plastic lined water harvesting pond, low cost poly house, demonstration of technology and machinery for post harvest processing, and farmer-scientist interaction. Dr B.C. Deka, Director, ICAR-ATARI, Umiam in his inaugural speech appealed the farmers to adopt post harvest management technology for value addition and



**Fig 32. Machinery Demonstration Mela**

loss reduction. He also suggested the farmers to create implements and machinery bank in their village and adopt custom hiring practice for costly agricultural implements to reduce drudgery and timely operations.

### Demonstration of improved farm tools and equipments

Technology of briquette making was demonstrated to the farmers in collaboration with KVK, Ri-Bhoi. Paddy cultivation tools and implements including vertical conveyer reaper for harvesting paddy, pedal operated paddy thresher, and cono weeder, horticultural tools suitable for hills, posthole digger for making pits for erecting posts on the field boundary and for plantation of horticultural crops and technology of banana fibre extraction were demonstrated to the farmers of the region.

## SOCIAL SCIENCES

### Socio-Economic and cultural dynamics of *Jhum* cultivation in NEH Region: A study in Manipur

Primary data collected through personal interview using a semi-structured interview schedule, group interaction and field visits involving 30 numbers of respondents selected through random sampling from 3 villages of Tamenglong district in Manipur viz., Haochong, Izeirong and Puichi (Oktan) for the study. The collected data were cross-checked from the secondary sources. Tamenglong in Manipur is a hilly district characterized by steep slopes and flat land surface hardly reaching around 1000 ha, which limits the cultivation of wet paddy and makes *jhumming* adominant cultivation practice. The *Inpui* tribes are the main originals of the three villages under study. They follow *Jhumming* on a particular land for one year followed by a fallow period of 10-13 years for regeneration. *Jhumming* is considered as the main source of livelihood with an average income of about



**Fig 33. Demonstration of improved farm tools and implements**



Rs. 35,000 per annum per family besides other subsidiary income that comes from handicrafts, embroidery, tailoring, animal husbandry, other government and private services, etc. The major crop components of *Jhum* cultivation are paddy, banana, king chilly, ginger, orange, potato, pumpkin, cabbage and other seasonal vegetables which are being marketed at the local *Noney* market.. The farmers were quite aware of the changes in climate (unusual rainfall, frequent hailstorms, atmospheric temperature fluctuation, delaying in onset of monsoon/winter etc.), loss in soil fertility which was apparent from the decreasing trend in productivity and degradation of forest resources. Hence, urgency was felt to make some interventions with suitable climate resilient technologies in *jhum* farming system.

Jhumming is marked by different festivals and rituals with different names in different villages, but there is an underlying similarity in the time, purpose and the way of observance of the festivals/rituals (Table 16). *Katangranaallounu* is a ritual of the *Inpui* tribe in Haochong village performed during the time of forest cutting/clearing. During this festival, boys and girls from the village cut the banana stem and assemble on a common ground of the village from where they are distributed to different homes. The ritual like *Loujanu* is performed at the time of ripening of paddy, when animals are offered to God but not sacrificed, after the advent of Christianity. An interesting festival with variant names *Muliangnu* or *Muliangngei*, is celebrated at the time of harvesting of paddy. This is celebrated by the farmers with the expectation of highest harvest of rice. This festival instills a sense of competitiveness in their farming performance.

### Impact assessment of improved technologies Demonstrated under TSP project in North East

In order to assess the impact of improved technologies under Tribal Sub Plan (TSP) programmes

of the Institute, a survey was conducted by following the ex-post facto experimental design. Data collected through Focused Group Discussion (FGD), in which both the beneficiary and non-beneficiary farmers under various demonstration programmes in agriculture, horticulture, livestock and fishery sectors in the states of Meghalaya, Mizoram, Nagaland and Tripura were interviewed. The result of rice demonstrations (cv. Gomti, Naveen, Swarnamashuri, Ranjit, Shasharang, RCM 9, RCM 10 and RCM 11) showed that the beneficiary farmers were able to obtain additional rice yield in the range of 38.6 to 50.2 % with an average yield in the range of 3.8- 5.5 tonnes against the non-beneficiary farmers who could manage only 2.7 - 3.1 tonnes per hectare. The demonstrated improved varieties of rice have also increased the income level of the farmers ranging from Rs 8,780 to Rs 14,940 per hectare. Similarly, in case of maize (var. RCM 76 and RCM 75) demonstration in Garo Hills in Meghalaya; the average yield was substantial to the tune of 2.8- to 3.3 tonnes per hectare as compared to that of non-beneficiary farmers (1.5- 2.5 t/ ha). Besides, the RCM 76 variety of maize was the most preferred variety as it has the criteria of having yellow seeds. In case of pulses, demonstrations were conducted in lentil (var. HUL 57 and PU 8) and black gram (Tripura Muskalai) covering some districts in Meghalaya, Mizoram, Nagaland and Tripura. Tripura Muskalai was found to have promising yield potential in the range of 10.5- to 12.1 q/ha. .

### Critical analysis of factors affecting technology transfer through Model Village System (MVS) of extension approach

Under the project, the study locale was selected on the basis of sixteen point criteria through a survey conducted over 12 ICAR adopted villages of Ri-Bhoi district, in which Nongthymmai village was selected on the basis of rank analysis with max total average score of 57.13 and highest rank index of 89.27

**Table 16. Festivals and rituals practiced by the *Inpui* tribes under *jhum* cultivation**

Sl. No.	Festivals/rituals	Stages of <i>jhum</i> in which rituals performed	Details
1	<i>Katangranaallounu</i>	Cutting of forest	At the time of cutting of forest for <i>jhumming</i>
2	<i>Puanthwangnu</i>	Land preparation	Tilling and land preparation
3	<i>KaringNgei</i>	Sowing	Festival of seed sowing
4	<i>LouthokNgei</i>	After sowing	After sowing of paddy
5	<i>TarokNgei / Mangaipui</i>	Weeding	Cleaning , common dinner and pray for more harvest
6	<i>Loujanu</i>	Rice ripening	Animal offering and pray for bumper harvest
7	<i>Loulaknu / Ba NgeiPui</i>	After harvest	Singing and dancing while thrashing of rice and resting
8	<i>Muliangnu / Muliangngei</i>	After harvest	Celebrated for farmers with highest harvest of rice



followed by its validation through secondary data and participant observations. Before the interventions of technologies as a part of the action research under the project, SWOT analysis was carried out in Nongthymmai village through semi-structured interview schedule in respect of TOT system on the basis of different perceived attributes of strength, weaknesses, opportunities and threats. The *Kendall's Coefficient of Concordance* test indicated significant values in all the four cases ( $w_s=0.37$ ,  $w_w=0.48$ ,  $w_o=0.40$  and  $w_t=0.39$ ) at 0.05 LS showing that there is differences within the perceived attributes of SWOT and there is certain degree of association/agreement among the ranks/marks assigned by different experts on various perceived attributes of TOT system. SWOT analysis illustrated that well connectivity with roads was ranked as first attribute in case of strength followed by easy access to source of information and frequent contact with extension agencies as the third rank. Similarly, rainfed farming was the major attribute of weaknesses and lack of storage and processing facilities were noted to be biggest threats; whereas scope for area expansion under cultivation was given top priority among the perceived attributes of opportunities in respect of transfer of technology system. Keeping view upon this, the technology index (TI) of some intervened technologies like improved tomato, potato and capsicum production technologies was measured for testing their feasibility, which was found to be 14.71, 20.36 and 22.48 per cent, respectively, (Table 17). Lower is the value of technology index more is the feasibility of the demonstrated technology in farmers' field. It was found that extension gap (EG) in case of all the technologies was almost double the technology gap (TG) except in case of potato cultivation which indicated that there is need for bridging the extension gap and which needs the convergence of all the stakeholders with a stake in food value chain through Model Village System (MVS) of extension approach.

### Network Project on Market Intelligence

Forecasting of wholesale prices of Potato, Tomato, Ginger, Turmeric, and Pineapple in Meghalaya have been prepared using secondary wholesale prices that have been collected on monthly basis from different markets in Meghalaya. Price forecasting was prepared using various methods of forecasting namely ARIMA, SARIMA, ARCH and GARCH methods. Pre-sowing forecasts for Meghalaya state was given on potato for October-November, 2015, on tomato for November-

December, 2015 and on turmeric for April-June, 2016. The pre-harvesting forecasts were also given on crops like pineapple for June-September, 2015, on ginger for November-December, 2015, on turmeric for November-January, 2015, on potato for February-March, 2016 and on tomato for March-April, 2016. The forecasted results were disseminated through the Local Newspaper *i.e.* Mawphor as well as through the KIRAN website ([www.kiran.nic.in](http://www.kiran.nic.in)). As per the preliminary market survey there was 70-75 % usability and reliability in the forecast price of the selected commodities. The prices of the agricultural produce in Meghalaya depend on arrivals of the agricultural produce in a particular date in the wholesale market. The prices also largely depend on the weather conditions which influences the production of the agricultural produce. Price forecasts are useful for taking decisions regarding the choice of crop to be cultivated, selection of crop variety, planting/harvesting dates, when and where to sell the agricultural products and investments in farm inputs. The pre-harvest forecast (80-85%) is better than the pre-sowing (70-75%) forecast and the usability of pre-harvest forecast was found to be significant in case of all the crops chosen for the study.

### Designing participatory decision support system for horticultural crops in Meghalaya

Under this project Ri-Bhoi district in Meghalaya has been selected purposively in which five villages viz. *Kyrdem, Nongthymmai, Nonglakhiat, Mynsain, Nongjri* has been selected through the stratified random sampling method out of total fruit, vegetable and spice growing villages. The decision support system was proposed to be designed for some important fruits, vegetables and spices selected on the basis of certain criteria namely farmers preference, maximum area coverage, yield potential, availability of technology, germplasm, Post harvest facility, marketing, crop insurance and credit facility etc.

On analysis of the secondary data (2012-13) collected from horticulture, Government of Meghalaya it was found that in Ri-Bhoi district stands first in pineapple growing both in area (hectare) and production (Metric tonnes) while Khasi Mandarin stands fifth. Similarly, among vegetables broccoli top the list in terms of the state share percentage in area coverage (31.1%) and tomato occupies 5<sup>th</sup> position in terms of state share of area coverage of 11.3% whereas tomato ranks 1<sup>st</sup> in terms of production with state share percentage of 50.3% among the five selected vegetables.



## LIVESTOCK PRODUCTION

### Feeding strategies to mitigate climatic variability in weaned piglets

Three groups of Indigenous grower piglets just after weaning are selected for the experiment. Control group is fed solely with standard concentrate mixture. Rest experimental groups are fed with kitchen waste (60%) mixed with standard concentrate mixture (40%) where one group is treated with 7% molasses with standardized feeding schedule. The results of the study revealed that the group which is fed with 7% molasses have better growth rate (280g/d) as compared to control group (230g/d) and molasses may help in protecting the animals from climatic stress.

### Water harvesting and efficient water productivity in climate resilient pig housing models

The surface area of the roof of each shed was 72 square feet. Accordingly to the surface area of the roof and rainfall, total of 1.2 lakh litre/year rainwater from each shed can be harvested (Fig 1). Since there is no-need of cleaning of pig shed and only drinking water requirement in the developed pen, therefore, the water requirement in the developed pigpen was very less (7-10 liters/day/pig).



Fig 1. Low cost-deep litter

### Estrus synchronization in sow to improve fertility during summer season

Estrus synchronization was done in anestrus sow during summer season to improve fertility using PMSG and hCG in combination. Estrus induction rate was more than 90% with farrowing rate of 80% and litter size of more than 7. Hence, it is a better strategy to cope with summer infertility in sows.

### Recovery rate of porcine follicular oocytes by different methods

In the present study we found better recovery rate of porcine oocytes by slicing method than aspiration

method. We found 82.46% recovery rate in slicing method whereas the recovery rate for aspiration method was 76.01 %. In slicing method we found highest recovery rate of type A oocytes (35.69%) followed by type B (27.82%), type C (20.47%) and type D (16.10%). Whereas in aspiration method the figure is highest for type B oocyte (35.67%) followed by type A (29.85%), type C (21.11) and type D oocytes (13.34). From the present study it can be concluded that the recovery rate and extraction of good quality oocytes is better in slicing method than aspiration method.

### In-vitro fertilization

Ten numbers of oocytes matured *in vitro* in TCM-199 + additives + EGF + IGF-I were subjected to *in-vitro* fertilization and observed that two oocytes were fertilized *in-vitro* on incubation in fertilization medium containing spermatozoa (Fig 2) and one oocyte was found to be developed to 4- cell embryo and the other developed to 8- cell embryo (Fig 3).

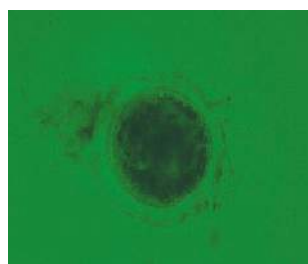


Fig 2. Zona binding

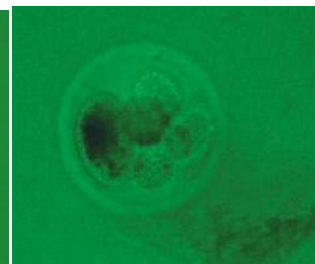


Fig 3. 8-cell embryo

### Increasing productivity and reproductive efficiency through selective breeding and genetic characterization of Assam-Hill goat using Microsatellites markers

A nucleus-breeding flock of selected Assam Hill goats (n=20) as foundation stock was established on basis on twinning and triplets kidding of dam, phenotypic characteristics. A selective breeding programme was performed to improve the reproductive and productive performance. Various parameters were studied in F1 and F2 generation. A total of 32 blood samples of unrelated, healthy goat were collected from jugular vein following the aseptic measures from different locations and DNA from the blood samples were isolated.

Twenty two polymorphic markers were selected following the guidelines of FAO. The genotyping was carried out on an automated ABI PRISM 3730 genetic analyzer. Analysis of fragment size and allele calling was performed using Gene Mapper version 4.0



software (Applied Bio systems). The genotypic data were analysed using the software POPGENE version 1.31 and different parameters for the 22 microsatellite loci such as number of alleles, effective number of alleles, allele frequency, observed and expected heterozygosity, Chi-square value and F-statistics were obtained. Polymorphic information content (PIC) was calculated using standard formula. The observed number of alleles ranged from 2 (ETH225) to 19 (ILSTS022) with an average of  $8.818 \pm 0.829$ . As expected, the effective number of allele ( $3.108 \pm 0.317$ ) for all the loci studied was lower compared to the observed number of alleles and ranged from 1.116 in the loci ETH225 to 6.547 in OMHC1, suggesting that the loci used in the present investigation were suitable for determination of genetic polymorphism and diversity within Assam Hill goat. The observed heterozygosity was found to be  $0.565 \pm 0.051$ , which showed the average genetic variation. The observed heterozygosity was lower than the expected heterozygosity in 14 out of 22 loci. The Shannon information index was found to be  $1.354 \pm 0.107$  and ranged between 0.271 (ETH225) and 2.159 (ILSTS022), indicating the informative nature of the loci. The average PIC for all the loci studied was  $0.570 \pm 0.041$ . The locus OMHC1 revealed the highest PIC (0.831) and the lowest PIC was for the locus ETH225 (0.132), which also revealed lowest number of observed alleles. Out of the 22 loci, 17 loci showed PIC value above 0.5. The chi square test of goodness of fit revealed that the population was in Hardy-Weinberg equilibrium for only 7 loci i.e. ILSTS082, ILSTS087, OARHH64, OMHC1, ETH225, ILSTS022 and ILSTS049. The  $F_{IS}$  estimate across the 22 loci was positive indicating heterozygote deficiency.  $F_{IS}$  ranged from -0.228 to 0.553 with an average  $0.078 \pm 0.041$ . Considerable genetic diversity was observed, All locus are polymorphic (except-ETH225) and inbreeding coefficient was 0.078 which is less than other breed. Assam Hill goat characterized by early sexual maturity and highly prolificacy, superior chevon quality-famous for taste and tenderness, superior quality skin and good adaptability to mid and high altitude hill ecosystem. Further planning for its conservation in its home tract is warranted.

#### **Establishment of hygienic meat processing unit and preparation of different value added pork and chicken products**

Considering the importance and demand for different meat products in the north eastern region

India, modern hygienic meat processing unit was established to develop innovative value added meat products, provide hands on training and technical knowledge on meat processing to the educated rural youth for entrepreneurship development in the region (Fig 4). The unit includes raw meat area, processing area, cold storage facilities, laboratory and equipment like portioning machine, meat slicer, meat mincer, planetary mixer, sausage filling machine, bowl chopper, vacuum packaging machine, etc. Under this unit, basic training was conducted for individual and group for the educated rural youth for entrepreneurship development in the region.



**Fig 4. Meat processing unit**

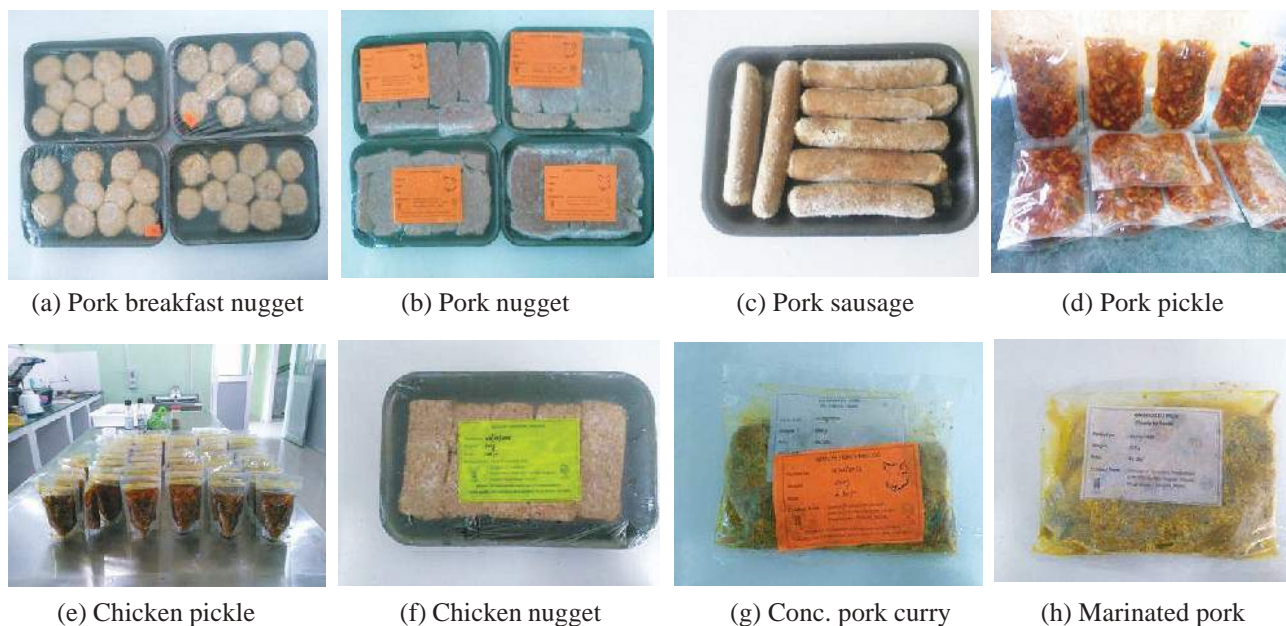
To find out suitable pork packing method in term of self-life and consumer preference, a study compared various packaging methods (vacuum packing, plastic tray packing, poly-propylene box packing) and the indicated that the consumer preference was highest for plastic tray packing, followed by vacuum packing. In term of self-life, the vacuum packing was better as compared to other packing methods.

Different value added products like sausage, nugget, breakfast nugget, blending with traditional herbs and bamboo shoots were prepared and attracted revenue to the institute (Fig 5a - h). New products like concentrated pork curry which is ready-to-eat and ready-to-cook products are also being developed. These products were exhibited in different Agri-fare for popularization.

#### **Establishment of AICRP on Pig unit at Livestock Farm**

AICRP on pig unit has been established at Livestock Farm and piglets (75% Hampshire) have been purchased from AICRP, Khanapara for further research as per mandate of project.





**Fig 5. Meat products developed at Meat Processing Unit**

## ANIMAL NUTRITION

### Performance of Murrah Buffalo under Agro-climatic condition of Meghalaya

Considering the changing climatic conditions of the region and potential of buffaloes to adjust to a wide range of agrarian and diversified agro-climatic situations, 7 Murrah germplasm was introduced on March, 2012 for the first time in north east conditions as a pilot study. The pooled data of 4 years generated from 12 clinically healthy female Murrah buffalo showed increase in growth rate with average daily weight gain over and above 514.52 gm/day in this region. The age and weight of puberty of buffalo heifers averaged  $727.5 \pm 28$  days and  $430 \pm 26$  kg respectively, age at first service  $689 \pm 35$  days, gestation period averaged  $309 \pm 05$  days, birth weight of calf,  $34.66 \pm 02$  kg, respectively. Lactating buffaloes resumed reproductive cyclicity within  $60 \pm 18$  days postpartum with average lactation length of 289 days producing total milk yield 1739.83 kg/lactation. The animals showed regular cyclicity even in the months of March to June and July as validated by ultrasonography in contrast to the buffaloes in its home tract in north India where they show higher incidence of summer anoestrus during these months indicating that these Murrah buffaloes may be a part of integrated farming system of north east if managed with proper nutritional and managerial skills.

### Successful birth of a male calf through embryo transfer

Successful birth of a male calf through non-surgical embryo transfer technology has taken place for the first time at Dairy Unit, Animal Nutrition Section. Elite female crossbred cow (donor) was super ovulated using FSH-P (400mg) and inseminated with elite bull semen and 3 embryos were transferred non-surgically to 3 synchronized recipients under epidural anaesthesia. One recipient cow conceived and gave birth to a male calf weighing 23 kg on 17<sup>th</sup> October, 2015 (Fig 6). The calf and the dam are healthy. The encouraging result reaffirms our belief that the use of this technology will be helpful for faster multiplication and propagation of elite cattle germplasm.



**Fig 6. Calf born by embryo transfer**



## POULTRY SCIENCE

### Growth hormone gene polymorphism in indigenous normal feathered and naked neck chicken of North East India

Polymorphism of Growth Hormone gene was studied using PCR-RFLP, which revealed 3 genotypes in Naked Neck and 2 genotypes in Normal Feathered chicken of Meghalaya.

### Studies on the reproductive traits of emu in Meghalaya

The reproductive performance of emu reared in the institute farm for the second cycle in terms of age at first egg, egg weights, egg production, fertility and hatchability were recorded (Fig 7, Table1).

**Table 1. Performance of emu in Meghalaya**

Traits	Values
Age at first egg (months)	21
Ave egg weight at second season (g)	575
Egg production at second season	56
Fertility (%)	28.57
Hatchability on FES (%)	37.5
Average body weight (Kg)	37.91
Feecal sample examination for internal parasites ( 6 samples from 6 compartments)	Negative



**Fig 7. Emu birds**

### Amelioration strategies to reduce climate stress in poultry by supplementing locally available herbs in the feeds.

Indigenous Naked Neck, Indigenous Normal Feathered and Improved variety bird (Vanaraja) were selected for the experiment. Total thirty six (n=36) poultry birds were reared under identical management and environmental conditions except nutritional treatment given to them. The birds were divided into 3 groups viz. T1, T2 and T3 containing 12 birds in each group of Indigenous Naked Neck, Indigenous Normal Feathered and improved variety bird (Vanaraja). Commercial layer mash with herbal feed supplement @ 1% Turmeric powder and @ 0.5% Roselle powder was fed to the poultry birds. The performance of Vanaraja birds in terms of body weight gain, growth rate and FCR is better in comparison to Indigenous Normal feathered and Indigenous Naked Neck birds. Mortality is high in Vanaraja bird in comparison to Indigenous Normal Feathered and Indigenous Naked Neck bird at stress condition (cold stress). Sera samples collected from all the groups for evaluation of biochemical, serological and hormonal estimation by estimation of biomarkers for stress (Cortisol, SOD and HSP) in relation to climatic changes (seasonal variation).

## ANIMAL HEALTH

### Surveillance of Brucellosis

A total of 5283 sera samples were collected over 4 years from various livestock species [cattle (n=1706), pig (n=2958), goat (n=595), buffalo (n=21) and sheep (n=3)] were screened for *Brucella* antibody by standard serological tests such as Rose Bengal Plate Tests (RBPT) and ELISA. The prevalence rate of bovine and swine brucellosis were recorded as 10.61% (181/1706) and 1.32% (39/2958), respectively. A total of 62/165 bovine blood DNA samples were positive for

**Table 2. Performance of Indigenous Naked Neck, Indigenous Normal Feathered and Vanaraja bird**

Traits	Indigenous Naked Neck	Indigenous Normal Feathered	Vanaraja (Improved variety)
Day old body weight (g)	24.25 ±0.57	25.28 ±0.39	31.03 <sup>a</sup> ±0.39
Body weight at 16 <sup>th</sup> week (g)	956.67±7.69	998.57±12.27	2405.61±12.25
Growth rate (g/b/d)	7.77±0.15	8.32±0.22	19.79±0.24
FCR	5.07±0.09	5.01±0.18	4.75±.014
Mortality (%)	9.65±1.67	10.06±1.77	16.67±2.57



*bcsp* gene and out of which 27 DNA samples were reconfirmed by Real time PCR assay, indicating active infection of *Brucella* spp. Moreover, a total of 9 *Brucella* isolates were characterized by Bruce Ladder PCR assays (Fig 8) and confirmed as *B. abortus* (n=8) and *B. suis* (n=1).

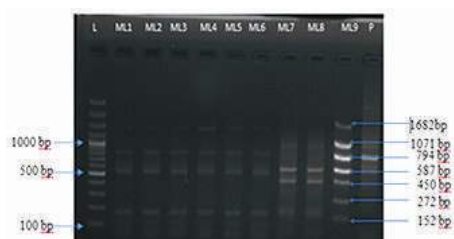


Fig 8. Bruce ladder PCR assay

### AICRP on Animal Disease Monitoring and Surveillance (ADMAS) 2015-16

The major livestock diseases reported from different districts of Meghalaya are Foot and Mouth Disease (FMD), Black Quarter (BQ), Haemorrhagic Septicaemia (HS), and Classical Swine Fever (CSF). Results revealed high positivity of Infectious Bovine Rhinotracheitis (IBR), Bovine Viral Diarrhoea (BVD) and Brucellosis in cattle; CSF in pigs; Peste-des-Petits Ruminants (PPR) in goats. However, diseases like bluetongue and brucellosis in goats, Porcine Reproductive and Respiratory Syndrome (PRRS) in pigs were negligible (Fig. 9). In addition livestock disease outbreaks were investigated including enterotoxemia in goats caused by *Clostridium perfringens* type A, PPR in goats and FMD in cattle.

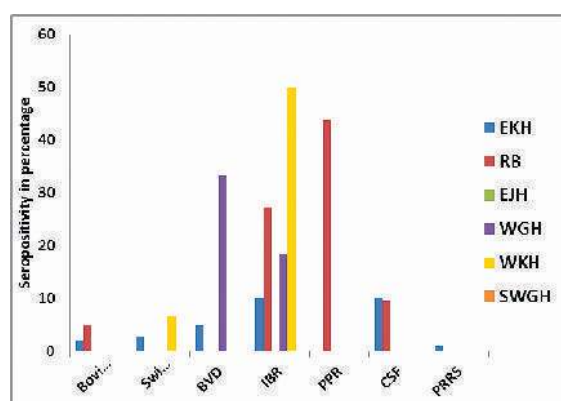


Fig 9. Seropositivity of livestock diseases

### *Listeria* in animal, human and environment

From 289 samples of diverse origin, 6 strains of *Listeria* spp. were isolated. Isolates were confirmed through BD Phoenix system and molecular methods.

Two of the isolates confirmed as *L. monocytogenes* originated from fresh water fishes, whereas none of the human samples were positive for *Listeria* spp.

### Oncogenic viruses of Poultry

Oncogenic Mareks disease virus (MDV) was adapted into MDCK cell lines (Fig 10 a-b). MDV is being attenuated by serial passaging since the *Meq* gene, which is absent in HVT vaccine strain, was present in the isolate indicating its virulence.



(a) Non-infected cells (b) Cytopathic effect of MDV

Fig 10. MDV on MDCK cell lines

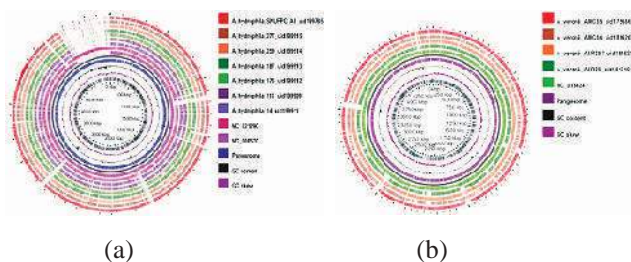
### Studies on therapeutic effects of indigenous plant (*Roselle sabderiffa*)

The expression of various apoptotic genes in the roselle treated Hela cells at various concentrations showed that the extract induced apoptosis. The apoptotic pathways genes like Caspase 8 and 9 were expressed. The apoptotic genes Bclw, Bclxl, Bax, Bik, Noxa, Puma and A1 and regulatory protein like p21 and p53 were also studied.

### Analysis of Pan-genome of *Aeromonas* species

A study was undertaken to analyse the pangenome of *A. hydrophila* and *A. veronii*. Whole genome sequence data were subjected to pan-genome, core-genome, accessory-genome, unique-genome, single nucleotide polymorphism (SNP) analysis and whole genome alignment (WGA). Results (Fig 11a-b) indicated that genome sizes were 5200 kb and 4550 kb for *A. hydrophila* and *A. veronii*, respectively with more variations (genome reorganization, inversions and divergence) in the genomes of *A. hydrophila* compared to *A. veronii*. Whole genome analysis proved useful for evolutionary studies of *Aeromonas* species and might help identify genomic regions of diagnostic importance for this important pathogen of humans and animals.





**Fig 11. Pan-genome maps of *A. hydrophila* (a) and *A. veronii* (b)**

### Antimicrobial resistance at the interface of human-animal-plant continuum

Extended spectrum beta-lactamase producing *E. coli* were isolated from a total of 165 samples of diverse origin. PCR screening of isolates targeting genes for beta-lactam, fluoroquinolone, chloramphenicol and tetracycline resistance revealed highest incidence for *bla*CTXM- 80%, followed by *tetA*- 67%, *qnrA* and *bla*TEM- 47% each, *qnrB*- 27%, *tetB*- 20%, *cmy2* and *cat*-13% each followed by *cmy1*-7%. Pulsed field gel electrophoresis (PFGE) of isolates from various sources indicated role of horizontal gene transfer in dissemination of antimicrobial resistance across sources.

### Molecular characterization of fermented food bacteria

Characterization of Lactic acid bacteria (LAB) from NE region for their functional properties indicated that riboflavin production potential was present in 87% of isolates followed by 77% isolates with amylase production. Of these LABs, 61% was resistant to bile salts indicating their putative use as probiotic. None of these bacteria harboured antimicrobial resistance (AMR) genes highlighting negligible risk for spread of AMR through these LABs.

### Incidence of *Mycobacterium* spp. in food, environment and humans

Screening of 150 milk sample for *M. bovis* yielded 1 isolate of Mycobacterial tuberculosis bacillus complex and 22 as Non tuberculosis *Mycobacterium* species. Additionally, 25 human isolates and 5 environmental isolates were obtained from 300 samples. Molecular characterization and phylogenetic analysis of the isolates are underway.

### Japanese encephalitis (JE) in Meghalaya

A total of 1113 porcine sera samples were processed for JE antibodies from Meghalaya and 17 sera were

found to be positive till now. Epidemiological analysis revealed that JE is following the seasonal pattern in tribal belt in and around sanctuary and water bodies. Highest incidence was observed in RiBhoi district. Awareness programme on JE has been carried out in various institutional and state government sponsored programme.

### Sero-prevalence of *Erysipelothrix rhusiopathiae*

Sero-prevalence study for *Erysipelothrix rhusiopathiae* infection in two representative district of Meghalaya (Ri-Bhoi and East Khasi Hills) was carried out. Sample size was calculated using EpiInfo epidemiological tool. Results indicated sero-prevalence of 6.34% and 3.9% for Ribhoi and East Khasi Hills respectively. The disease seems to be silently present in a low frequency in the state of Meghalaya.

### Green synthesis of silver nanoparticles: Antibacterial properties against foodborne pathogens and resistant bacteria

Silver nano particles were prepared from extracts 9 indigenous plant species (*Houttuynia cordata*, *Solanum khasianum*, *Flemingia vestita*, *Rhododendron* spp., *Centellia asiatica*, *Xanthoxylum armatum*, *Zingiber* spp., *Curcuma ceasia* and *Curcuma augustifolia*). Electron microscopic characterization of nano-particles indicated wide variation in shape and size with respective plants. An effective antibacterial property was observed from the phytofabricated silver nanoparticles, varying with the respective plants used but better than their initial plant extracts (200 mg/ml) alone. Results highlight the antibacterial potential of silver nanoparticles synthesized using indigenous plants.

### Molecular characterization of multidrug resistant (MDR) *Escherichia coli* and *Salmonella* from food producing animals of north eastern region

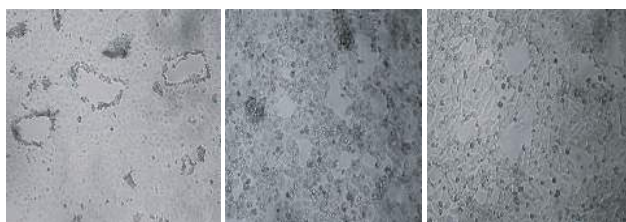
A total of 47 *Salmonella* and 174 MDR *E. coli* were subjected to molecular characterization for MDR genes (n=19) and putative virulence genes (n= 7). Results revealed that >6 % of the *E. coli* isolates were resistant to all the tested antibiotics while > 80 % of *Salmonella* isolates were multidrug resistant. The most effective antimicrobials as revealed in the study were meropenem, levofloxacin, moxifloxacin and piperacillin-tazobactam. Variable incidence of various resistance genes were observed for both type of organisms. However, *bla*<sub>SHV</sub> and *FimA* genes could



not be detected. The resistant traits both in *E. coli* and *Salmonella* were transferable and the resistant isolates showed 2 fold increase in the expression level of *marA*.

### Isolation of CSFV and adaptation in RK-13 cell line for putative vaccine against classical swine fever (CSF)

The classical swine fever virus (CSFV) was isolated from tissue material collected from an outbreak of CSF in Rongmen, Ri Bhoi in 2014. The material was used to inoculate Rabbit Kidney 13 cells by a novel method of co precipitation. Identity of the virus was checked by ELISA, RT-PCR, Taqman/Sybr green real time PCR and sequencing of 5'-NTR and E-2 regions of CSFV. Currently available vaccines present risks of virulence reversion (lapinized vaccine) and harboring endogenous viruses (PK-15 adapted vaccines). In this context RK-13 adapted CSFV isolate might prove to be an effective vaccine candidate and to the best of knowledge this is the first report of CSF being adapted in the rabbit kidney 13 cell line and using a virulent field isolate of CSFV.



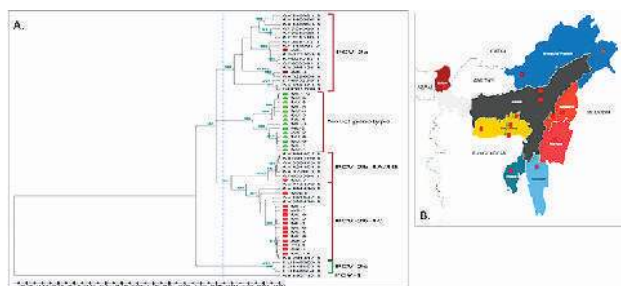
**Fig 12. RK-13 cell line infected with CSFV; P-14 ,P-15 and P-25**

### Molecular epidemiology of Porcine Circovirus 2

Among the 161 seropositive samples, total 23 (14.37%) samples were found positive for PCV-2 from sera. All the PCR positive samples of these three farms were amplified for ORF-2 full gene and one representative sample from each of the three farms were sequenced. Sequence analysis showed 99% to 100% identities among the isolates (nucleotide and amino acid). Phylogenetic analysis revealed that all PCV2 isolates of Meghalaya were clustered along with PCV2b-1C isolates and were distinctly separated from other genotypes of PCV2 (Fig 13).

### Development of realtime PCR based dual quantification assay for porcine viruses

An assay for quantitation of two porcine viruses (Porcine circovirus 2 and porcine parvo virus) was developed. Detection limit of this single tube dual pathogen assay was as low as 10 gene copies/μl of



**Fig 13. Phylo-geographic analysis of PCV2 from NE region**

reaction for PCV-2 and PPV. Evaluation of the assay with field samples indicated considerably better results than conventional PCR based detections.

### Other animal pathogens from NE region

In addition to specific pathogens other pathogens of livestock were also studied across various regions of northeast India. This included sero-prevalence study of PCV2 and PPV in Meghalaya, Nagaland and Assam; CSF in Nagaland; PRRS in Meghalaya and Nagaland; infectious bovine rhinotracheitis and bovine viral diarrhea in Meghalaya. Moreover, 111 bacterial isolates including *E. coli* (38), *Pseudomonas* spp. (19), *Klebsiella* spp., *Aeromonas* spp. (7), *Staphylococcus* sp. (1), *Vibrio* spp. (3) were recovered from the 87 samples. These isolates were confirmed through BD Phoenix-100 system and genus specific PCR.

### Functional cell culture facility

Various cell lines (RK13, Vero, MDCK, CMO, MA104, Vero/h slam, ESK, B95a, DEF, QT35, BMK21, PK15) are being maintained for various type of work like viral isolation and checking the effectiveness of phytochemicals on cancerous cells like HeLa, MCF7, Jurkat. Moreover, cell lines have been supplied to various organizations including IIT Guwahati, NEIGRIMHS, Shillong, Veterinary College, CAU, Aizwal, Veterinary College, AAU, Khanapara.

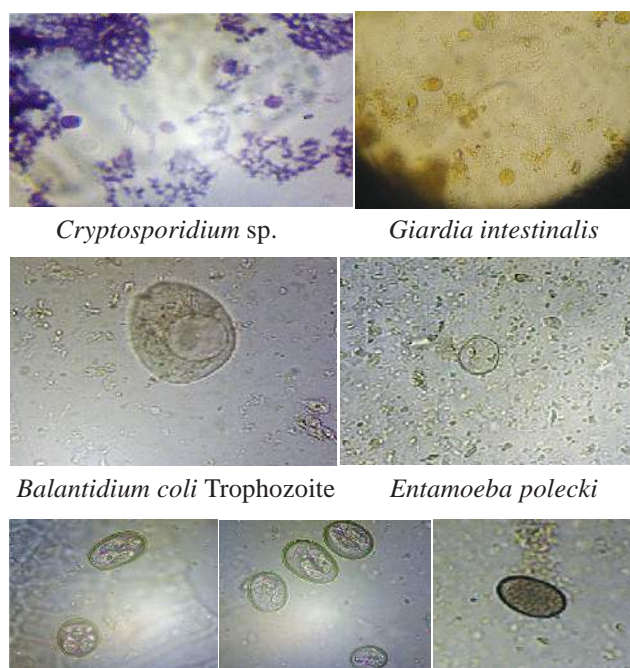
## VETERINARY PARASITOLOGY

### Protozoan parasitic infections of swine in Meghalaya.

The overall prevalence of gastrointestinal protozoan parasitic infections in swine of Meghalaya was 29.77%. *Balantidium coli* (9.83%), *Eimeria* sp. (11.56%), *Cryptosporidium* sp. (2.32%), *Entamoeba polecki* (1.74%), *Giardia intestinalis* (1.45%) and *Isospora suis* (2.89%) were detected in infected



animals. Morphological identification of swine coccidia revealed presence of different species of *Eimeria* viz., *Eimeria deblickei*, *E. porci*, *E. suis*, *E. perminuta*, *E. cerdonis*, *E. spinosa* and *Isospora suis* (Fig 14). Both single (13.30%) and mixed (16.48%) infections were recorded in infected pigs. *Cryptosporidium* sp., *Giardia intestinalis*, *Entamoeba polecki*, *Eimeria perminuta*, *E. cerdonis* and *E. spinosa* were recorded for the first time from pigs in Meghalaya.



**Fig 14. Different species of *Eimeria* in pigs of Meghalaya**

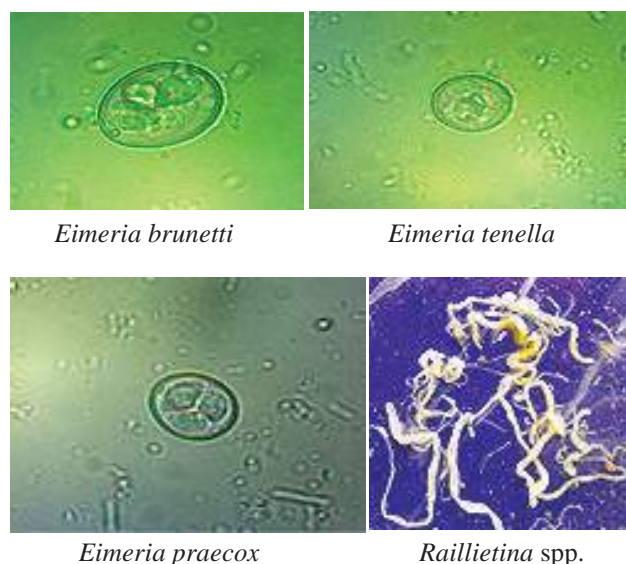
### Gastro intestinal parasitic infections in poultry of North Eastern region of India

The study on prevalence of GI parasitic infections in poultry of north eastern region of India was undertaken in Meghalaya, Manipur, Arunachal Pradesh and Tripura states.

In Meghalaya 29.26% faecal samples of poultry maintained in organized farms were found positive for GI parasitic infections. Coccidiosis (28.45%) caused by different species of *Eimeria* and *Ascaridia galli* (0.81%) were recorded in organized poultry farms. *Eimeria brunetti*, *Eimeria tenella* and *Eimeria praecox* were identified as the species of *Eimeria* prevalent in Meghalaya (Fig 15). In poultry maintained in village condition, 68.00% were found positive for GI parasitic infections. *Ascaridia galli*, *Eimeria* spp. and *Capillaria*

spp. were identified in faecal samples of poultry birds collected from villages.

Post mortem examination of GI tracts of poultry birds of both local birds and organized farms collected from butcher shops of Meghalaya revealed overall 15.92% as positive for helminth infections. Indigenous poultry birds were found as 23.68% positive where as birds maintained in farm condition were found totally negative. *Raillietina* spp. (Tape worm) and *Ascaridia galli* (Round worm) were identified after postmortem examination of GI tracts of poultry birds. Among positive, 19.73% local birds were found positive for *Raillietina* spp. infections, 10.52% were found positive for nematode *Ascaridia galli* infection and 6.57% were found to suffer with mixed infections.



**Fig 15. Different gastro intestinal parasites of North East India**

In Manipur, faecal samples collected from organized poultry farms, 28.00% were found as positive for GI parasitic infections and only coccidiosis of low grade infections (OPG range between 200-250) were noticed. The faecal samples collected from poultry birds from this state revealed a higher percentage of infections (62.06%). *Eimeria* spp. (58.62%) and *Ascaridia galli* (6.89%) were identified in faecal samples of poultry birds of Arunachal Pradesh. In Tripura, Faecal samples of poultry maintained in organized farm revealed 63.15% as positive for GI parasitic infections. *Ascaridia galli* (5.26%), *Strongyloides* spp. and *Eimeria* spp. were detected in these faecal samples.



## FISHERIES

### Isolation of virulent *Aeromonas hydrophila* from diseased carp fishes and its associated environments under mid hill aquaculture, Meghalaya

*Aeromonas* species are facultative anaerobic Gram-negative bacteria, belong to the family *Aeromonadaceae*. In fish, these bacteria cause hemorrhagic septicemia, dropsy, fin rot, soft tissue rot and furunculosis which cause huge economic losses to fish farming. There is a need for a practical method of screening large number of *Aeromonas* isolates for potential virulence. In this study, we isolated virulent *A. hydrophila* for the first time from naturally infected *Labeo gonius*, *L. bata*, *L. calbasu* and *Puntius javanicus* under mid hill condition, Meghalaya exhibiting various clinical signs including surface ulcer, fin rot, opacity of eye, and hemorrhagic septicemia (Fig 16a). We also isolated *A. hydrophila* from clinically observed other diseased carps viz. *Labeo rohita*, *Cirrhinus mrigala*, *Cyprinus carpio* var. *communis* and their associated environments from three fish farms under Ri-Bhoi District, Meghalaya. Isolation was done from eye, surface ulcer and kidney of infected fish and pond waters using *Aeromonas* selective agar as a selective presumptive isolation medium (Fig 16b). A total of 21 representative isolates were identified as *A. hydrophila* when subjected to biochemical test. The isolates were further screened by PCR to detect the presence of four putative virulence



*Cyprinus carpio* var. *communis*      *Puntius javanicus*      *C. mrigala*

**Fig 16a. Moribund fish used for detection of *Aeromonas* sp.**



**Fig 16b. Typical *Aeromonas* colony in *Aeromonas* selective agar**

genes viz. Aerolysin (326 bp), CYT (482 bp), AHCYTOEN (235 bp), Lipase (155 bp) and found to be positive. The LD<sub>50</sub> was determined by intramuscular (IM) injection to common carp fingerlings (15.3±0.4 gm) and it was found to be 1.9x10<sup>4</sup> cfu/fish at 96 hrs. Injected *A. hydrophila* was re-isolated from kidney of the challenged fish.

### First reporting of Argulosis commonly occurring parasitic fish diseases in farmer's pond of Meghalaya

Parasitic diseases are often encountered more frequently than microbial diseases in carp culture systems. Among the parasitic diseases, Argulosis caused by *Argulus* sp (crustacean parasites), more commonly known as fish lice often cause severe mortality of fish in farm ponds, and sometimes in natural waters. Both larvae and adults of *Argulus* are parasitic to fish. They can cause considerable damage to its host through their aggressive attachment and feeding behaviour. They penetrate the upper layers of the host skin and feed on blood and body fluids.

The affected fishes become restless with erratic swimming movements, reduced feeding, hanging at the surface. Fish may “flash” or rub against hard surfaces in an attempt to relieve irritation or to remove the parasites. In this study, the diagnosis and treatment was carried out for Argulosis outbreak in two fish farms of Ri-Bhoi District, Meghalaya in the month of August (Fig 17).



**Fig 17. *Argulus* infected fish farms under Ri-Bhoi District, Meghalaya**

Gross observation revealed that there were *Argulus* sp. attached on the lateral and ventral surface of the body and fins (Fig 18). There were severe haemorrhagic, ulcerative lesions on the caudal peduncle in some fishes. The skin of *Argulus* affected areas of some fishes was pale and there were loss of scales (Fig 19). Gills were pale in colour. There was severe damage in the mouth part of some fishes probably due to rubbing with hard substratum in order to get relieved from irritation or to remove the parasites.





Fig 18. *Argulus* sp. isolated from infected fish



Fig 19. *Argulus* attached on fish scale

Both adult/mature and sub-adult *Argulus* were isolated from fish with fine brush. The parasites were then preserved for further studies. The adult/mature *Argulus* were 5 mm in length whereas sub-adult were around 4 mm. In both the farms, *Labeo rohita* and *Labeo bata* were affected the most. Swab was prepared and after brief vortexing, the sample was streaked on *Aeromonas* agar plates, incubated at 30° C and observed after 18-24 h. The isolates were identified as *A. hydrophila* using BD-Phoenix.

Fishes were treated with Cypermethrin (EC 10% w/v) @ 100 ml/ha once in a day for 3 alternate days and then once in a week for three consecutive weeks. Thereafter, the treatment could be repeated after every three months depending on the condition of infestation. The fishes responded to treatment and showed significant improvement after one week.

#### First reporting of Saprolegniasis in the month of August commonly occurring fish diseases in winter under Meghalaya

Saprolegniasis often contribute to heavy mortality among fishes. In the present study, we encountered a severe outbreak of Saprolegniasis in *Labeo gonius* fingerlings in the month of August under mid-hill altitude condition. The disease outbreak was occurred in an earthen nursery pond (400 m<sup>2</sup> area) where *Labeo gonius* spawn was stocked for rearing up to fingerling stage. The average size of the infected fingerlings was 4-6 cm TL. Moribund fish were collected from the pond by examining individually for the presence of external lesions and brought to the laboratory and fixed immediately in 10% NBF. The main characteristic lesions of saprolegniasis were appearance of cotton wool like tufts on the tail (caudal). (Fig 20)

The main postmortem lesions were appearance of cotton wool tufts on caudal fin (tail), pale to grayish gills, serious fluid or exudates in the abdominal cavity, intestine free from any food particles, dark enlarged liver, distended gall bladder with bile, splenomegaly. For the isolation of fungi associated with fish, swab

of skin was cultured in Potato Dextrose Agar (PDA). To inhibit the bacterial growth, 40ug/ml of Ampicillin was added to the medium. The plates were incubated at room temperature (24-28° C) and fungal growth was observed after 3-7 days (Fig 21). For purification, grown fungi were transferred to fresh medium.



Fig 20. Cotton wool like tufts on the tail

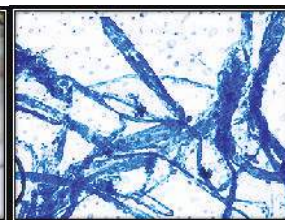


Fig 21. Fungal mycelium under microscope (10X)

#### Growth performance of Pengba (*Osteobrama belangeri*) advance fry cultured in different stocking densities.

Advance fry of Pengba – an endangered medium carp of Northeast India at three different stocking densities ( $SD_1=20$  fry/m<sup>3</sup> of water volume,  $SD_2=25$  fry/m<sup>3</sup> of water volume and  $SD_3=30$  fry/m<sup>3</sup> of water volume) in three outdoor cemented tanks (T1, T2 & T3 of size 1.2mx1.2x1.2m) with mud bottom were cultured for 105 days (from last week of August to first week of December). The stocking densities (20 fry/m<sup>3</sup>, 25 fry/m<sup>3</sup> and 30 fry/m<sup>3</sup>) were maintained in the tanks (T1, T2 and T3). The fry were fed ad libitum with feed composed of locally available mustard oil cake (MOC) and rice polish at the ratio of 1:1. Initial size of fry was  $2.59\pm0.1$ cm in total length and body weight of  $0.3\pm0.03$ g and after culturing for 105 days the fry reached the size of  $7.8\pm0.07$  cm and  $5.4\pm0.17$  g for  $SD_1$ ;  $7.86\pm0.09$ cm and  $5.39\pm0.3$  g for  $SD_2$ , and  $7.53\pm0.1$ cm and  $4.71\pm0.15$  g for  $SD_3$ . The survival rate of fishes for  $SD_1$ ,  $SD_2$  and  $SD_3$  were 55%, 74% and 68.33% respectively. Maximum water temperature ranged from 27° C to 18° C during the period (Fig 22)

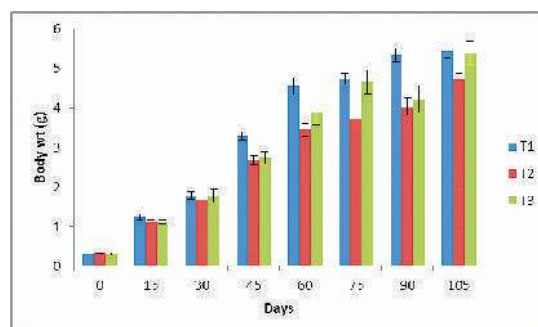


Fig 22. Growth of advance fry of Pengba in three tanks of different stocking densities



# ARUNACHAL PRADESH

## WEATHER REPORT

Agrometeorological Observatory of ICAR Research Farm, Gori, Basar is located at Lat: N 27°59.537, Long: 94°41.269, Alt: 616 m amsl, Zone: Eastern Himalaya Ecozone-II Total rainfall received was 2656.8 mm, which is mostly distributed between Months of May and September (Fig 1) with highest rainfall in the month of August (825.2 mm). A mid-season dry spell was experienced in the month of July. The number of rainy days was 156 (Fig 2), which is above the normal of 144 days. The monthly average maximum and minimum temperature trends are shown in Fig 3. The highest temperature recorded during the period was 33.8° C in the month of June and lowest temperature recorded was 4.1° C in the month of December. The relative humidity trend is depicted in Fig 4.

## RICE

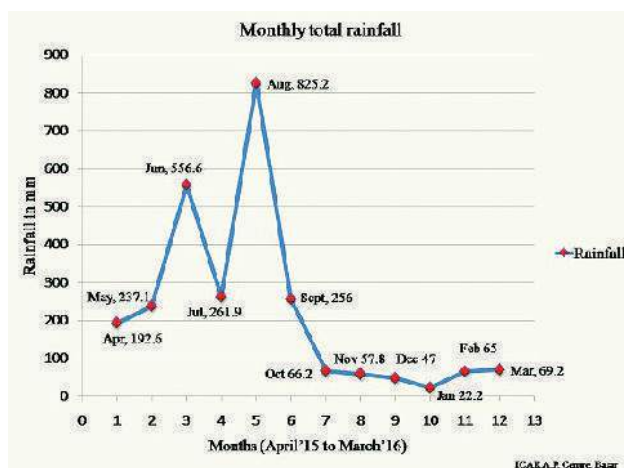


Fig 1. Monthly total rainfall

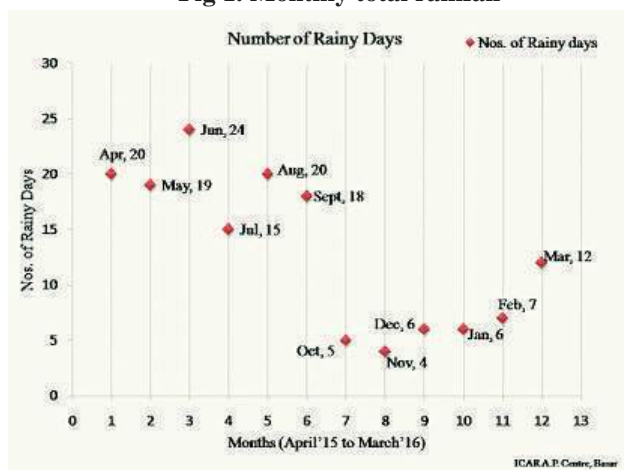


Fig 2. Number of rainy days

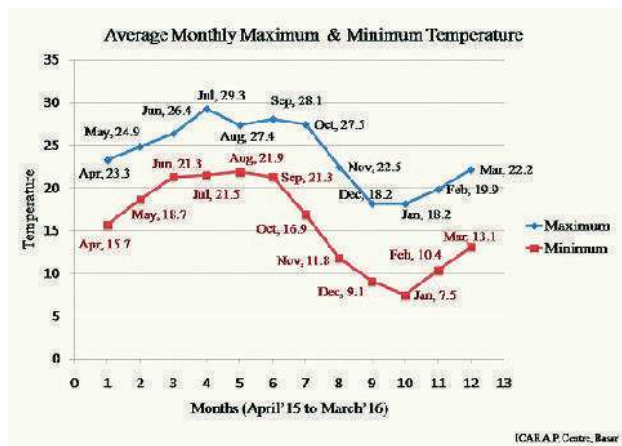


Fig 3. Average max. and min. temp

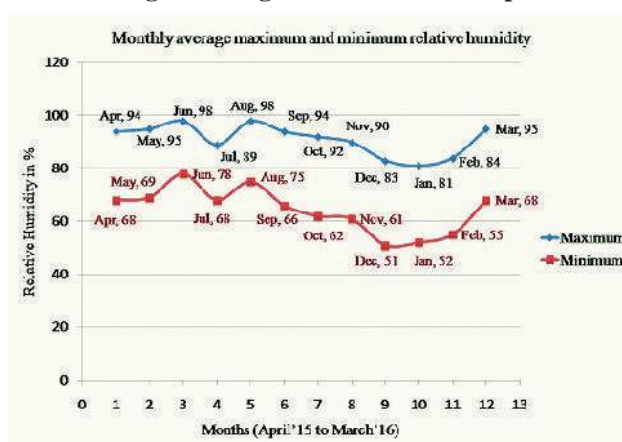


Fig 4. Average max. and min. relative humidity

## Collection, characterization and evaluation of local rice germplasm

A total of 42 local rice germplasm were collected comprising of 23WRC and 19 *jhum* rice landraces. Evaluation and characterization indicated less variation in qualitative characters whereas significant variation was observed in quantitative characters among the accessions. Among the collected lowland rice accessions, the good yielder were Amham (3.6 t/ha), Pumde (3.23 t/ha), Amtum (3.1 t/ha) and Riew Ammo (2.8 t/ha) respectively (Fig 5). The good yielders among the collected *jhum* rice landraces were Pumik (2.7 t/ha), Bali Red (2.63 t/ha), Chipu (2.5 t/ha).



Fig 5. Performance of lowland rice varieties



ha), Mingpong (2.43t/ha) and Yali Amo (2.3 t/ha) respectively (Fig 6).



Fig 6. Performance of local *jhum* rice varieties

## MILLET

### Evaluation of different finger millet varieties

Performance evaluation of finger millet (*Eleusine coracana*) varieties in local climatic conditions was carried in two different seasons of *rabi* 2014 and *kharif* 2015. The varieties under trial consisted of 15 high yielding improved varieties from AICSMIP, Bangalore and one local check *viz.*, VL-352, VR-708, VL-324, VL-315, GPU-45, VL-149, KMR-204, Indaf-9, GPU-48, KMR-301, GPU-66, GPU-67, Indaf-8, HR-911, PR-202, GPU-28 and kongpu (local check). The highest yield in *rabi* was recorded in VL-324 (1.23 t/ha) followed by VR-708 (1.2 t/ha) and GPU-48 (1.18 t/ha) respectively (Fig 7). While in *kharif*, highest yield was recorded in Indaf-9 (2.1 t/ha) followed by GPU-48 (1.65 t/ha), VL-324 (1.61 t/ha) and VL-352 (1.57 t/ha) respectively, and the lowest yield was recorded in HR-911 (0.43 t/ha). Highest mean yield of two season was recorded in Indaf-9 (1.53 t/ha) followed by VL-324 (1.42 t/ha) and GPU-48 (1.42 t/ha) respectively. Replacement of low yield traditional varieties with these suitable high yielding varieties could play vital role in increasing production and productivity of finger millet in Arunachal Pradesh.

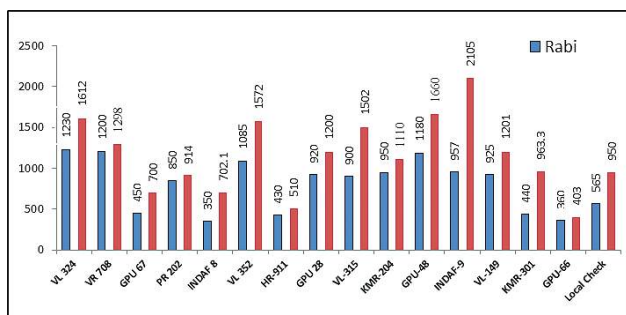


Fig 7. Yield of finger millet (Kg/ha)-*kharif* and *rabi*

### Evaluation of baby corn varieties

Evaluation of 12 varieties (including VL baby corn-1, HM 4, RCM 1-1, RCM 1-2, RCM 1-2, RCM 75, RCM 76, DA 61 A, local maize (Sago), Vijay composite etc.) of maize available as baby corn revealed that there was difference in characters among the varieties (Fig 8).



Fig 8. Performance of different maize varieties for baby corn purpose

Among varieties, VL Babycorn-1 matured the earliest and had the highest yield (4.92 t/ha) though other characters like baby cob length, girth and colour were not found desirable and appealing. Among the varieties, HM 4 followed by RCM 1-2 and Sago local had the preferable characters with slight yellow creamy colour.

## TORIA

### Effect of sowing dates and urea foliar application on the performance of toria in upland condition in Basar

Experiment was conducted to find out the performance of toria on different sowing dates with different concentrations of urea foliar spray during *rabi* season under upland condition of Basar. Growth parameter like plant height, dry matter accumulation, number of branches was found to be higher in first date of sowing (15<sup>th</sup> October 2015) with a mean value of 93.86 cm in comparison to 81.23 cm at 3<sup>rd</sup> sowing date (i.e. 15<sup>th</sup> November, 2014). Similarly grain yield (0.9 t/ha) and yield parameters like siliqua length (4.29 cm), number of siliqua per plant (154.6), seed per siliqua (16.13) etc. was found to be higher in first date of sowing. However, in the case of different concentration of urea foliar spray, most of the



Fig 9. *Kharif* toria TS-38



parameters were found to be showing no significant difference in two years of the experiment.

### Effect of forest litter on soil quality and crops performance pea

An experiment was conducted to adjudge the effect of forest litter on performance of pea. Five species of trees (*Castonopsis indica*, *Altingia excels*, Hiko, *Symingtonia populnea* and *Cinnamomum camphora*) were chosen with FYM as control. The rate of application of the forest litter was @ 10 t/ha for each treatment. From the first year of the experiment, it was found that there was no significant difference in yield, yield attributes of pea crop with respect to different forest litter treatments and towards control (FYM).

### Development of tuber crop based cropping system

Considering the importance tuber crops in the *jhum* field a study was carried out with the objective to evaluate the yield performance of different local and improved cultivars of tuber crops as Crop Model in *jhum* field. Local and improved varieties of tuber crops viz. Colocasia, Sweet potato, Cassava, Elephant Foot Yam (EFY), Dioscorea etc. were grown under uniform standard and timely cultural practices. Yield of different varieties are presented in Fig 10. Economic analyses revealed that Dioscorea recorded the highest benefit cost ratio of 5.98 followed by Elephant Foot Yam with benefit cost ratio of 5.86.

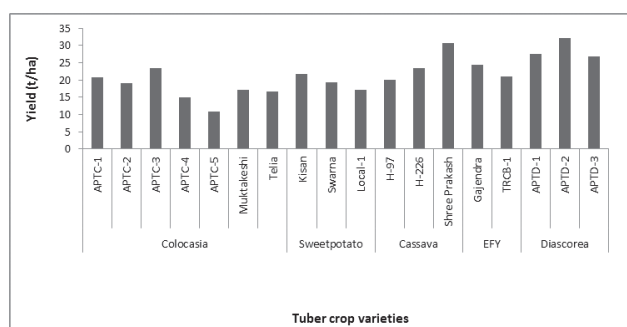


Fig 10. Yield of different varieties of tuber crops (t/ha)

### Farming system approach through land-use model in Arunachal Pradesh

Various cropping systems were evaluated under Farming System Research involving fruit crops, spices, oilseeds, vegetables, tuber crops, cereal crops and other crops (Fig 11). Data were recorded as maize equivalent yield (MEY) for easy comparison. Among

the cropping system, spice-based cropping system of ginger/turmeric + soybean- pea registered the highest production with a MEY of 1.55tonnes. Among vegetable based, cucurbits-brinjal- French bean offered the highest MEY of 0.24 tonnes. Among fruit crops, pineapple offered the highest MEY of 0.9 tonnes and lowest in the case of *Khasi* mandarin (0.02 tonnes). Therefore, with the adoption of this approach, very high MEY of 3.64 tonnes will be achieved from a farm holding of 0.22 ha.

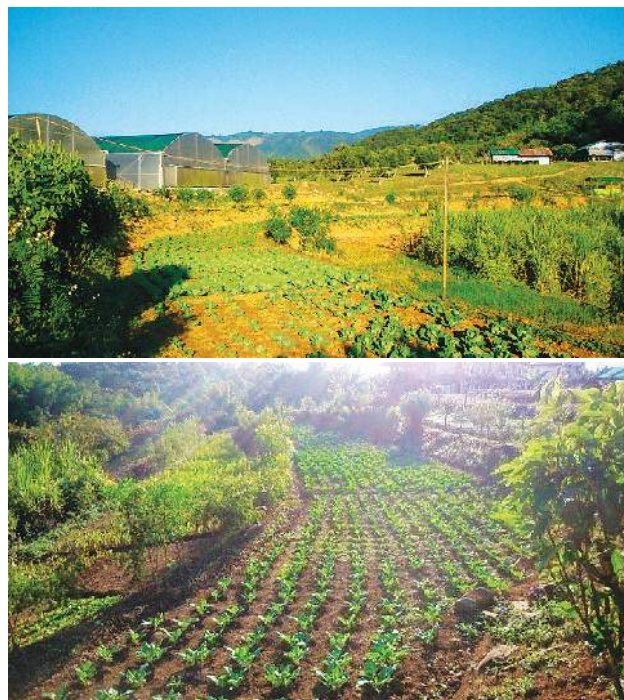


Fig 11. Farming system model

### Evaluation of multipurpose trees

During 1997-2001, 53 MPT species were planted (Fig 12), out of which 49 species are established. Among 16 tree species established in 1997, *Pinus kesia* attained maximum basal girth (130.3 cm) followed by *Michelia obtusifolia* (123.3 cm) and *Cuppressus torulosa* (114.2 cm). Canopy spread was recorded highest (8.45 m x 8.56 m) in *Pinus kesia* followed by *Cuppressus torulosa* (7.63 m x 7.17 m) and *Terminalia myriocarpa* (7.53 m x 7.42 m) after seventeen years of planting. Highest plant height was recorded in *Michelia obtusifolia* (18.25 m) followed by *Castonopsis indica* (17.76 m) and *Anthocephalus cadamba* (17.23 m). Highest light intensity in inter-rows was recorded highest in *Terminalia myriocarpa* (673.13 lux) followed by *Gmelina arborea* (550.21 lux) and *Anthocephalus cadamba* (392.1 lux) and lowest in *Mesua ferrea* (6.6 lux).





*Pinus kesiya*



*Michelia obtusifolia*



*Cupressus torulosa*



*Mesua ferrea*

**Fig 12. Best performing MPTs**

Among the 20 tree species planted in 1998, *Acacia mangium* attained maximum height (25.3 m) followed by *Pinus wallichiana* (17.7 m) and Penlow (16.8m) and lowest in *Morus alba* (2.46 m). Basal girth was recorded highest in *Acacia mangium* (143.3 cm) followed by *Pinus wallichiana* (117.7 cm) and *Caryotaurens* (95.83 cm). The canopy spread was found highest in *Acacia mangium* (10.42 m x 9.63 m) followed by *Pinus wallichiana* (8.89 m x 8.75 m) and Penlow (6.43 m x 6.26 m) and lowest in *Morus alba* (1.31 m x 2.14 m). Highest interspacing light intensity was recorded in *Graveliarobusta* (868.2 lux) followed by *Alnus nepalensis* (612.1 lux) and *Lagerstoemia speciosa* (543.3 lux) and lowest in *Cunninghamia lanceolata* (8.3 lux) followed by *Symmingtonia populnea* (23.3 lux) and *Cephalo taxus* (26.2 lux).

Among six species established in 1999, *Manglietia insignis* attained highest plant height (16.8 m) followed by *Parkia roxburghii* (15.4 m) and *Aleurites montana* (12.68 m) and lowest in *Bauhinia purpurea* (5.42 m). The basal girth was found highest in *Manglietia insignis* (101.3 cm) followed by *Aleurites montana* (89.0 cm) and *Engelhardtia spicata* (87.1 cm) and lowest in *Bauhinia purpurea* (5.42 cm). *Aleurites montana* recorded the highest canopy spread (6.86 x 6.21 m) followed by *Manglietia insignis* (5.9 x 5.88 m) and *Engelhardtia spicata* (5.64 x 5.55 m) and lowest in *Bauhinia purpurea* (3.01 x 2.91 m). *Aleurites montana* showed the highest inter spacing light intensity (871.3 lux) followed by *Embllica officinalis* (417.5 lux) and *Bauhinia purpurea* (311.3 lux).



### Performance of different intercrops in combination with different MPTs

Among 31 combinations of 51 species of MPT and 5 species of cane, *Alnus nepalensis* + Takek was reported best in terms of basal girth (36.83 cm) followed by and *Pinus khassiana* + Takek (31.96 cm). The plant height of canes was found highest under *Duabanga grandiflora* (3.45 m) followed by *Terminalia myriocarpa* (2.87 m) and *Castanopsis indica* (2.62 m). Among 28 combinations of MPT species and Guinea grass, the combination *Terminalia myriocarpa* + Guinea grass recorded the highest guinea grass yield (23.6 kg/row). Among 22 combinations of MPT species and Broom grass, the combination *Gravelia robusta* + Broom grass recorded the highest yield (81.2 kg/row) (Fig 13).



*A. nepalensis* + Takek



*T. myriocarpa* + Guinea grass



*G. robusta* + Broom grass

Fig 13. Tree inter-cultivation with cane and grasses

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

The spacing trial of Ghamari was established in 1999. In 17<sup>th</sup> year of establishment, ghamari obtained highest plant height (18.87 m) in the spacing 2 x 3 m followed by the height (18.2 m) in spacing 4 x 3 m. The girth at breast height was found highest (122.4 cm) in the spacing 4 x 4 m followed by 103.2 cm in 6 x 3 m spacing.

### Spacing trial of Bola (*Morus laevis*)

The spacing trial of Bola (Fig 14) was established in 1998. After 18 years, maximum plant height (9.62 m) was attained in the spacing 3 x 3 m followed by height (8.64 m) in 4 x 3 m spacing. The average girth at breast height was also found highest (25.8 cm) in the spacing 5 x 3 m followed by 21.9 cm in the spacing 3 x 3 m spacing.



Fig 14. *Morus laevis*

### Spacing trial of bamboo species

Out of 13 species of bamboo grown under three spacing, maximum clump circumference was recorded in *Bambusa cacharensis* (15.93 m) at 5 x 5 m spacing followed by the same species (13.64 m) planted at spacing 6 x 6 m. But in spacing 7 x 7 m, *Bambusa nutans* recorded the highest clump circumference (11.2 m). Highest number of culms per clump was recorded in *Bambusa pallida* (75) at 7 x 7 m spacing followed by *Dendrocalamus sahnii* (65) at 6 x 6 m spacing and *Dendrocalamus hamiltonii* (60) at 5 x 5 m spacing.

## FRUITS

### Biochemical profiling and shelf life of Taktir (*Garcinia lancifolia*) fruits in different packages under storage

Evaluation of packaging materials (bamboo basket, non-perforated LDPE, non-perforated HDPE,



perforated LDPE, perforated HDPE, leaf, CFB) to extend the shelf life of Taktir fruits indicated that maximum decrease in acid content was observed in fruits stored in bamboo basket (1.22 %) on the 6<sup>th</sup> day of storage. Better retention of acidity (2.17%) was found in non-perforated HDPE followed by non-perforated LDPE with 1.72 % on the 6<sup>th</sup> day of storage.

#### Productive response of strawberry cv. Chandler to different Plant bio regulator under mid hill condition

Studies to assess the effect of NAA (50, 100, 150 ppm), GA<sub>3</sub> (50, 100, 150 ppm) and BA (50, 100, 150 ppm) on vegetative growth, yield and quality of strawberry cv. Chandler was carried. Results revealed that the plants treated with GA<sub>3</sub> at 100 ppm produced highest plant height (22.06 cm), number of fruits per plant (21.44) and yield (209.11 g) per plant while, GA<sub>3</sub> at 150 ppm resulted in maximum fruit length (3.69 cm), fruit width (2.74 cm), number of leaves per plant (20.11), number of runners per plant (9.17) and minimum days taken for first flowering (62.11 DAT). As far as the quality parameters are concerned, the plants treated with NAA at 100 ppm produced fruits with maximum TSS (9.02°B) and total sugar (10.39 %), while NAA at 150 ppm treated plants produced fruits with maximum ascorbic acid content (77.82 mg per 100 g). The highest titratable acidity (0.48 %) content was recorded in GA<sub>3</sub> at 100 ppm (Fig 15).



Fig 15. Growth regulator treatments on strawberry

#### Physico-chemical characteristics of budded citrus with different rootstock and scion combination

The physico-chemical characteristics of budded citrus species obtained from different rootstock and scion combination viz., four types of mandarin oranges (*Khasi* Mandarin, Nagpur Santra, Hill Mandarin and Sikkim Orange) and six species of rootstock Tanyum (*C. medica*), *C. volkameriana*, *C. latipes*, Trifoliate Orange, Rough lemon and Karna Khatta were examined. Among different combinations of rootstocks and scions, *C. volkameriana* + *Khasi* mandarin produced maximum fruit weight (308.54 g). *C. latipes* + Hill mandarin exhibited maximum fruit length (5.58 cm) and fruit breadth (6.46 cm). The

combination of *C. volkameriana* + Nagpur santra produced minimum number of seeds per plant (5.00). Further, it was observed that Trifoliate orange + *Khasi* mandarin recorded the highest TSS content (11.6° B).

#### Genetic variability in physico-chemical characteristics of some pummelo collections from mid hill condition of West Siang District

The performances of twelve lines of pummelo were studied with an objective to screen superior germplasm (Fig 16). Results revealed wide variations in the parameters studied. Fruit weight ranged from (0.56 – 1.56 kg), number of seeds per fruit ranged from (13.00 – 114.33), TSS from (7.50 – 10.83° B), acidity from (0.39 – 1.71 %) and ascorbic acid ranging from 27.57 – 48.28 mg per 100 ml juice. The wide variation in physico-chemical composition of fruits offers wide scope for breeding to develop desirable hybrids.

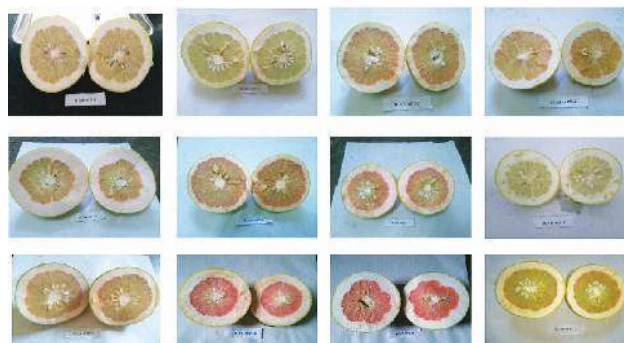


Fig 16. Variabilities in Pummelo

#### Evaluation of different citrus species in citrus germplasm repository

Fruits of various citrus species were collected from the citrus germplasm repository block, ICAR Research farm, Gori, Basar and were evaluated for some its physico-chemical traits. The results showed that highest fruit weight (252.37 g) was recorded in *Citrus medica* whereas the lowest fruit weight (36.24 g) was recorded in acid lime. Thorny mandarin and Cleopatra mandarin recorded the highest number of seeds per fruit (11.2) meanwhile Assam lemon exhibited the lowest number of seeds per fruit (1.4). It was observed that acid lime have lowest peel thickness of (0.28 cm) and Kamala orange attained the highest peel thickness of (1.64 cm). Highest TSS (13.9° B) was recorded in Whittawarmalta followed by Mediterranean orange with (12.6° B). Maximum titratable acidity (6.37 %) was recorded in Acid lime whereas the minimum (0.65 %) was recorded in sweet orange cv. Mosambi.



### Maturity Indices of 'Kew' Pineapple in mid hill condition

Experiments conducted to standardize maturity indices of Kew pineapple revealed that fruit harvested during 151-155DAF (50 % colour development stage) was the right stage of harvesting for distant market and fruit harvested during 156-160 DAF (75 % colour development stage) was found to be the right stage of harvesting for local market. In both the stages, the harvested fruits retain a better quality attributes (Fig 17).



Fig 17. Different maturity stages of pineapple

### Productive response of chilli cv. Kashi Anmolto foliar application of micronutrients

Field trial on chilli (cv. Kashi Anmol) was conducted to evaluate the response of chilli to foliar application of micronutrients for maximizing the yield. The treatments included  $\text{CuSO}_4$  (0.2 %, 0.4%, 0.6%),  $\text{MnSO}_4$  (0.2 %, 0.4%, 0.6%),  $\text{ZnSO}_4$  (0.2 %, 0.4%, 0.6%), boric acid (0.2%, 0.4%, 0.6%) and control (water). Among all the treatments, the treatment  $T_8$  (Zn sulphate @ 0.4%) recorded best in terms of plant height (101.80 cm), number of fruits per plant (131.00), average fruit weight (3.09 g) and green fruit yield per plant (378.67 g). The treatments  $T_4$  (Mnsulphate @ 0.2%) and  $T_7$  (Zn sulphate @ 0.2%) recorded maximum in ascorbic acid (81.12 mg per 100 g) and capsaicin content (0.691 %) respectively.

### Effect of different grades of rhizomes on growth and yield of turmeric

The effects of seed rhizome size on growth and yield of turmeric was evaluated. The treatment with finger rhizome of 40-60 g gave the best performance in all parameters studied viz. plant height (115.33 cm), leaf length (60.58 cm), leaf breadth (17.78 cm), number of leaves (7.61), stem diameter (2.20 cm), number of tillers (2.89) and a total yield of 15.21 t/ha.

### Disease intensity of *jhum* crops

The impact of disease sometimes results in loss of indigenous crop varieties as well as yield. The disease incidence of leaf blast, leaf blight and powdery mildew was highest in *jhum* paddy, colocasia and *khasi* manderin, respectively.

### Management of pests and diseases in WRC

Evaluation of traditional lures used in north east region of India indicated that rotten frog and the fermented paste prepared from *Puntius* spp. had the maximum potential among the lures for trapping gundhi bug.

### Evaluation of Improved backyard and nondescript poultry birds its impact under farmers field condition

Following introduction of Vanaraja birds a survey of adoption practices among poultry farmers (n=36) was undertaken in three circle viz., Daring, Tirbin and Aalo circles. Results (Table 1) indicated that with introduction of Vanaraja and interventions from ICAR, poultry farming practice among farmers have improved. Moreover, twelve training cum demonstration on scientific poultry and piggery production covering 148 farmers were done.

Table 1. Improvement in poultry farming practices following introduction of Vanaraja birds

Practice	Adoption (%)
Scavenging for feeding poultry	100.0
Monthly cleaning of shed	44.4
Chick brooding	64.7
Vaccination against Ranikhet	52.7
Use of ectoparasiticide instead of ash	77.8
Hygienic disposal of dead birds	75.0
Healthcare seeking from ICAR RC	52.8

### Comparison of fish production, productivity in Rice-Fish culture practice at Apatani Plateau (Ziro) and Basar

Farmers who practise paddy-fish cultivation were selected randomly from Basar (650 msl) and Ziro (1500 msl) respectively. At Ziro, the traditional agriculture is unique in the manner that both paddy and fish are cultivated together in the same plot with no tillage farming. No chemical fertilizers and pesticides are used. The average fish production and productivity at Ziro (022 t/ha/yr) was found significantly lower than that of Basar (1.33 t/ha/yr)



condition, prevailing water temperature and species composition might be a reason. The rice production and productivity was nearly similar in both the case. Moreover, one day awareness programme among the fish growers were conducted at Ziro, Lower Subansiri District which was attended by 31 paddy-cum-fish farmers.

### Flagship programme on “Improvement of *jhum* through horticulture interventions”

With the objective of improving the *jhum* through horticulture intervention, 3000 nos. of orange (*Khasi mandarin*) seedlings, 2000 nos. of banana suckers (*var. Grand naine*) and 3000 nos. of pineapple suckers (*var. Kew*) were distributed to the *jhum* farmers under orange, banana and pineapple based modules covering an area of around 9.50 ha alongwith demonstration on scientific agro-techniques with the advice to follow intercropping with leguminous crops in initial years of the plantation.

Under rice based cropping module focused has been made on the first year *jhum* fields through improved varietal interventions with scientific cropping systems. Keeping in view the inherent low

productivity of indigenous local *jhum* rice and non-scientific way of cropping system traditionally followed by local farmers, improved upland rice varieties like Bhalum-1,2,3 and along with Maize, Pulses, Oilseed and vegetables seeds have been distributed to selected farmers covering an area of 25 ha. The varieties introduced are- Maize (*var. DA-61-A*), Black gram (*var. Uttara & Pant-U-31*), Green gram (*var. Pratap*), Cowpea (*var. Kashi Kanchan*), Soyabean (*var. JS-335*), Groundnut (*var. ICGS-76*) and vegetable seeds. Under this module leguminous crops were intercropped with rice at different intervals across the slope to reduce the surface runoff, improvement of soil fertility and productivity. Under tuber based module different improved varieties of tuber crops *viz.*, *Colocasia*, *Dioscorea*, Sweet potato, Tapioca and Elephant foot yam have been distributed. This module has been integrated with rice based module (Fig 18).

### Disease intensity of *jhum* crops

Incidence of diseases in *jhum* crops is summarized in Table 4. The disease incidence of leaf blast, leaf blight and powdery mildew was highest in *jhum* paddy, colocasia and *khasi mandarin*, respectively (Table 2).



Fig 18. Established crops under different modules in farmers field

Table 2. Major *Jhum* crops and their diseases in Basar and Daring circles of West Siang district, Arunachal Pradesh

<i>Jhum</i> Crop	Diseases	PDI	Occurrence period
Paddy ( <i>Oryza sativa</i> L.)	Leaf blast ( <i>Pyricularia oryzae</i> )	66.24	April-July
	Leaf scald ( <i>Rhynchosporium oryzae</i> )	57.50	July-August
	False smut ( <i>Ustilaginoideavirens</i> )	00.60	August- Sept.
Maize ( <i>Zea mays</i> L.)	Leaf blight ( <i>Exserohilumturcicum</i> )	20.50	June-July
	Maydis leaf blight ( <i>Bipolaris maydis</i> )	08.56	June-July
	Rust( <i>Puccinia polysora</i> )	16.19	Nov.-Dec.
Sesamum ( <i>Sesamumindicum</i> )	Leaf blight ( <i>Alternaria sesami</i> )	32.29	June-Aug.
Yam ( <i>Dioscorea</i> spp.)	Leaf blight ( <i>Glomerellac ingulata</i> )	33.33	June-Oct.
Taro ( <i>Colocasiaesculenta</i> L.)	Leaf blight ( <i>Phytophthora colocasiae</i> )	67.04	June-Oct.
Ginger ( <i>Zingiberofficinale</i> L.)	Leaf spot ( <i>Phyllosticta zingiberi</i> )	28.14	May-Aug.
Sweet potato ( <i>Ipomoea batatas</i> (L.) Lam.)	Leaf spot ( <i>C. ipomoeae &amp; C. henningsii</i> )	44.39	July-Oct.
	Southern blight ( <i>Sclerotium rolfsii</i> )	64.32	Aug.-Nov.
Khasi manderin	Scab( <i>Elsinoefawcetii</i> )	46.67	Mar.-Sep.
	Powdery mildew ( <i>Oidium</i> sp.)	78.67	Mar.-April
Banana ( <i>Musa</i> spp.)	Sigatoka leaf spots ( <i>Mycosphaerella</i> spp.)	36.67	July-Feb.



### Forecasting Agricultural Output using Space, Agro-meteorology and Land Based Observations (FASAL)

Pre-harvest yield forecasting two rice varieties, *Mipun* and CAUR 1 for *kharif* 2015 was done by subtracting the correction factor from simulated yield which was 2.26 t/ha and deviated from the actual yield i.e. 2.18 t/ha with an error percent of 3.55. Also, a trend value of 2.33 t/ha for the year 2016 was determined based on the observed trend values from the past year yields.

### AICRP on Mushroom

Biodiversity analysis of 32 specimens of wild mushrooms categorized the specimens into 32 different genera, 20 families and 10 orders (*Agaricus* sp., *Auricularia auricula-judae*, *A. delicate*, *A. polytricha*, *Boletus* spp., *Crinipellis* spp., *Cantherellus* spp., *Clavulinopsis* spp., *Cordyceps* spp., *Favolus* spp., *Fomes* spp., *Fomitopsis pinicola*, *Ganoderma applanatum*, *G. lucidum*, *Inonotus* sp., *Lepiota* spp., *Lenzites betulina*, *Lycoperdon* sp., *Marasmius* spp., *Macrolepiota* sp., *Morchella* spp., *Oudemansiella* spp., *Pleurotus* spp., *Polyporus* spp., *Russula* spp., *Schizophyllum commune* Fr., *Suillus* spp., *Schizopora* sp., *Trametes gibbosa*, *Volvaria* sp., *Termitomyces microcarpus* and *Tricholoma* spp.). Of these, *Schizophyllum commune* could be successfully domesticated for the first time in Arunachal Pradesh.

### AICRN on Potential Crops

#### Standardization of Job's tears (*Coixlacryma-jobi*) cultivation technique

Field experiment was conducted during *kharif* 2015 on Job's tears cultivation techniques indicated that highest average yield (3.82 t/ha) was recorded in sowing of first fortnight of May with a spacing 50 x

15 cm and NPK dose of 100:60:40 kg/ha. Further experiments for validation of the results are undergoing.

### Collection and evaluation of Perilla

Experimentations with two distinct varieties of perilla (Bold seeded with brownish color and small seed size with whitish color) revealed that the variety with bold seed with brownish color yielded better with late maturity while small seeded with whitish color matured earlier.

### Germplasm evaluation of Ricebean, Buck wheat and Faba bean

Evaluation of germplasms of Rice bean (24 accessions), Buck wheat (30 accessions) and Faba bean (58 accessions) indicated that the accessions of Rice bean (IC-469192, PRR-2 and PRR-1), Buck wheat-IC-13191 (4 t/ha), IC-169728 (3.6 t/ha) and IC-13144 (3.1 t/ha) and Faba bean (HB-11-38 and Vikrant) respectively were more suitable.

### National Mission on Sustaining Himalayan Ecosystem (NMSHE), TF-6

Different land use patterns soils were sampled and analysed in laboratory for their physico-chemical parameters (Table 3) and found *Khasi* mandarin orchard having high pH. However, high organic carbon was found in the forest at 0-15 cm depth of soil. Moreover, 6 field demonstration units (1. *Khasi* mandarin + Banana + French beans + Agro-compost unit, 2. Vegetables (Cucumbers, Tomato, Brinjal, pumpkin, bottle gourds, coriander etc.) + Vermi-compost + Mushroom and 3. *Jhum* paddy + Agro-compost unit + vegetables (Cucumbers, Tomato, Brinjal, pumpkin, bottle gourds, coriander etc.) + fruits (*Khasi* mandarin/Banana) were established in the project site.

Table 3. Physico-chemical parameters of different land use patterns

Land use pattern	pH	EC	OC (%)	N(kg/ha)	P <sub>2</sub> O <sub>5</sub> (kg/ha)	K(kg/ha)
<i>Jhum</i> fallow	4.0	0.80	2.04	238	13	179
Forest	4.2	0.90	2.70	281	21	210
Guava	4.1	1.30	0.55	190	11	157
<i>khasi</i> mandarin	4.5	1.10	0.85	272	14	126
WRC paddy	4.4	1.20	2.09	270	20	196



# MANIPUR

## AGROMETEOROLOGY

During 2015-16, the average maximum and minimum temperature was 26.7° C and 15.5° C, respectively; whereas average relative humidity was 88.4% and 62.9% at 700h and 1300h, respectively. Average wind speed and sunshine was 4.0 km/hr and 5.1 hours, respectively; whereas average cloud cover at 700 h and 1300 h was 3.4 and 3.7 Octa, respectively. The total rainfall during 2015-16 was 1685.0 mm. The maximum and minimum temperatures, morning and evening relative humidity, total rainfall, average sunshine hours received each month from April, 2015 to March, 2016 are graphically plotted below (Fig 1).

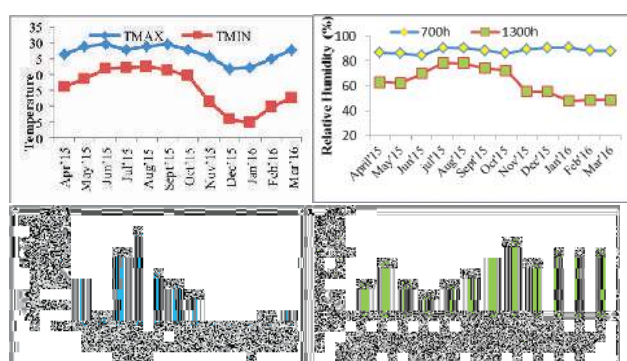


Fig 1. Mean monthly variation of temperature, relative humidity, total rainfall and average sunshine hours

## CEREAL CROPS

### RICE

#### A new rice variety RC Maniphou-13

A new medium duration (125-130 days) rice variety RC Maniphou-13 was released by “State Seed Sub-Committee on Crop Standards, Notification and Release of Varieties, Govt. Of Manipur” in March, 2016. The ceremonial release of the variety was done by Hon’ble Chief Minister of Manipur in the inaugural function of National Seminar on ‘Integrating Agri-Horticultural and Allied research for food and nutritional security in the era of global climate Disruption’ held at Imphal (Fig 2). The variety is a derivative of cross between Leimaphou (KD-2-6-3) × Akhanphou. It is semi-dwarf, fertilizer responsive high yielding variety suitable for main *kharif* season under Manipur conditions. It is photo-insensitive with yield

potential of 7 to 8 t/ha and is tolerant to leaf and neck blast diseases.



Fig 2. Field view of RC Maniphou-13 and its Ceremonial release of RC Maniphou-13 by Hon’ble Chief Minister of Manipur

#### Preliminary station trial of rice

In first year preliminary station trial five advance lines namely, MC-40-10-1-1 (8.37 t/ha), MC-49-4-3-2 (8.04 t/ha), MC-49-4-4-1 (7.87 t/ha), MC-40-10-1-2 (7.77 t/ha), MC-44-2-2-2 (7.71 t/ha) performed at par with the best check, RC Maniphou-10 (7.71 t/ha).

#### Advanced station trial of rice

Four genotypes of Rice MC-45-7-3-17(7.33 t/ha), MC-45-7-2-17 (6.94 t/ha), MC-45-2-2-11 (6.48 t/ha) and MC-45-6-1-14 (6.46 t/ha) were found promising. Based on two years station trial, two genotypes MC-45-2-2-11(RCM-32) and MC-45-7-2-17 (RCM-33) were nominated for AICRIP 2016 under IVT medium duration (hills) trial.

#### Characterization and development of rice plant ideotype for improved yield under upland conditions of Manipur

First year evaluation of 33 families of segregating populations (MC-53 and MC-54 series) and fifteen fixed lines of rice were evaluated for yield related traits and plant vigour under direct seeded condition. Seven segregating families and seven fixed lines (MC-35-26-46, MC-35-60-5-52, MC-37-12-6-5, MC-43-13-1, MC-45-5-10, MC-45-4-4, MC-45-3-2) were found promising and were selected for replicated yield trial for the next *kharif*.

#### DUS testing of farmers varieties of rice from North eastern region

DUS characterization of 99 farmer varieties and 11 reference varieties of Rice of Manipur and other North Eastern states, received from PPV and FRA, New Delhi were carried out at the centre. Two farmers varieties namely *Chahao* (REG/2013/1194), *Chahao amubi* (REG/2012/459) were found to be distinct by 27 morphological characters and these varieties need to be further revalidated for its registration.



## All India Coordinated Rice Improvement Project 2015

Four trials were conducted during *kharif* 2015 namely IVT–Upland hills, AVT-1–Upland Hills, IVT-MH- Irrigated and AVT-1-MH- Irrigated. Under AVT-1, nine entries were tested including checks and entry IET 2305 (CAUR1) showed significantly higher yield (3472 kg/ha) compared to best local check RCM-5(2446 kg/ha).

### 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 390 rice entries constituting NSN-H (77 entries), NHSN (131 entries) and DSN (182 entries) received from IIRR, Hyderabad were screened for leaf and neck blast diseases under modified uniform blast nursery (UBN) and natural disease pressure, respectively. Moderate disease pressure was recorded during the *Kharif* 2015. In NSN-H trial 24 entries exhibited low disease score (0-3) for leaf blast and 30 entries for neck blast. 17 NSN-H entries showed resistance to both leaf and neck blast. In NHSN, 33 entries showed resistant reaction (score of 0-3) for leaf blast and 66 entries for neck blast. 30 NHSN entries showed resistance to both leaf and neck blast. 136 entries in DSN trial exhibited a score of 0-3 for leaf blast disease.

### Evaluation of rice germplasm and breeding populations against leaf and neck blast disease under the DBT sponsored twinning project “Identification and molecular mapping of a novel blast resistance gene(s) from local landraces and introgression lines of *Oryza*”

Nine germplasm lines viz. Meghalaya Lakang (from Meghalaya), Kumta Mah (from Chandel), Kemenya Pepeu (from Nagaland), Wainem (from Senapati), Thekrulaha (from Nagaland), Vishkv (from Nagaland), Phoural Utlou (from Bishnupur), Mesao Tsuk (Nagaland) and Gum Dhan (Nagaland) and ten other germplasm lines (Phoutum Mah, Yungra Makrei, Ching Phouren, Keda, Wonder Rice, Chandel Exhibition, Sapet Maso, Paikho Mah, Rukhatang, Malon Tsok) which had shown resistant reaction in last three years to both leaf and neck blast could be putative sources of leaf and neck blast resistance.

In addition four  $F_2$  populations:  $F_2$  (Akhanphou  $\times$  Leimaphou),  $F_2$  (Akhanphou  $\times$  B95-1),  $F_2$  (Akhanphou  $\times$  CO-39) and  $F_2$  (IL-1  $\times$  BPT) were

screened for leaf and neck blast disease (Fig 3). Out of 80 plants of  $F_2$  (Akhanphou  $\times$  Leimaphou) 35 showed resistant reaction (score 0-3) to leaf blast and 43 to neck blast (score 0-3). In  $F_2$  (Akhanphou  $\times$  B95-1), out of 108 plants, 49 showed resistant reaction to neck blast (score 0-3). 34 plants out of 70 in  $F_2$  (IL-1  $\times$  BPT) were resistant to leaf blast (0-3 score). Out of the 29 plants of  $F_2$  (Akhanphou  $\times$  CO-39), 9 were recorded to exhibit low leaf blast and 16 to neck blast disease (score 0-3).



Fig 3. Reaction of Akhanphou, Leimaphou, Co-39 and BPT to neck blast disease

### Frontline demonstration under NFSM in collaboration with IIRR, Hyderabad

RC Maniphou-9, 10 and 11 was demonstrated in 20 ha area of Imphal west (Khurai, Moidangpok, Nongada and Langol), Imphal east (Kangchup and Terapokpi) and Thoubal districts comprises 21 farmers (Fig 4).



Fig 4. Rice crop demonstrated in farmer's field at Moidangpok village under ICM (integrated crop management) and weeding was performed with Conoweeder)

### AICRP Agronomy Trial

#### Agronomic bio-fortification of rice with zinc and iron

The results revealed that application of FYM (2.5 t/ha) + crop residue (2.5 t/ha) + lime (400 kg/ha) recorded highest rice grain (2.38 t/ha) and straw (3.77 t/ha) yield. The application of organic manures increased available soil organic carbon (0.20% to 0.40%), N (32.16 – 80.22 kg/ha), P (0.7-5.15 kg/ha), K (18.90 - 65.40 kg/ha), Zn (0.03-0.18 g/kg) and Fe (19.47 – 35.86 g/kg). On the other hand foliar spray of micronutrient Zinc (1.5%) and Iron (2%) was found to increase the quality grain production of rice through increases in Zn and Fe content of rice grain which is 40.69% and 45.94 %, respectively.



## AICRP on Soil Test Crop Response (STCR)

### Soil test based fertilizer recommendation for targeted yield of rice in acid soils of Manipur

The targeted yield equations for low land rice and fertiliser recommendations were developed by conducting experiments in the farmers' field during 2014 and 2015. The equation developed for fertilizers requirement is  $FN = 3.19T - 0.18SN$ ,  $FP = 1.48T - 0.89SP$  and  $FK = 2.80T - 0.17SK$ . On an average, we observed 12.5% higher grain yield over the target yield of 5.0 t/ha, with soil test based fertilizer NPK application.

The demonstration in kharif crops were conducted in 24 ha area comprising 54 beneficiaries (Fig 5). Total area of rice demonstration was 11.0 ha in response of crop to liming (furrow application) and fertilizer application (N, P and K at 80, 60 and 40 kg/ha, respectively) was demonstrated in Chandel, Churachandpur and Ukhrul.



Fig 5. Demonstration of soil test based fertilizer application in rice crop for acid soils of Manipur

## MAIZE

### Organic Amendments: An ideal approach to enhance maize productivity and soil quality of acidic soils of North eastern region

Experiment was conducted with seven treatments namely,  $T_0$  (control),  $T_1$  (compost),  $T_2$  (Vermicompost),  $T_3$  (Neem cake),  $T_4$  (Compost + *Azospirillum*),  $T_5$  (Vermicompost + *Azospirillum*) and  $T_6$  (Neem cake + *Azospirillum*) under RBD and replicated thrice. *Azospirillum* ( $10^8$  CFU/ml) used for seed treatment @ 10 ml in 100 ml water for per kg seed. Compost contains N, P and K (1.1, 0.6 and 0.6%); Vermicompost (3.20, 1.65 and 1.55%) and Neem cake (2.80, 0.68 and 1.38%), respectively (~ 60 kg N/ha). Application of Vermicompost + *Azospirillum* significantly ( $P < 0.05$ ) enhanced root and shoot biomass, leaf area development, days to 50% tasseling, days to 50% silking and yield attributes of maize followed by compost. Significantly higher productivity was found in Vermicompost + *Azospirillum* ( $3.43 \pm 0.14$  t/ha) followed by Compost + *Azospirillum* ( $3.2 \pm 0.17$  t/

ha). The minimum grain yield was recorded under control treatment ( $1.73 \pm 0.08$  t/ha).

### Biomass management in cropping systems for enhancing productivity and resource use efficiency under Hill regions of Manipur

The experiment was laid to evaluate the impact of crop residue recycling and crop rotations on resource-use-efficiency, system productivity and profitability and soil quality. The highest Chlorophyll Content Index (CCI) was recorded in maize sole and groundnut sole with sesbania green manuring followed by cowpea and greengram (Fig 6). Under cropping system, maize + groundnut (additive series) (11.23 t/ha) gave significantly higher maize grain equivalent yield over sole groundnut and sole maize, respectively. The soil, nutrient and water loss were maximum under maize sole cropping than sole cropping of groundnut and maize + groundnut intercropping. The residual effect of green manuring enhances the enzymatic activities (Acid phosphatase and Dehydrogenase), MBC and nutrients, C-stock under sesbania followed by cowpea and green gram. The residual effect of green manuring with sesbania gave highest dry pod yield (19.3 t/ha) followed by cowpea green manuring (16.8 t/ha) than control (15.7 t/ha) treatment.

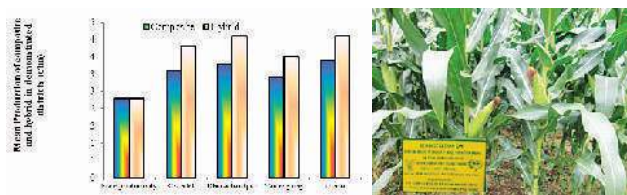


Fig 6. Effect of biomass management and cropping pattern on soil, water and nutrient loss

### Promoting unproved technology of maize production among tribal farmers of Manipur in collaboration with IIMR, New Delhi

Maize production technology has been demonstrated in four districts viz., Churachandpur (eight villages), Chandel (six villages), Tamenglong (two villages) and Ukhrul (five villages) district of Manipur which have been chosen as the target area under the project "Promoting improved technology of maize production among the tribal farmers of Manipur" (Fig 7).



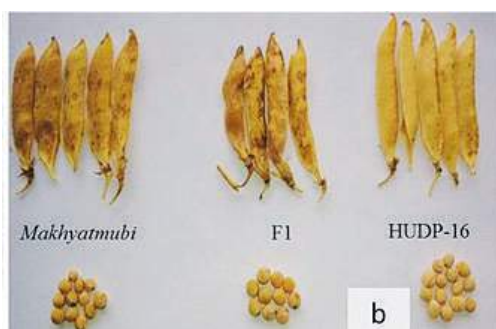


**Fig 7. State productivity and production from improved technology and demonstrated hybrid in Chandel**

## PULSES

**Evaluation and development of high yielding cultivars of field pea (*Pisum sativum* L. spp. *arvense*) with combined resistance to powdery mildew and rust suitable for Manipur**

In order to incorporate powdery mildew resistance in *Makhyatmubi*, a popular pea cultivar of Manipur, crosses (Fig 8) were attempted between (*Makhyatmubi* × HUDP-16) and its reciprocal cross (HUDP-16 × *Makhyatmubi*).



**Fig 8. Successful F<sub>1</sub> pods & seeds of Cross *Makhyatmubi* × HUDP-16**

**Enhancing lentil production in eastern and north-eastern states for nutritional security and sustainable rice-based production system in India” under DAC-ICARDA-ICAR, collaborative project on NFSM-pulses**

Lentil crop was demonstrated during 2015-16 in 60 ha area comprising 62 farmers at Thoubal, Imphal West and Imphal East districts (Fig 9). Technology diffused among farmers from 89 (2013-14) to 1205 (2015-16) and area extend from 60 to 735 ha. The highest mean grain yield of lentil was recorded, when it was sown during 1<sup>st</sup> -5<sup>th</sup> November (CS I) (682.5 kg/ha) followed by 15<sup>th</sup> -20<sup>th</sup> November (CS II) (651.8 kg/ha), which were significantly higher than 1<sup>st</sup> -5<sup>th</sup> December (CS III) (525.6 kg/ha). In another hand, the mean maximum grain yield was recorded under reduced tillage (RT) 715.5 kg/ha followed by zero



**Fig 9. Lentil crop was demonstrated and technology diffusion among farmers**

tillage (ZT) (639.8 kg/ha) and minimum yield was recorded with conventional tillage (CT) (504.7 kg/ha) with mean net returns by Rs. 27708 than ZR (Rs 24999) and CT (Rs 9777), respectively. The higher WUE was also found under the same treatment.

## POTENTIAL CROPS

### AICRP on potential crop

#### Local genotype screening trial on Perilla

In first year preliminary station trial, five lines namely RC Thoiding 14 (3.66 t/ha), RC Thoiding 6 (3.37 t/ha), RC Thoiding 21 (2.76 t/ha), RC Thoiding 3 (2.58 t/ha) and RC Thoiding 10 (2.38 t/ha) were found promising.

#### Local genotype screening trial on ricebean

In first year preliminary station trial, five lines namely RC Chak hawaii -24 (4.2 t/ha), RC Chak hawaii -10 (3.35 t/ha), RC Chak hawaii -33 (3.0 t/ha), RC Chak hawaii -32 (2.95 t/ha) and RC Chak hawaii -26 (2.73 t/ha) were found promising.

#### Screening trial on ricebean

Among the 24 genotypes for initial screening including 4 checks received from NBPGR Regional station Shimla, EC16136 gave maximum yield (1.16 t/ha) as compared to better performing check RBL-1 (1.11 t/ha).

#### Initial varietal trial on ricebean

Among the 2 genotypes for IVT including 1 checks VRB-3 received from NBPGR Regional station Shimla, VRB-3 check gave maximum yield (1.76 t/ha) as compared to other 2 genotype RBHP 117 (1.3 t/ha) and IC108858 (1.06 t/ha).

#### IVT and AVT trial on ricebean

Among 2 genotype for IVT and 3 genotype for AVT, RBHP-121 (IVT) gave maximum yield (2.2 t/ha) as compared to other genotype. In AVT, RBHP-109 gave maximum yield (2.47 t/ha) as compared to other.



### Germplasm screening on ricebean

Among 10 genotypes, RBHP-307 gave maximum yield (1.98 t/ha) as compared to other genotypes.

### Local genotype screening trial on broadbean

After collection of 31 local genotypes of Broad bean (Hawai Amubi) across the Manipur, first year preliminary screening trial conducted and evaluated for yield attributes, yield and quality in randomized block design (RBD) with three replications at Lamphelpat research farm. Five lines namely RC Hawai Amubi-16 (3.44 t/ha), RC Hawai Amubi-24 (3.21 t/ha), RC Hawai Amubi-30 (2.86 t/ha), RC Hawai Amubi-22 (2.73 t/ha) and RC Hawai Amubi-25 (2.71 t/ha).

### Germplasm evaluation of broadbean

Among the 52 genotypes for initial screening including 2 checks Vikrant and PRT-12 received from AICRP on Potential Crops, Pusa New Delhi, IC329612 gave maximum yield (0.79 t/ha) as compared to better performing check Vikrant (0.78 t/ha) and PRT-12 (0.41 t/ha), respectively.

### Initial varietal trial of broadbean

Among 6 genotypes along with one Check (Vikrant), HB-11-12 gave maximum yield (0.11 t/ha) as compared to check (0.8 t/ha).

### Advanced varietal trial on broadbean

In advanced varietal trial, HB-69 gave yield (0.22 t/ha) as compared to check (0.79 t/ha).

### Nutrient management in maize + ricebean (2: 4) intercropping

Nutrient management experiment was conducted with seven treatments including with control under RBD and replicated thrice. 75% RDF (80-60-60 kg NPK/ha) + 25% RDF (20-40-40 kg NPK/ha) has recorded maximum maize equivalent yield 8.16 t/ha as compared to other treatments (Fig 10).



**Fig 10. Nutrient management in maize + rice bean (2: 4) intercropping**

### Nutritional characterization and antioxidant capacity in different tissues of underutilized potential crops *Allium* species and *Neptunia oleracea*

Nutrient partitioning and nutraceutical properties in stem, shoot and root of potential crops (*Allium adorosum*, *Allium hookeri* and *Neptunia oleracea*) have been determined (Fig 11). The micronutrients of *Allium* species including Fe, Zn, Mn, and Cu were found to be in the range, 17.1- 218.2, 7.2-33.35, 0.75-16.2 2.35-28.85 and 6.3-12.35 mg/g respectively and also micronutrient of *Neptunia oleracea* were Fe (617-1678.45 ppm), Zn (20.05-31.3 ppm), Mn (123.05-675.8 ppm), and Cu (5.75-14.05 ppm, respectively. The results of macronutrients obtained having values of Ca (21.5- 2010.5 ppm), Mg (2.5-156.4 ppm), K (895.0-22375 ppm), Na (0.42- 631 ppm), and P (1205.5-3435.1 ppm), respectively. The quantity of Pb was found in negligible amount in the *Allium* species but was found in traces in *Neptunia*.



**Fig 11. *Allium adorosum* (Nakuppi) cultivation and edible parts; *Allium hookeri* (Napakpi) cultivation and edible parts; *Neptunia oleracea* (Mimosa) cultivation and edible parts**

### SOIL HEALTH CARD

On the 5<sup>th</sup> December 2015, World Soil Day was organized by all the five KVKs under ICAR, Manipur Centre (Fig 12). For this, a total number of 1250 soil samples from five districts (250 samples per district), viz., Imphal West, Tamenglong, Churachandpur, Chandel and Ukhrul were analyzed at the Soil Science Laboratory of ICAR, Manipur Centre. Thirteen soil chemical parameters, viz., soil pH, electrical conductivity, organic carbon, N, P, K, S, Ca, Fe, Mn, Cu, Zn and B, were considered for the issue of Soil Health Card. In the card, the details of the farmer and fertilizer recommendations were made for rice and maize based on the soil analysis report (Fig 13). The farmers from these five districts were trained for the



procedure of soil collection from their fields. It is targeted to distribute 1000 Soil Health Cards for every district during the financial year 2016-17.



**Fig 12. Distribution of Soil Card by Hon'ble MP Dr. T. Meinya Chandel**

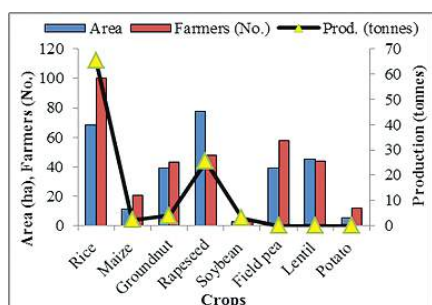


**Fig 13. A picture of soil health card ready for distribution**

## SEED TECHNOLOGY

### Participatory development of quality seed production practices for seed village concept

To find the feasibility of quality seed production through farmers participatory approach, a study was carried out in major crops in different districts of Manipur involving KVKs (Fig 14). 85.60% of the farmers could successfully meet the seed certification standards in rice and 84.50% in rapeseed. Formation of farmers' groups based on compactness of plots was effective in quality seed production. Financial benefit of seed production over crop production ranged from Rs. 40,000 to Rs. 54,000/ha.



**Fig 14. Seed production of different crops (2015-16)**

### Maintenance breeding of released varieties

Studies on maintenance breeding of released crop varieties are being undertaken to check the varietal degeneration. Quality seed production of some locally recommended varieties are also done to maintain the purity level. As there was severe flooding during kharif re-sowing was also taken up. Altogether 4.11 tonne pure seeds including 3.83 tonne breeder seed of rice, maize, groundnut, soybean and rapeseed were produced (Fig 15a to 15c).



**Fig 15(a). Ground nut Seed Production plots**



**Fig 15(b). Rice Seed Production**



**Fig 15(c). Cleaned and packed seeds at ICAR Manipur centre**

## NATIONAL SEED PROJECT

### Encrustation enabled direct seeding technology of rape seed (TS 44):

Under this experiment, four treatments were taken up viz.,  $T_0$  Control (no treatment),  $T_1$  (Encrusted 1:1:2 Build-up with Thiram),  $T_2$  (Encrusted 1:1:2 Build-up with Thiram and Mycorrhiza) and  $T_3$  (Encrusted 1:1:2 Build up with Thiram and Genius coat TM) among these only  $T_0$  Control (no treatment) were found to be viable and the other treatments were not viable.

## JHUM IMPROVEMENT

### Productivity enhancement through resource conservation technology (RCT) in *jhum* lands:

The different target crops in these experiments were, Maize, Rice, Groundnut and soybean. Among all the treatments, the use of bio-prime seed along with application of Vermicompost (1 t/ha) recorded 48, 55, 29.3 and 66% higher yield of maize, rice, groundnut and soybean over the control. However, the highest cost benefit ratio was recorded in the cultivation of groundnut.

### *Jhum* improvement for food security of tribal farmers through Sustainable Agriculture:

Project baseline survey has been done on socio, economical and agriculture activities of 120 farmers in four districts viz., Chandel (Lambung village), Churachandpur (Henkot Village), Ukhrul (Ramva



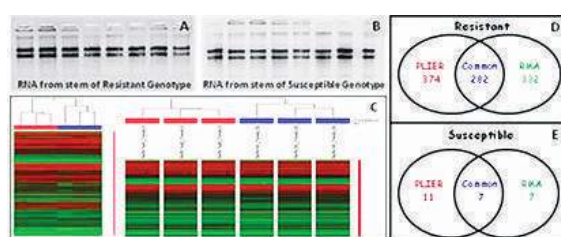
Village) and Tamenglong (Sepa village). The improved varieties of Crops i.e. maize, paddy, soybean, groundnut, vegetables, colocasia, ginger, turmeric, banana, tree beans, orange, piggery, backyard poultry, fishery Critical inputs like manures and biofertilizers and other soil water conservation practices were adopted at farmer's field in cluster. The experiments reveal that the improved varieties with crop management practices gave 40-60% higher yield for maize, rice, soybean and groundnut.

## HORTICULTURAL CROPS

### VEGETABLE AND TUBER CROPS

#### Transcriptional profiling of resistant and susceptible genotypes of Tomato against *Ralstonia solanacearum*

Transcriptional gene expression profiles of resistant and susceptible genotypes of tomato with *Ralstonia solanacearum* or water as a control mock at 5 dpi with three biological replicates were analyzed using Affymetrix Tomato Genome Array Gene Chip representing over 9,200 tomato genes. By using PLIER, about 374 genes were found to be differentially expressed in resistant genotypes whereas, 332 were observed between both PLIER and RMA, out of which 114 were up regulated and 168 were down regulated. In a similar way about 11 genes were reported to be differentially expressed in susceptible genotype through PLIER and 7 through RMA; out of which 5 were up regulated and 2 were down regulated (Fig 16).



**Fig 16. Transcriptional profiling of resistant and susceptible tomato genotypes against *R***

#### Detection of reactive oxygen species (ROS): A rapid and efficient tool to screen for host resistance against invading pathogens:

A quick, robust and efficient method of screening for resistance based on production of ROS by *in situ* DAB (3, 3 diaminobenzidine) staining in Tomato-*Ralstonia* and *Colocasia-Phytophthora* pathosystem were developed. The rapid ROS accumulation at the

site of pathogen attack is accompanied with accumulation of  $H_2O_2$ , which can be localized in plant tissues by DAB producing a brown stain. Infiltration of tomato leaves with saturated cultures of *R. solanacearum* ( $OD_{600}=1.0$ ) resulted in higher ROS production in susceptible genotypes as compared to the resistant. In *Colocasia-Phytophthora* interactions, inoculation of taro leaves with spore suspension of *Phytophthora colocasiae* (15000 spores  $ml^{-1}$ ) resulted in lower ROS production in resistant genotypes as compared to susceptible ones. The elevated levels of  $H_2O_2$  content and increased malondialdehyde (MDA content), marker of lipid peroxidation, showed positive correlation with DAB results. This is a robust technique for early detection of resistance mechanism which could be used to screen a wide genetic base against a plethora of pathogens at a shorter span.

#### Evaluation of chinese potato (*Solenostemon rotundifolius*) under polyethylene glycol mediated osmotic Stress

Five genotypes of Chinese potato were grown under *in vitro* conditions in MS containing PEG-6000 (0, -0.2 MPa and -0.5 MPa) and subsequently evaluated under hydroponics containing Hoagland solution incorporated with PEG-6000 which would help to generate information on drought tolerance of Chinese potato at whole plant level. A significant variation in growth response was observed in all the studied genotypes. The adverse effect of induced osmotic stress was prominent in susceptible genotypes as compared to the tolerant ones. Based on the variations in the morpho-physio-biochemicals properties under PEG mediated stress, the pattern of moisture stress tolerance in the Chinese potato genotypes was Sreedhara>Subala>TVM>Co-1>Nidhi. The genotype Sreedhara may be recommended for low moisture regime conditions.

#### Standardization of *in vitro* and *in vivo* Seed Germination of True Taro Seeds (TTS)

True Taro Seeds (TTS) were collected from 21 genotypes of taro including 5 hybrids. Out of the media combinations tested for seed germination, the per cent germination was recorded higher (88.5 to 98.5%) at  $MS+GA_3$  (0.5 mg/l) across the genotypes. The seedlings at 2 leaves stage were subcultured in the same medium after 3 weeks of inoculation. After 4 weeks of subculture, the plantlets were hardened off in soil + vermicompost + vermiculite (1:1:1) in the poly house at  $25\pm 1^\circ C$  which can be transferred to the main field



after 1-2 weeks. Under *in vivo* conditions, the seeds were treated with *Trichoderma viridae* @ 20g/kg seeds and soaked in sterile water for 2 hours. The treated seeds were sown in soil + vermicompost (1:1) and watered with Hoagland solutions. Per cent germination *in vivo* was recorded to be lower (58-65%) as compared to *in vitro*.

## FRUIT AND PLANTATION CROPS

### Standardization of *in vitro* regeneration protocol for tree bean and kachai lemon

An attempt has been made to establish an efficient *in vitro* regeneration protocol in tree bean (*Parkia roxburgii*) and Kachai lemon (*Citrus jambhiri*) to raise disease free elite planting materials (Fig 17). Direct regeneration was achieved from nodal explants and shoot tip cultures in MS media supplemented with various doses of benzyl adenedine (BA) and kinetin (Kn). Multiple shoot regeneration was achieved when subculture to MS with GA<sub>3</sub>. The shootlets were subcultured at regular intervals of 2 weeks to minimise phenol accumulation in the media. Root initiation experiments are in progress for these 8 weeks grown shootlets. Callus cultures have been initiated in MS medium containing different concentrations of 2,4-D (1-3 mg/l) from different parts of *in vitro* raised seedlings.



Fig 17. *In vitro* regeneration of Tree bean and Kachai lemon

### Molecular characterization of a new *Potyvirus* associated with Yellow Mottle Disease of passion fruit in north east India and development of efficient immunodiagnosics

In a survey of passion fruit plants of different varieties (Yellow passion fruit, Kaveri hybrid and Brazilian golden) symptoms of yellow mottling, puckering, severe leaf deformation was observed on leaves of infected vines. Four isolates PFPV-1 (Yellow passion fruit), PFPV-2 (Kaveri hybrid), PFPV-3

(Brazilian golden) and PFPV-4 (Brazilian golden) were characterized at molecular level based on the sequences of coat protein (CP) of *Potyvirus* genome. These isolates had a sequence identity of 98-99% among them for nucleotide sequences of CP. Passion fruit *Potyvirus* isolates shared an identity of 63-72% with other potyviruses infecting passion fruit in different parts of world. Phylogenetically all the isolates were placed in *Bean common mosaic virus* (BCMV) cluster, although genetically distinct from already reported potyviruses. Anti Pep-III, identified *in silico* in the coat protein region of this newly identified *Potyvirus* was successfully used for ACP-ELISA based detection of passion fruit field samples collected from Manipur and Meghalaya. This is the first report of association of a new *Potyvirus* infecting passion fruit in North East India and development of efficient immunodiagnosics (Fig 18).

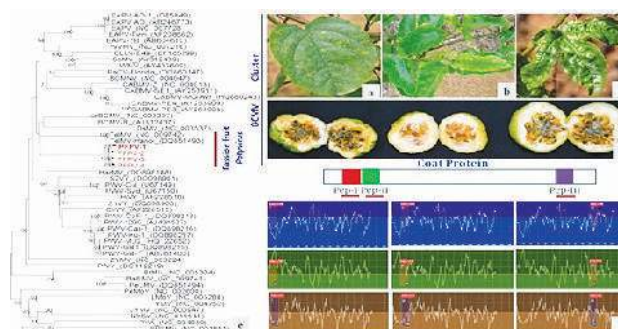


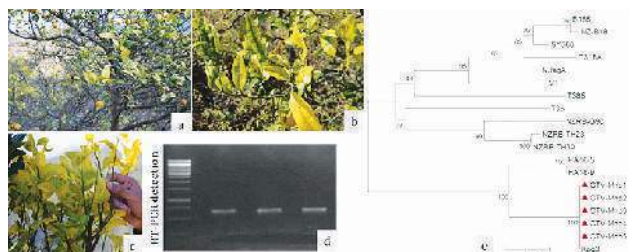
Fig 18 Symptoms of viral infection on Brazilian golden (a), yellow passion fruit (b) and Kaveri hybrid (c); dappled and mummified fruits due to viral infection (d); phylogenetic relationship (e) and immunodominant epitopes in CP region of viral genome (f)

### Prevalence and genetic diversity of *Citrus tristeza virus*: development of robust diagnostics for routine indexing:

Extensive surveys were conducted in different citrus growing groves of Manipur (Churachandpur, Chandel, Tamenglong, Ukhrul and Imphal West) to identify the prevalence and distribution of CTV on citrus species like mandarin, oranges, mosambi, *Citrus macroptera* and Kachai lemon. Out of total 480 samples tested using double antibody sandwich-ELISA (DAS-ELISA) and reverse transcription-PCR (RT-PCR), 72% samples were tested positive for CTV. Five CTV isolates from Manipur (CTV-Mnp1, Mnp2, Mnp3, Mnp4 and Mnp5) had 82-91% identity among them and 88-98% with other Indian CTV isolate Kpg3 for nucleotide sequences of CP and were placed in Kpg3 phylogenetic cluster. A high prevalence of brown



citrus aphids (*Toxoptera citricida*) in different citrus groves surveyed indicated the risk of spread of viral inoculum to new citrus plantations and new areas (Fig 19).



**Fig 19. *Citrus tristeza virus* (CTV) infected citrus plant (a); mixed infection of CTV and huanglongbing (b-c); detection of CTV by RT-PCR (d) and phylogenetic analysis of CTV isolates from Manipur (Mnp1-5) (e)**

#### Record of almond moth, *Cadra cautella* on tree bean

In autumn of 2014 and 2015, scrapping on the surface of newly formed pods of tree bean was observed associated with numerous immature pod drops with typical blackish scrapping on the pods. A small greyish caterpillar with brown head was found feeding on the immature seeds of the green pods. The early instars of this caterpillar feed by scrapping on the surface of pods. The later instars then mine into the immature seeds and feed on them (Fig 20).



**Fig 20. Scrappings on surface of pods; caterpillar feeding on developing seeds; holes, larval frass and webbings made on pod heads by caterpillar**

The larva pupates inside the galleries made in the pod head. The adult that emerges is dirty grey in colour with dark spots on the wings. Adult emergence confirmed that the insect was the almond moth, *Cadra cautella*. This study for the first time reports the field infestation of the pest as a cause of immature fruit drop in tree bean field with conclusive evidence.

## SPICES

### Improvement programme on turmeric

A set of 28 turmeric clones of  $F_7$  generation including Megha Turmeric-1 as check was evaluated under rainfed terraced condition for development of suitable varieties. Maximum yield (37.25 t/ha) was recorded with RCMT-19, followed by RCMT-6 (34.50 t/ha) as compared to 24.60 t/ha yield with Megha Turmeric-1.

### Improvement programme on ginger

For development of high yielding variety of ginger for foothill condition of Manipur, 15 ginger clones of  $F_6$  generation was evaluated under rainfed terraced condition including Nadia as check variety. Among the different clones, maximum yield of 19.75 t/ha was recorded for RCMG-1.

### Physico-chemical analysis of shirarakhong chilli of Manipur

Physico-chemical analysis of Shirarakhong chilli, revealed high (164 ASTA) extractable colour value. This chilli can be commercially utilized for production of edible natural colour. The pericarp and placenta contains 74.86 mg QE/g total flavonoids, 148.14 mg GAE/4 total phenolics and 4.32 mg/g total carotenoids; whereas the total flavonoids, phenolics and carotenoids content in seed are 62.18 mg QE/g, 57.17 mg GAE/g and 0.068 mg/g, respectively. The chilli has been found to be a good source of ascorbic acid (200 mg/100 g); however capsaicin content was found to be low (0.14%). The weight of individual fruits varies from 3.70 to 7.0 g; whereas, average length and breadth varies between 126.00 -177.80 mm and 9.00 - 13.50 mm, respectively. Shirarakhong chilli was also found to be good source of nutrients (Table 1).

**Table 1. Nutrient content of shirarakhong chilli**

Nutrient	Value
Nitrogen	1.98%
Phosphorus	10.82 mg/kg
Potassium	2525.00 mg/kg
Magnesium	296.30 mg/kg
Calcium	465.25 mg/kg
Zinc	16.73 mg/kg
Copper	11.43 mg/kg
Iron	2.20 mg/kg
Manganese	16.65 mg/kg



## MEDICINAL PLANTS

### High antioxidant potential revealed in indigenous medicinal plants of Manipur

A total of 17 medicinal plants were evaluated for their antioxidant potential using MTT antioxidant assay. The plant material was extracted using various solvents namely distilled water, ethanol and chloroform and all total 43 extracts were obtained for performing MTT antioxidant assay with L-Ascorbic acid as control. Of these 23 extracts have shown more than 90% antioxidant potential (Fig 21a and b), 10 extracts have shown 70-90% antioxidant potential and 10 extracts below 70% antioxidant potential. Aqueous extracts of three plants namely *Arisaema tortuosum*, *Paris polyphylla* and *Rhus semilata* have shown better activity compared to L-Ascorbic acid

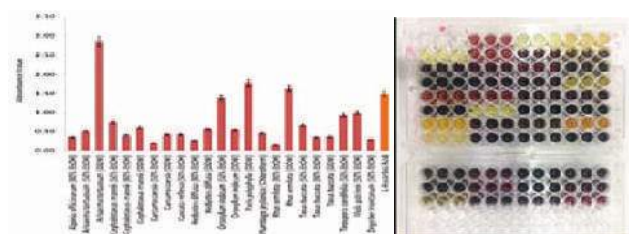


Fig 21(a). Antioxidant Potential of Most Promising 23 Plant Extracts; (b): MTT Assay Plates of Plant Extracts

### Antioxidant activity and micronutrient profiling of wild edible plants collected from Loktak Lake scosystem of Manipur:

Ten wild edible vegetables viz. Indian pennywort (*Centella asiatica* (L) Urban), Lamb's Quarters (*Chenopodium album* L.), Hemlock Water Dropwort (*Oenanthe crocata*), Cudweeds (*Gnaphalium indicum* L.), Ginger lily (*Hedychium flavum* Roxb.), Water spinach or Swamp cabbage (*Ipomoea aquatica* Forssk.), Chinese plantain (*Plantago asiatica* L.), Knot grass (*Polygonum barbatum* L.), Parsley (*Portulaca oleracea* L.) and Black nightshade (*Solanum nigrum* L.) were collected from Loktak lake ecosystem (4.5500° N, 93.7833° E, 768 m amsl) and evaluated for their antioxidant potential, total phenolic and total flavonoids. Antioxidant activity of these plant samples ranged from 47.56 to 167.49  $\mu$ M TE/g (FW). Highest antioxidant activity was shown by Cutweeds (167.49 $\mu$ M TE/g), followed by Knot grass (152.3 $\mu$ M TE/g). Total phenolic was ranged from 2.13 to 10.18 mg GAE/g (FW). Maximum phenolic content found in Knot grass (10.71 mg GAE/g (FW)); followed by Cudweeds (10.18 mg GAE/g (FW)); whereas, total

flavonoids was ranged from 5.08 to 55.94 mg QE/g (FW). Maximum flavonoids content was found in Cudweeds (55.94 QE/g (FW)); followed by Knot grass (46.71mgQE/g (FW)). Micronutrient profiling of the collected wild edible plants was also accomplished. The Fe, Zn, Cu and Mn content vary in the range of 2.4-67.5  $\mu$ g/g, 1.8-14.9  $\mu$ g/g, 2.6-4.6  $\mu$ g/g and 3.15-107.0  $\mu$ g/g, respectively. Cutweeds (*Gnaphalium indicum* L.) is rich in Fe (67.5  $\mu$ g/g) and Cu (4.6  $\mu$ g/g); whereas maximum Zn content (14.9  $\mu$ g/g) was found in Parsely (*Portulaca oleracea* L.). Maximum Mn content (107.0  $\mu$ g/g) was associated with Indian pennywort (*Centella asiatica* (L) Urban). Among the studied plants, Cudweeds (*Gnaphalium indicum* L.) and Knot grass (*Polygonum barbatum* L.) were found to be most promising.

### Demonstration of Kiwifruit under Tribal Sub-Plan

Under Tribal Sub-plan, during 2015-16, all total 5000 numbers quality planting material, procured from Arunachal Pradesh has been distributed to the farmers in Ukhrul and Senapati district.

An approximate area of 10 hectares has been covered under the demonstration programme. The planting materials distributed during previous years have already started bearing fruits and farmers started earning good profit from their plantation (Fig 22a-b).



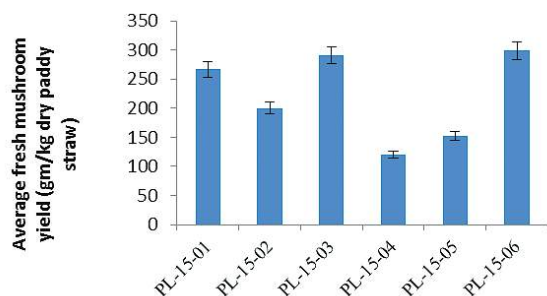
Fig 22 (a): Kiwifruit Plantation Developed under Tribal Sub Plan at Shokvao Village, Ukhrul, Manipur; (b) Bearing Kiwifruit Plants at Purul Akutpa Village, Senapati, Manipur

## SECONDARY HORTICULTURE

### MUSHROOM

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 shitake (*Lentinus edodes*) were produced and supplied to different stakeholders. 10 training programmes (335 participants) on scientific mushroom spawn production and cultivation technology were organized for farmers, farm women, women shelf help groups, entrepreneurs etc. Under AICRP-Mushroom, six oyster mushroom strains were evaluated during winter 2015-16. Strains PL-15-01, 03 and 06 were found to be superior.





**Fig 23. Average fresh mushroom yield (gm/kg dry paddy straw) of different strains (1<sup>st</sup> harvest)**

#### Incubation centre for value addition of tuber crops

A Launching Workshop-cum-Training Programme on “Incubation Centre for Value Addition of Tuber Crops” at Riha and Thoyee villages of Ukhrul district under ICAR-CTCRI-NEH programme and special funds for tuber crops, respectively was organized (Fig 24). Two numbers of village level incubation centres for tuber crops were established with advanced tuber crops machines such as cassava starch extractor, cassava chipping machine, dough making machine, cassava flour mill, weighing, packaging and sealing machines etc. The concept of a Village-level incubation Centre to the NEH region will bring sustainable increase of agricultural household income. About 100 progressive farmers/ SHG members/ prospective entrepreneurs from Riha and Thoyee villages were trained in the tuber crops snack food production.



**Fig 24. Establishment of incubation centre for tuber Crops**

#### Development of value added products from underutilized fruits and vegetables

About 30 different value added products from different underutilized fruits and vegetables indigenous to this region were developed under DBT twinning project in collaboration with PJTSAU, Hyderabad (Fig 25). The major products such as, bay leaf tea powder,

biryani spice cubes, sprinkle masala, fish masala, king chilli sauce, tree bean pickles, king chilli pickles, king chilli and kachai lemon chocolates were assessed by the sensory descriptors following 9 point Hedonic scale for acceptance of colour, flavor, texture, taste and overall acceptability. The nutritional properties of the processed products were analyzed. The products with high Hedonic score are to be popularized through small scale entrepreneurs.



**Fig 25. Value added products from underutilized fruits and vegetables**

#### *In situ* conservation of Shirui Lily plantlets at Shiroy Peak

An Awareness Campaign-cum-Plantation Programme of Shirui Lily- An Endangered Heritage Flower of Manipur was organized under DST WOS-B programme in collaboration with KVK, Ukhrul and the Shirui Village Authority at Shirui, Ukhrul on 10<sup>th</sup> April, 2015. The photo exhibition-cum-live exhibits of *in vitro* regenerated plantlets, bulbs and bulblets, seeds, growing media, acclimatization and hardening medium of Shirui lily was displayed in programme. All the dignitaries and participants took part in the signature campaign of “Conservation of Rare Endangered Shirui Lily” (Fig 26). About 200 plantlets of Shirui lily out of the 500 plantlets raised through tissue culture techniques at ICAR have been planted in the Shiroy hill peak at about 2750 meters above the mean sea level. These initiatives for *in vitro* regeneration, *in situ* and *ex-situ* conservation of Shirui lily will be helpful to save this beautiful endangered species and also to prevent the perceived loss of lily biodiversity in the Shiroy hill range.



**Fig 26. From Lab to Land: Awareness campaign-cum-plantation programme of Shirui Lily organised by ICAR**



### Anti-fungal Activity Discovered in Native Actinomycetes isolated from rhizospheric soil of tomato:

All total 11 actinomycetes strains were isolated from rhizospheric soil of tomato from Mayang Imphal area of Manipur using starch casein nitrate agar (SCNA) medium. All the isolates were screened for antagonistic activity against three major fungal phytopathogens viz. of *Fusarium oxysporum*, *Rhizoctonia solani* and *Pyricularia oryzae*. Among the 11 actinomycetes isolates, 7 isolates have shown antagonistic activity against *Fusarium oxysporum*, 7 isolates against *Pyricularia oryzae* and 6 isolates against *Rhizoctonia solani*. Isolates RCM-SSR-5, RCM-SSR-9 and RCM-SSR-11 have shown more than 50% colony growth inhibition against the three fungal pathogens (Fig 27). The present experiments have shown good promises for development of novel biocontrol agents from the native actinomycetes strains.



**Fig 27. Colony Growth Inhibition of Fungal Pathogen by Native Actinomycetes Strains**

### Novel organic fertilizer produced from chicken feather using native microbes: the first report on keratinolytic bacteria from North East India

Feathers are the major waste by-product of poultry and accumulation of huge volume of feathers which is recalcitrant in nature, leads to environmental pollution. The feather contains over 90% (w/w) keratins which is a good source of nitrogen. With this background, 11 actinomycetes strains and 27 bacterial strains were isolated from different parts of North East and screened for keratinolytic activity using chicken feather as sole carbon and nitrogen source. Of these, 7 actinomycetes isolates and 9 bacterial isolates were able to degrade the chicken feather within 7 days of incubation at 30°C, 160 rpm. The actinomycetes strain RCM-SSR-2 and -6 have completely degraded the feather within 72 hrs of incubation. Among the bacterial strains, RCM-SSR-7 has shown outstanding performance in terms of time taken for feather degradation (within 24 hours), followed by RCM-SSR-14 (within 48 hours), -17, -43, -45 and -54 (within 72 hours). On an average, the organic fertilizer produced through feather hydrolization contains 12% nitrogen, 0.04% phosphorus and 0.45% potassium (Fig 28a & b).



**Fig 28 (a). Keratinolytic actinomycetes and bacteria; (b) Organic Fertilizer Produced by Hydrolyzing Chicken Feather using Native Microbes**

## ANIMAL SCIENCE

### VETERINARY PUBLIC HEALTH

#### Multiple locus variable number of tandem repeats (MLVA) and genotyping of multidrug resistant *Salmonella typhimurium*:

*Salmonella typhimurium* isolates (n=80) from diverse sources were characterized with MLVA, ERIC-PCR, REP-PCR, BOXA1R-PCR, (GTG)<sub>5</sub>-PCR and RAPD-PCR to explore the usefulness of these genotyping techniques in analyzing field isolates of *S. typhimurium*. Genotyping by MLVA identified a total of 46 distinct MLVA types (assigned as MLVA01 to MLVA46), whereby MLVA33 was the most common type shown by eight *typhimurium* isolates. MLVA typing of STTR5 locus yielded highest allelic diversity (0.920), followed by STTR9 locus (0.803), STTR10pl (0.702), STTR3 (0.722) and lowest diversity was observed in STTR6 locus (0.601). Index of association for *S. typhimurium* was 0.189. All the five loci showed allelic diversity in all the isolates typed. For comparative evaluation, all the *S. typhimurium* isolates were also subjected to repetitive sequence based PCR (ERIC and REP) and GTG<sub>5</sub> PCR. Fingerprinting with ERIC, REP and (GTG)<sub>5</sub>-PCR generated distinct amplification bands ranging from 11-13, 10-15 and 6-8, respectively. All the *S. typhimurium* isolates showed a 100 % typeability with the genotyping techniques. Cluster analysis revealed that, 58 types (E1 to E58) were observed for ERIC-PCR, 60 types (R1 to R60) were observed for REP-PCR, 15 types (G1 to G15) were observed for (GTG)<sub>5</sub>-PCR. Simpson's index of diversity (D-value) of MLVA was the highest (0.9911) followed by REP-PCR (0.982), ERIC-PCR (0.9829), and (GTG)<sub>5</sub>-PCR (0.8426).

## POULTRY SCIENCE

#### Poultry Seed Project (PSP):

Under the project, total chicks of 9860 (Vanaraja 9860 nos.) germplasm in the form of DOC chicks was supplied and benefitted to 93 individuals, 24 numbers



of families and 6 villages during 2015-16. Besides, three training programmes were also organized. Two trainings were conducted at ICAR Manipur centre, Imphal and one training at Tera, Imphal west. Total of 89 participants have been trained on different aspects of poultry production and they were benefitted from the trainings (Fig 29).



**Fig 29. Vanaraja poultry unit established at farmer's field and training programme under TSP**

## FISHERY SCIENCE

### Development of breeding and rearing techniques for small indigenous fishes for short cycle aquaculture

Study of *Schistura khugae* fish was taken up in view with having both food and ornamental value particularly in hilly areas (Fig 30a-c). Breeding experiments were carried out by using Wova-FH in captivity. A series of utility tray of (360×310×130) mm with a water depth of 8 cm. The breeding trays were maintained with the following parameters-temp,  $26\pm2.0^{\circ}\text{C}$ ; pH,  $7.5\pm0.2$ ; dissolved oxygen,  $5.5\pm2.0$  ppm. The male fish weighing 4.0 g and female being 2.5 g have been selected for the study. Breeding is done in the evening 4 pm in 2:1 ratio, two males and one female. Wova-FH was injected intramuscularly on the dorsal muscles above the lateral line near the dorsal fin. Four sets of brood stocks were selected at the ratio of 1:2 (female: male). Four different doses of

Wova-FH i.e 0.6 ml, 0.7 ml, 0.75 ml and 0.8 ml/kg body weight were given to each sets. After the injection, the breeding sets were released in four utility trays. The fertilized eggs were hatched on the third day after spawning. The spawn feeds on the yolk upto fourth day after hatching. From the fifth day, the fries



**Fig 30a. Matured Male *Schistura khugae***

**Fig 30b. Matured female *S. Khugae***



**Fig 30c. Ovary of *S. khugae***

were fed with egg yolk for continuous ten days. Later, live feeds (*Daphnia*, *Cyclops*) are given.

### Evaluation on growth, reproductive competent and captive breeding of cyprinid fish, *Tor* species and a silurid fish, *Ompok bumaculatus* in Manipur

214 samples of *Tor putitora* were collected (Fig 31a to c) and 64 fishes were maintained in earthen pond at ICAR Manipur Centre and 150 were maintained at farmers' pond at Nungba, Tamenglong district, Manipur. Gut content analysis reveals that the fish feeds on a wide variety of food of plant and animal origin such as green filamentous algae, insect larvae, small mollusks, and algal coatings on rocks etc.



**Fig 31a. *T. putitora* from Ukhrul**



**Fig 31b. *Tor* spp. from Barak river**



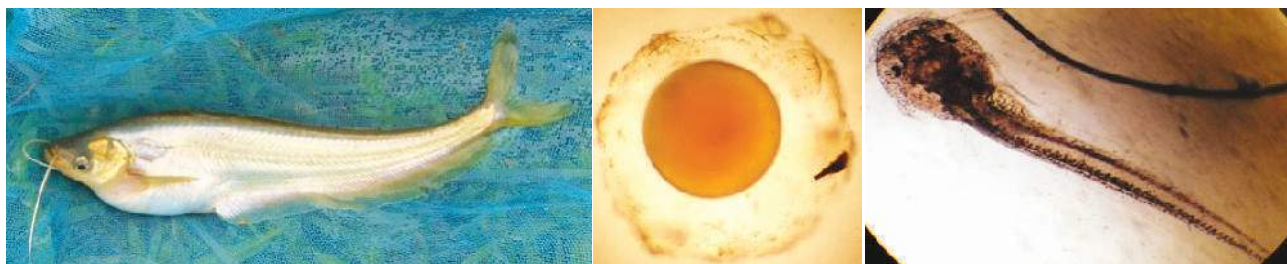
**Fig 31c. *Tor putitora* from Lokchao river**

*Ompok bimaculatus* fish is considered an esteemed food fish in the Indian subcontinent and is the subject of targeted fisheries and categorized as *near threatened* species (IUCN 2001). A total of 37 fishes were collected from Imphal river at Laphupat Tera and maintained in ponds for further studies. It is carnivorous and sexes are separate. It shows sexual dimorphism during breeding season. The females are usually larger than the males. During breeding season females have rounded belly whereas males have flat belly (Fig 32a-c).

### Molecular taxonomic study of *Pethia manipurensis* and *Puntius chola* and *P. sophore* using mit. Cox1 gene sequences:

The partial sequences of 650 bp length of COI gene of *Pethia manipurensis*, *Puntius sophore* and *Puntius*



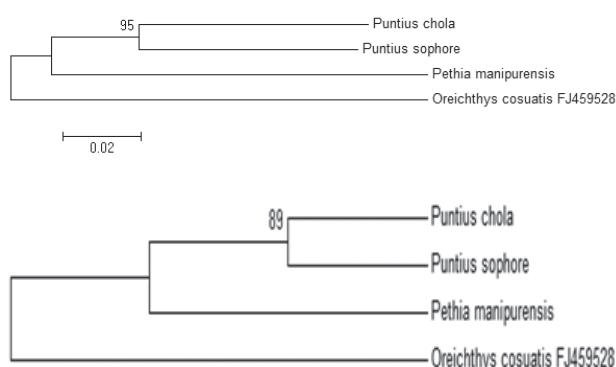


**Fig 32a. *Ompok bimaculatus* gravid**

**b. Fertilized eggs**

**c. 2 days old spawn**

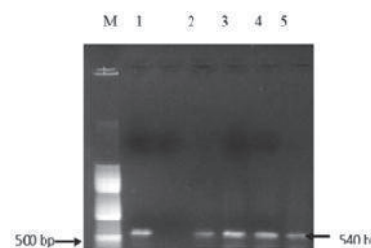
*chola* were generated and deposited in NCBI Gen Bank. NJ and MP trees were constructed by using the available data and had same topology. *P. sophore* is closely related with *P. chola* and distantly related with *P. manipurensis*. NJ and MP trees show same topology which suggest that three species are distinct species. The present results indicate that mtDNA COI gene is useful in study of taxonomic relationships in these three species of two genera.



**Fig 33. Molecular phylogeny of barbin fishes of North East India**

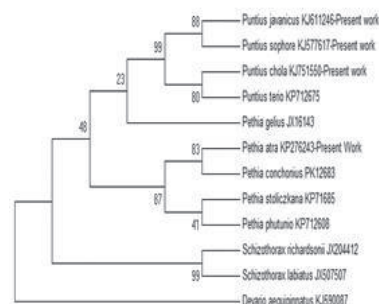
### Neighbour Joining tree and Maximum Parsimony tree of the three species under study, (FJ459528) as out group:

Out of 21 species of Barbin fishes of North East India, 4 species were collected from different water areas of Manipur, India and partial sequences of mitochondrial 16S rRNA gene sequences (540-615 pb) were generated (Fig 34). The partial sequence of mitochondrial 16S rRNA gene of *Pethia atra*, *Puntius chola*, *Puntius javanicus* and *Puntius sophore* were generated and deposited in NCBI GenBank. Eight Barbin fishes namely *Pethia chonchonius*, *P. gelius*, *P. phutunio*, *P. stoliczkana*, *Puntius terio*, *Schizothorax labiatus* and *S. richardsonii* were downloaded from NCBI GenBank. For rooting of the phylogenetic tree, *Devario aequipinnatus* is used as outgroup.



**Fig 34. Gel photographs showing 16S rRNA genes (M-100bp DNA step ladder, Lane 1 to 5 – mitochondrial 16SrRNA gene region of fish sp. Studied**

**Phylogenetic analysis:** The phylogenetic tree of Maximum Parsimony was constructed from the combined dataset of 16S rRNA consisting of 11 sequences aligned with one outgroup as a root (*Devario aequipinnatus*). From dendrogram it is clear that all the genera of Barbinae were differentiated into 3 clusters with *Devario aequipinnatus* as root (Fig 35).



**Fig 35. Maximum Parsimony tree of mitochondrial 16S rRNA gene of Barbinae fishes found in North East India**

### MASTEC-ICAR joint venture project on pisciculture and its allied activities for socio-economic development in Manipur:

10,000 fingerlings of mixed carps comprising *Catla catla*, *Labeo rohita*, *Cirrhina mrigala*, *Ctenopharyngodon idella*, *Bangana dero* and *Osteobrama belangeri* in different ratio were stocked. The fishes were stocked in March-April and harvested in the month of October (Fig 36). Good survival of





**Fig 36. Fish harvest at Khabam & Khabi (7 month culture) and *Bangana dero* from the harvest**

*Pengba* was observed 80-85%. *Bangana dero* survival was the highest among the culture fishes 87-90% in all the locations. Highest growth rate was obtained in rohu. The fish productions ranged 1300-1700 kg/0.25ha in 7 months. In this study, *B. dero* and *O. belangeri*, being high price fishes and having high demand and also high survival rate, one can harvest and earn more income by using these two local fish in place of Mrigal and rohu stock.

#### Study on fish diversity and stock assessment

Study of Species diversity in relation with changing climate has been conducted at Ukhrul district in the (Yangwui kong) headwater of Thoubal River, Manipur at Litan village locally called as Litan stream on monthly basis (Fig 37). A total of 32 fish species belonging to 4 orders, 10 families and 18 genera were recorded. Highest number of species were found in Order Cypriniformes (23 species), followed by order Siruliformes (6 species), Order Perciformes (2 species) and Order Cyprinodontiformes (1 Species), respectively. Overall values of diversity, richness and evenness indices were calculated. It was observed that

*Garra litanensis*, under vulnerable categories of the IUCN Red List described from Litan stream was not found in the collections. It was also observed that Catfishes like *Mystus* spp, *Heteropneustes fossilis* and *Channa gachua* included in the catch after the monsoon season of 2015. It might be due to inundation of the Thoubal Mojar Irrigation Project at Mapithel. Fish species viz., *Barilius ngawa*, *Schistura khugae*, *Gara* spp. dominated the catches.

#### FARMING SYSTEM RESEARCH

##### Technological ontervention through adoption of integrated farming system for livelihood improvement of the farmers in Manipur:

Under the project, five different models of IFS have been established in hill districts of Manipur. The major components included in the IFS are cropping systems (Kharif: paddy, groundnut, Beans and maize; Rabi: Pea and mustard), Vegetables (Tomato, cabbage, cauliflower, chilli, cucurbits), Fruit cultivation (Orange, Kachai lemon and Gooseberry), Piggery (Cross breed Hampshire), Goatry (Black Bengal), Backyard poultry (Vanaraja), Duckery (Khanki Campbell), Fishery (Common carp and grass carp), Agroforestry (Tree bean), Residue management (Composting and vermicomposting), Soil management (liming, bench terracing), Water harvesting (Pond, Jalkund) etc. The net farm income was realized by farmer who maintained “crop-livestock-fish-vegetable-fruits-water harvesting” integration on their field as follows.

**Table 2. Net farm income realized by farmers**

Farmer	Location	B : C Ratio
R. D. Peter	Purul Akutpa village, Senapati	7.93
A. S. Somi	Nungshangkhong village, Ukhrul	3.89
V. Tuime Lolly	Kachai village, Ukhrul	3.85
Henkapao	Tollen village, Churachandpur	4.08



**Fig 37. Fish species collected from Litan, Ukhrul District, Manipur**



### National Mission on Sustaining the Himalayan Ecosystem -Task Force on Himalayan Agriculture:

The pilot studies under the project were undertaken at Chandanpokpi village, Chandel district. PRA has been done and major agricultural problem have been identified. Lentil, field pea and high quality protein maize (HQPM) were introduced for the first time through participatory seed production. Cultivation of rabi vegetables especially legumes was undertaken to increase the cropping intensity and enhance the soil fertility. Climate smart technologies like preparation of early vegetable nursery under low cost polytunnel were introduced. Improved poultry strain Vanaraja and Rainbow Rooster were introduced in the village with improved housing and feeding management. Four rain water harvesting structure (Jalkund) were constructed for providing life saving irrigation to rabi crops. Income generating secondary agricultural activities like mushroom production and community based fruit processing were popularized with an aim for agri-preneurship development. One awareness programme, three training programmes and one field day were organized.

### IMPORTANT EVENTS

- National Seminar on Integrating Agri-Horticultural and Allied Research for Food and Nutritional Security in the Era of Global Climate Disruption, 4-6, march, 2016.
- First Manipur National Horti Expo and National Workshop on Strengthening Horticultural Development for Enhancing Productivity, Quality and Sustainable Livelihood, in collaboration with Department of Horticulture and Soil Conservation, Government of Manipur and ICAR Research Complex for NEH Region, Manipur Centre, Imphal during 11-13, June 2015.
- 10 days Short Course on Climate Change: Approaches and Strategies for Mitigation and Sustainable Agriculture under NICRA during 3-12, August 2015.
- 10 days ICAR sponsored Short Course Integrated Farming System: An Approach Towards Livelihood Security and Natural Resource Conservation during 15-25, September 2015.



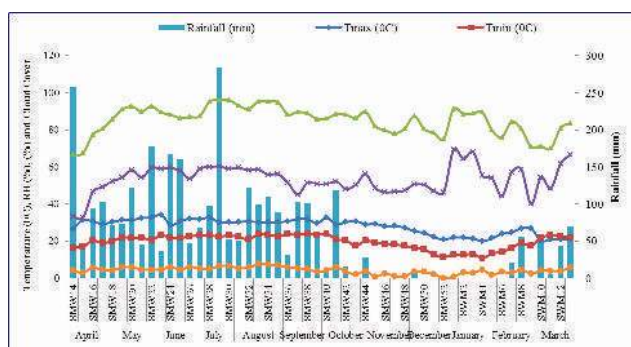
Fig 38. Technological Interventions under NMSHE (TF-6) at Chandanpokpi Village, Chandel, Manipur



# MIZORAM

## WEATHER REPORT

During April 2015 to March 2016, Mizoram received 3107.2 mm total annual rainfall with 142 rainy days (>2.5 mm/day). The state received 985 mm rainfall during pre-monsoon, 1687 mm during monsoon; 187.4 mm during post-monsoon and 256.8 mm during winter, respectively (Fig 1). The variation in the mean monthly maximum temperature ( $T_{\max}$ ) and mean monthly minimum temperature ( $T_{\min}$ ) showed year-round similar pattern. Highest maximum temperature was observed on 05<sup>th</sup> June 2015 (35.3° C) and lowest minimum temperature was observed on 27<sup>th</sup> January 2016 (7.3° C). The variation RH-morning was much less than the RH-evening, and varied from 76% (during March) to 96% (during July) while the RH-evening varied between 47% (during November) to 59% (during July). Southerly to South-Easterly was most prevalent throughout the year.



**Fig 1. Weekly meteorological variables from April 2015 to March 2016 at Kolasib Mizoram (SMW-Standard Meteorological Week)**

## Monsoon variability analysis of Mizoram

Monsoon variability was analyzed from the seasonal and monthly rainfall data record from 12 selected rain-gauge stations across the Mizoram viz., Aizawl, Neihbawih, Sialsuk, Lunglei, Hnahthial, Tlabung, Kolasib, Bilkhawthlir, Saiha, Lawngtlai, Serchhip and Champhai. The spatial extent and temporal trend in Standardized Precipitation Index (SPI) were analyzed for different timescales (1 month- 1 SPI, 2 months- 2 SPI, 3 months- 3 SPI, 4 months- 4 SPI, 6 months- 6 SPI and 12 months- 12 SPI) from 1986 to 2014. The rainfall received during May to September will be more useful to sustain the agricultural production scenario in Mizoram rather than simply citing the monsoonal rainfall (JJAS). The

local annual SPI (12-SPI) showed a negative trend over Southern Mizoram viz., Champhai, Serchhip, Lawngtlai and Tlabung, which indicates an increasing trend in dry conditions with time and increasing annual wetness over Northern Mizoram viz., Sialsuk, Lunglei and Aizawl. The increasing trend in August rainfall may hamper crop harvesting from the distant *jhum* fields and increase the possibility of crop damage from the excess moisture availability (Table 1). In contrast, the decreasing rainfall trends in the post-monsoon season with increasing dryness pose a serious threat to the effort for increasing cropping intensity by adopting the *rabi* vegetable cultivation in Mizoram.

**Table 1. Theil–Sen’s estimator value for estimating the magnitude of changes (1986-2014) in August rainfall at different rain-gauge stations of Mizoram**

Site	Theil–Sen’s estimator (mm/decade)
Aizawl	-2.30
Neihbawih	+11.25*
Sialsuk	+8.90*
Lunglei	+16.12*
Hnahthial	+3.54
Tlabung	-5.59*
Kolasib	+5.05
Bilkhawthlir	+4.28
Saiha	+7.07ä
Lawngtlai	-1.55
Serchhip	-3.68ä
Champhai	-1.19

(äsignificance at p d” 0.1; \*significance at p d” 0.05)

## Effect of different *jhum* fallow ages on soil enzymes

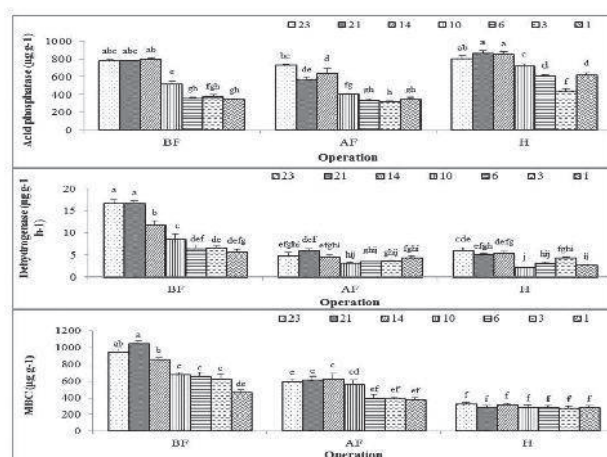
Surface soil samples were collected from different *jhum* fallow ages; 23, 21, 14, 10, 6, 3 and 1-year old before burning (BP) plant biomass, 45 days after burning (AF) the biomass and at the time of rice harvest (H) representing sub-tropical zone of Mizoram (Fig 2a). Acid phosphatase enzyme (ACP), an indicator of organic P mineralization, and dehydrogenase enzyme (DHY), an indicator of microbial activity and microbial biomass carbon (MBC), decreased with the decrease in fallow ages. Both the enzyme activities along with MBC decrease after burning. While MBC decrease up to harvesting stage of rice, the DHY activity decreases slightly and ACP activity tend to increase slightly suggesting that the increase in the fallow ages has tremendously improved the soil health by way of building up and accumulation of biomass



through increasing activities of the soil enzymes and microbial biomass carbon. Burning and cultivation of rice has decreased both the enzyme activity but this was somewhat temporary as the acid phosphatase enzyme was revived at the latter stage.

### Effect of land uses on soil fertility

Soil samples were collected from different land uses, and depths from sub-tropical ecosystems of Mizoram to study the impact of land use on soil fertility. Soils from secondary forests, abandoned *jhum* fields after first year cultivation of rice, oil palm, arecanut, lowland rice, rubber and teak were collected from adjacent areas and analysed for pH and available N, P and K. Soil pH was highest for abandoned *jhum* because of the cations derived from burning of plant biomass through ashes as it was observed from the highest available potassium (Table 2 & 3). Available N and P were highest in oil palm land use system. However, forest had the highest content of organic carbon substantiating the fact that plant detritus over time with fewer disturbances than other land uses leads to accumulation of organic matter thus building up organic carbon content of soil. All parameters studied decrease with the increase in depth from 0-15 to 15-30 and 30-45 cm.



Note: Bars represent S.E and different letter indicate significant difference at  $P < 0.05$  by DMRT

\*BF-Before burning; AF-After burning; H-Rice harvest

**Fig 2a. Effect of different *jhum* fallow ages on acid phosphatase enzyme, dehydrogenase enzyme and microbial biomass carbon**

### RICE

#### Performance of different rice varieties under upland condition

Four upland rice varieties were evaluated for their yield potential (Fig 2b). The data presented in Table 4 reveal that the maximum plant height was recorded in

**Table 2. Effect of land use systems on soil pH, available N and organic carbon**

Land use	pH			Nitrogen (kg/ha)			Organic carbon (kg/ha)		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
A. Jhum	5.53	5.37	5.34	183.98	192.34	188.16	1.08	0.51	0.60
Oil Palm	5.26	5.07	5.09	209.07	192.34	188.16	1.35	1.15	0.88
Arecanut	4.93	4.76	4.64	175.62	150.53	188.16	1.31	0.99	0.86
Rice	5.17	5.14	5.27	192.34	183.98	209.07	1.28	0.83	0.56
Rubber	5.01	5.01	4.87	196.52	209.07	146.35	1.36	1.09	0.85
Teak	5.06	5.06	4.84	154.71	188.16	183.98	1.02	0.77	0.70
Forest	5.02	4.94	5.10	163.07	192.34	179.80	1.62	1.13	0.82

**Table 3. Effect of land use systems on soil available P and K**

Land use	Phosphorus (kg/ha)			Potassium (kg/ha)		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
A. Jhum	10.44	7.77	6.19	536.91	370.91	320.64
Oil Palm	17.51	12.72	9.86	428.46	364.71	303.47
Arecanut	6.52	5.18	2.91	355.73	320.72	216.65
Rice	5.60	4.08	5.66	371.44	258.03	200.68
Rubber	4.72	5.50	3.89	394.28	347.85	254.53
Teak	3.84	2.81	2.24	368.96	380.62	275.81
Forest	13.44	5.67	5.09	333.12	280.05	174.29





**Fig 2b. Performance of different upland rice varieties at ICAR Mizoram Centre**

Bhalum-4 which was at par with Bhalum-3 and the minimum plant height was found in Bhalum-1. Rice variety, Bhalum-3 recorded significantly higher number of tillers per hill (13.4) as compared to the remaining varieties and the minimum number was recorded in Bhalum-1. Number of panicle per hill and number of grains per panicle were statistically similar for all the varieties. The highest 1000 grain weight was jointly recorded by Bhalum-1 and Bhalum-3 (23.70 g) and the lowest was found in Bhalum 4 (22.30 g). The highest grain yield of 3.22 t/ha was recorded in Bhalum-3 which was followed by CAUR 2 (3.01 t/

ha), Bhalum-1 (2.86 t/ha) and Bhalum-4 (2.62 t/ha). All these treatments differed significantly from one another. Bhalum-3 recorded the highest straw yield (5.62 t/ha) and the lowest was recorded in Bhalum-1 (4.66 t/ha).

#### **Performance of different rice varieties under lowland condition**

Different rice varieties were evaluated under lowland conditions (Fig 3). Plant height ranged from 113.2cm in CAUR-4 to 83.1cm in RCM 9 (Table 5). The maximum number of tillers per hill was found in

**Table 4. Performance of different rice varieties under upland condition**

Variety	Plant height (cm)	No. of tillers /hill	No. of panicles /hill	No. of grains /panicle	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Bhalum-1	83.2	10.9	7.4	139.0	23.70	2.86	4.660
Bhalum-3	90.1	13.4	7.3	140.8	23.70	3.22	5.620
Bhalum-4	93.2	11.4	7.4	131.3	22.30	2.62	4.740
CAUR-2	87.8	11.7	7.9	135.8	22.80	3.01	5.210
SEM±5	1.5	0.5	0.5	2.3	0.06	0.01	0.014
CD (5%)	5.1	1.7	NS	NS	0.21	0.03	0.050

**Table 5. Performance of different rice varieties under lowland condition**

Variety	Plant height (cm)	No. of tillers /hill	No. of panicles /hill	No. of grains /panicle	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
RCM 9	83.1	9.3	8.2	140.4	23.50	4.07	4.90
RCM 10	104.4	9.1	8.5	119.8	22.63	3.60	4.33
RCM 11	93.8	11.2	9.1	129.5	23.43	3.47	4.77
RCM 30	93.1	9.3	7.7	124.3	22.53	3.03	4.70
RCM 31	88.3	9.0	8.2	121.6	23.13	3.13	4.70
CAUR-1	103.1	8.8	7.6	145.8	22.63	4.50	5.20
CAUR- 4	113.2	8.7	8.3	133.7	22.60	3.07	4.30
Gomati	103.8	10.9	10.3	168.8	23.57	4.83	5.57
Shasarang	107.9	11.4	8.9	134.9	23.37	4.53	5.57
Jatraphou	97.5	8.4	7.4	121.1	22.57	3.20	4.87
Thangjing phou	95.4	8.9	8.2	119.2	22.87	3.30	4.50
Darum	88.4	8.2	7.4	134.5	23.33	3.70	4.57
Ayangleima	93.2	8.4	7.5	115.3	22.27	3.37	4.50
Leirangbi	92.9	8.1	7.4	121.5	22.33	3.47	4.50
SEM±5	1.0	0.3	0.4	0.8	0.15	0.10	0.13
CD (5%)	3.0	0.8	1.1	2.4	0.44	0.30	0.37





**Fig 3. Performance of different rice varieties at ICAR Mizoram Centre**

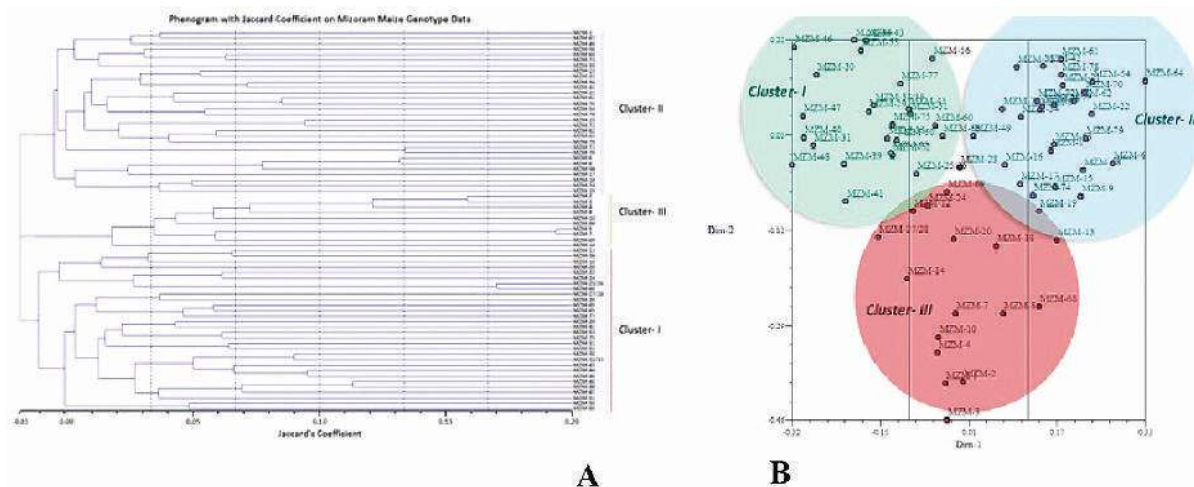
Shasarang (11.4) which was at par with RCM 11 (11.2) and Gomati (10.9), and the lowest number per hill was found in Leirangbi (8.1). Gomati (10.3) produced significantly more number of panicles per hill than remaining rice varieties. Number of grains per panicle ranged from 168.8 in Gomati to 115.3 in Ayangleima. The weight of 1000 grains was highest for Gomati (23.57g) which was at par with RCM 9 (23.50g), RCM 11 (23.43 g), Shasarang (23.37g) and Darum (23.33g), and the lowest value were recorded in RCM 31 (23.13g). The highest grain yield was found in Gomati (4.83 t/ha) which was significantly higher than the remaining varieties and the lowest grain yield was found in CAUR-4 (3.07 t/ha). Gomati and Shasarang recorded maximum straw yield of 5.57 t/ha which was significantly higher than the remaining varieties and the lowest value was found in CAUR-4 (4.30 t/ha).

## MAIZE

### Molecular characterization of maize landraces of Mizoram

About 70 maize landraces collected from different part of Mizoram were characterized through molecular

approaches for evaluation, conservation and utilization. The phenotypic characters were evaluated in field conditions. Sizes of the alleles in base pairs of landraces were estimated using GeneMapper analysis software. All the genotypes were scored for the presence and absence of SSR bands. The comparison of simulation populations with a phenogram was produced using UPGMA cluster analysis. The landraces were clustered into three major groups (cluster I, II and III) by UPGMA analysis based on Jaccard's similarity of SSR markers (Fig 4a). Maximum landraces were grouped in cluster I and least in Cluster III. Almost -0.03 coefficient value was observed where from the three major groups were segregated from one another. This genetic distance also showed a fine and integrated relationship with these internal groups and samples clustered into separate groups. MZM-5 and MZM-7 are the most similar as per their genotypic allele configuration is concerned with smallest genetic distance. Both the cultivars shared same space in cluster- III. The principal component analysis (PCA) depending upon the genetic relationship also provided the same cluster analysis as shown in the dendrogram (Fig 4b).



**Fig 4. Grouping of 70 maize landrace (a) on basis of the Jaccard's similarity of SSR markers and (b) principal component analysis (PCA) four dimensional plots.**



## GREEN GRAM

### Performance of different green gram varieties in Mizoram

Green gram variety, TRCM 314-1 recorded significantly taller plants than the remaining varieties, being at par with TRCM 151-1 and the shortest plants were found in TRCM 5-4-2 (Table 6). Varieties TRCM 314-1, TRCM 1-2-1 and Sonamung have statistically similar number of branches per plant and the lowest value was found in TRCM 151-1. The maximum number of pods per plant was found in TRCM 151-1 (18.3) and the minimum was recorded in TRCM 5-4-2 (15.4). TRCM 1-2-1 recorded significantly higher number of grains per pod (12.7) than the remaining varieties. TRCM 7-2-1, Sonamung and TRCM 314-1 had statistically similar 1000 grain weight and these varieties had significantly higher 1000 grain weight than the remaining varieties and the lowest value was found in TRCM 5-4-2. The highest grain yield was observed in TRCM 151-1 (1.01 t/ha) which was significantly higher than the remaining varieties and the lowest grain yield was found in TRCM 7-2-1 (0.81 t/ha).

### Effect of weed management on yield and yield attributing characters in green gram (variety: Tripura Moong 1)

Weedy treatment recorded significantly taller plants than remaining weed management treatments and the shortest plants were found in hand weeding treatment at 25 DAS (Table 7). Weed free being at par with hand weeding at 25 DAS produced significantly more number of branches per plant than hand weeding at 40 DAS and weedy (Fig 5). The highest number of pods per plant was found in weed free (28.4) which were followed by hand weeding at 25 DAS (26.2), hand weeding at 40 DAS (23.5) and weedy control (20.4), respectively. All these treatments differed significantly from one another. The number of grains



Fig 5. Field view of green gram under weedy (left) and weed free condition (right)

Table 6. Yield and yield attributes of different green gram varieties

Variety	Plant height (cm)	No. of branches /plant	No. of pods/ plant	No. of grains /pod	1000 grain weight (g)	Grain yield (t/ha)
TRCM 314-1	47.4	6.4	17.5	11.7	30.53	0.95
TRCM 151-1	47.1	4.6	18.3	11.7	29.53	1.01
TRCM 7-2-1	46.0	5.5	16.3	11.8	30.67	0.81
TRCM 5-4-2	39.2	5.7	15.4	11.8	27.57	0.91
TRCM 1-2-1	40.3	6.1	18.2	12.7	28.47	0.96
Sonamung	42.5	6.0	16.6	11.6	30.57	0.98
CD (5%)	0.6	0.5	1.0	0.3	0.76	0.78

Table 7. Effect of weed management on yield and yield attributing characters in green gram

Treatment	Plant height (cm)	No. of branches /plant	No. of pods /plant	No. of grains /pod	1000 grain weight (g)	Grain yield (t/ha)
Weed free	37.6	5.7	28.4	10.7	32.53	1.10
Hand weeding (25 DAS)	37.1	5.3	26.2	10.0	32.00	0.98
Hand weeding (40 DAS)	41.0	4.8	23.5	9.3	32.47	0.96
Weedy	49.0	4.2	20.4	8.8	31.77	0.773
CD (5%)	0.9	0.7	0.9	0.8	NS	0.95

\*DAS- days after sowing



per pod ranged from 10.7 in weed free to 8.8 under weedy treatments. Different treatments had no significant effect on 1000 grain weight. The highest grain yield was found in weed free (1.10 t/ha), which was followed by hand weeding at 25 DAS (0.98 t/ha), hand weeding at 40 DAS (0.96 t/ha) and weedy (0.77 t/ha).

## BLACK GRAM

### Effect of weed management on yield and yield attributing characters in black gram (var: Tripura Maskolai 1)

The maximum plant height was recorded under weedy (28.9 cm) and the shortest plants were found in weed free (26.4 cm) (Table 8). Different weed management treatments had no effect on number of branches per plant and it ranged from 8.4 in weed free and hand weeding at 25 DAS to 7.5 in weedy condition. Weed free recorded the highest number of pods per plant (39.5) which was at par with hand weeding at 25 DAS (37.5) and the lowest was found in weedy (29.7). Hand weeding at 25 DAS and weed free had statistically similar number of grains per pod and the lowest was found on hand weeding at 40 DAS. 1000 grain weight was not affected by different treatments. The highest grain yield was recorded in weed free (1.03 t/ha) which was followed by hand weeding at 25 DAS (0.99 t/ha), hand weeding at 40 DAS (0.95 t/ha) and weedy (0.84 t/ha). All these treatments differed significantly from one another.

## PEA

### Performance of pea cultivars in lowland rice fallow under zero tillage condition

The pea variety 'Prakash' was found comparatively taller than HUDP-15 (Fig 6). The average number of branches per plant was 3.5 in HUDP-15 and 3.2 in Prakash. Number of pods per plant was 14.9 in Prakash and 13.4 in HUDP-15 (Table 9). Average number of grains per pod was 5.3 in HUDP-15 and 5.0 in Prakash. Average grain and straw yield of HUDP-15 was comparatively higher than Prakash.



Fig 6. Performance of HUDP-15 (left) and Prakash (right) under zero tillage condition

### Effect of mulching treatment on pea (variety-Arkel)

Number of branches per plant ranged from 2.7 in leaf and polythene mulching 3.1 in control plots (Table 10). Straw mulching and leaf mulching recorded statistically similar number of pods per plant and the lowest number of pods per plant was found in control plots. Number of grains per pod and 1000 grain weight was not affected by mulching treatments. Straw

Table 8. Effect of weed management on yield and yield attributing characters in black gram

Treatment	Plant height (cm)	No. of branches /plant	No. of pods /plant	No. of grains /pod	1000 grain weight (g)	Grain yield (t/ha)
Weed free	26.4	8.4	39.5	6.2	30.77	1.03
Hand weeding (25 DAS)	26.8	8.4	37.5	6.6	30.63	0.99
Hand weeding (40 DAS)	27.3	8.2	34.4	5.9	30.70	0.95
Weedy	28.9	7.5	29.7	6.0	30.73	0.84
CD (5%)	2.3	NS	3.8	0.5	NS	0.126

\*DAS- days after sowing

Table 9. Performance of pea cultivars in lowland rice fallow under zero tillage condition

Variety	Plant height (cm)	No. of branches/plant	No. of pods /plant	No. of grains /pod	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
HUDP-15	74.6	3.5	13.4	5.3	150.7	1.82	2.76
Prakash	83.0	3.2	14.9	5.0	144.8	1.74	2.44



**Table 10. Effects of mulching on yield attributes and yield of pea**

Variety	No. of branches /plant	No. of pods /plant	No. of grains /pod	1000 grain weight (g)	Grain yield (t/ha)
Control (no mulch)	3.1	6.1	5.7	141.87	0.93
Straw mulch	2.8	15.2	5.6	141.73	1.43
Leaf mulch	2.7	13.3	5.5	141.57	1.33
Polythene mulch	2.7	10.3	6.1	141.47	1.13
CD (5%)	NS	2.2	NS	NS	0.260

mulching and leaf mulching being at par with each other (1.43 t/ha and 1.33 t/ha respectively) recorded significantly higher grain yield than polythene mulching (1.13 t/ha) and control (0.93 t/ha).

## LENTIL

### Performance of lentil varieties in lowland rice fallow

The number of pods per plant was statistically similar for different lentil varieties (Table 11 and Fig 7). The number of grains per pod for DPL-62 was significantly higher than the remaining varieties. 1000 grain weight ranges from 24.90 g in IPL-406 to 22.37 g in DPL-62 variety. Grain yield of DPL-62 (0.72 t/ha) and DPL-15 (0.71 t/ha) were statistically similar and both had significantly higher grain yield than the remaining varieties. The lowest grain yield was found in IPL-406 (0.47 t/ha). The maximum biological yield was found in IPL-81 (2.86 t/ha) and the lowest value was found in IPL-406 (2.27 t/ha). DPL-62 being at par with DPL-15 recorded significantly higher harvest

**Fig 7. Field view of DPL-15, DPL-62 and IPL-406**

index than the remaining varieties and the minimum value was found in IPL-406.

## RAPSEED-MUSTARD

### Evaluation of different rapeseed-mustard cultivars in lowland rice fallow under no till system for enhancing cropping intensity and productivity

The tallest plants were found in cultivar NPJ-113 (121.4 cm) and it was at par with P-27 (110.1 cm), both had significantly taller plant than M-27 (96.3 cm) (Fig 8). Number of siliqua per plant, number of seeds/pod and seed index of M-27 was numerically higher (Table 12). NPJ-113 and P-27 being at par with each

**Fig 8. Field view of M-27, P-27 and NPJ-113 under zero tillage practice at ICAR farm****Table 11. Yield and yield attributes of different lentil varieties**

Variety	No. of pods /plant	No. of grains/ pod	1000 grain weight (g)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
DPL-62	45.1	1.3	22.37	0.71	2.85	24.97
DPL-15	47.4	1.5	23.93	0.72	2.83	25.49
IPL-81	39.9	1.3	23.40	0.60	2.86	21.30
IPL-316	47.1	1.3	23.80	0.52	2.35	22.41
IPL-406	42.5	1.4	24.90	0.47	2.27	21.02
CD (5%)	NS	0.1	1.28	0.105	0.407	2.74



**Table 12. Performance of rapeseed and mustard cultivars under zero tillage practice**

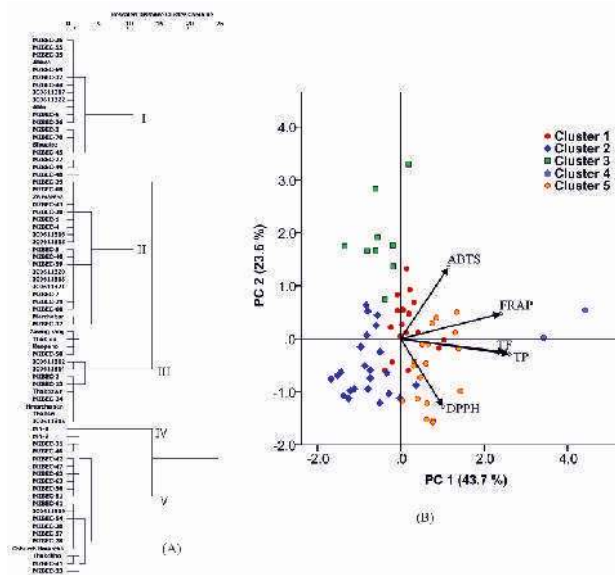
Variety	Plant height (cm)	No. of siliqua/plant	No. of seeds /siliqua	Seed index (g)	Days to maturity	Seed yield (t/ha)
M-27	96.3	168.7	13.5	0.41	93	1.26
P-27	110.1	150.5	12.9	0.37	112	0.94
NPJ-113	121.4	143.8	13.4	0.39	116	1.24
SEm±5	3.1	6.33	1.6	0.02	1	1.10
CD (5%)	12.1	NS	NS	NS	6	NS

other took significantly more number of days to mature (116 and 112 days, respectively) than M-27 (93 days). Seed yield ranges from 1.26 t/ha in M-27 to 0.94 t/ha in P-27

## CHILLI

### Assessment of antioxidants diversity in fruits of Bird's eye chilli (*Capsicum frutescens*) landraces of North East India

Bird's eye chilli (*Capsicum frutescens* L.) is one of the most important species grown and consumed widely in Mizoram and Manipur. Antioxidant property was assayed by scavenging abilities using diphenyl-2-picrylhydrazyl (DPPH), azinobisethylbenzothiazoline-6-sulphonic acid (ABTS) and ferric reducing antioxidant power (FRAP) assay and total phenolic (TP) contents and total flavonoid (TF) were evaluated. There was significant variation in the total phenolic content (12.4 to 133.2 mg GAE/g dry weight), total flavonoid (22.1 to 58.8 mg quercetin/g dry weight), DPPH (0.5 to 6.1 mM AAE/g dry weight), ABTS (20.5 to 44.3 mM AAE/g dry weight) and FRAP (0.7 to 7.8 mM GAE/dry weight) antioxidant capacity in *Capsicum frutescens* L. landraces. Two landraces of *Capsicum chinense* viz., MN-1 and MN-2 exhibited highest values for all the antioxidant assays. Positively significant correlation coefficients were observed between ABTS-FRAP, TF-FRAP, TP-FRAP, TP-DPPH and TP-TF. Principal component analysis (PCA) of first two components explained 67.3% of total variance and it was contributed mainly by TP, TF, ABTS and FRAP activities. 72 *Capsicum* landraces were grouped into five clusters based on the standardized squared Euclidean distance using Ward's hierarchical clustering method and separation based on PCA biplot (Fig 9). The experiment established that the landraces of *Capsicum frutescens* L. are potent source of natural antioxidants which reduces the oxidation processes in the body by protecting against reactive oxygen species.



**Fig 9. Grouping of 72 *Capsicum* landraces on the basis of (A) standardized squared Euclidean distance using Ward's hierarchical clustering method and (B) PCA biplot**

### Diversity of Bird's eye chilli (*Capsicum frutescens* L.) landraces of Mizoram in terms of qualitative morphological traits

Mizoram bird's eye chilli (*Capsicum frutescens* L.) is locally known as *Hmarchate* with considerable diversity of this crop with respect to fruit shape, size, colour, pungency, plant type, physiological characteristics, reactions to diseases and pests, adaptability and distribution found. In this study, 29 qualitative traits related to hypocotyl, cotyledon, leaf, stem, flower and fruits were used for classifying 72 landraces collected from all the districts of Mizoram. Frequency distribution of different traits were worked out for the whole set of germplasm. The patterns of qualitative morphological variation were assessed using multivariate approaches. Eleven principal components (PC) explained 71.5% of total variance and PC1 and PC2 contributed 11.1 and 8.5% variance, respectively. These landraces were grouped into five



clusters based on the standardized squared Euclidean distance using Ward's hierarchical clustering method (Fig 10) and separation based on PCA biplot (Fig 11). The experiment established that, there is significant diversity related to morphological qualitative traits in the landraces of *Capsicum frutescens* L. which provides the basis for selection and improvement of this local landraces and breeding elsewhere.

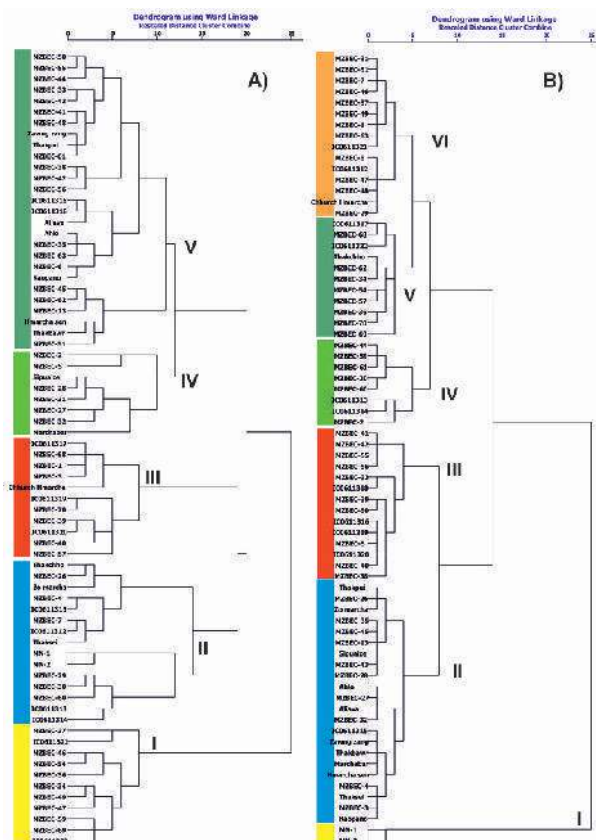


Fig 10. Grouping of 72 *Capsicum* landraces using A) qualitative traits and B) quantitative traits based on standardized squared Euclidean distance using Ward's hierarchical clustering method

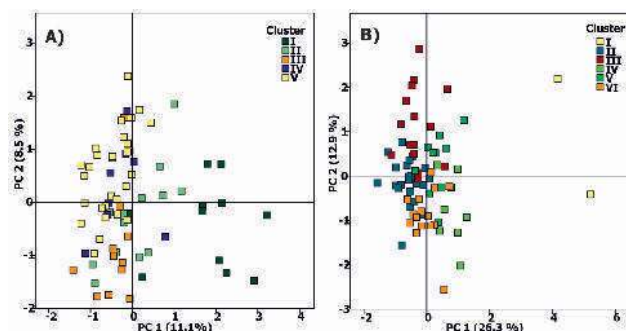


Fig 11. Separation of the *Capsicum* landraces in PCA biplot using A) qualitative traits and B) quantitative traits

## INSECT PESTS

### First report of economic injury due to the *Bactrocera tau* on Chilli in India

Fruit flies have a wide host range, which is capable of significantly reducing chilli crop yields under field conditions of northeastern India. A pest survey and subsequent identification confirmed the presence of the tephritid fruit flies, *Bactrocera tau* (Walker) (Diptera: Tephritidae) in chilli. This is the first report of the insect in the region and population outbreaks resulting in serious damage to chilli in India. Percent infestation by fruit flies in different chilli cultivars are shown in Fig 12. The highest percent infestation by fruit flies was in cv. Guntur Hope. The lowest percent infestation by fruit flies was in cv. Mohini.

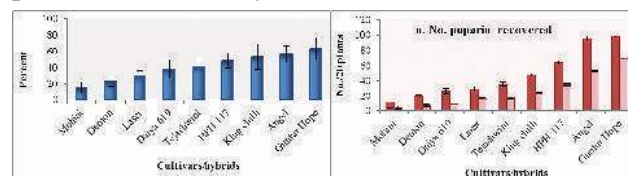


Fig 12. Percent infestation by *B. tau* in different chilli cultivars/hybrids

Fig 13. Number of fruit fly puparia in different Chilli cultivars

Level of maggot infestations and puparia varied in cultivars (Fig 15). The cv. Guntur Hope had the higher numbers of fruit fly puparia/20 fruit. The fewest fruit fly puparia/20 fruit was in cv. Mohini (Fig 13). The overall survival from pupal to adult stage varied with cv. King chilli exhibiting the highest percent adult emergence. The lowest percent adult emergence was in cv. Guntur Hope. The highest number of adult emerged was in cv. Angel and the lowest in cv. Mohini (Fig 14). The highest male and female populations were in cv. Angel. The lowest male and female populations were in cv. Mohini (Fig 15).

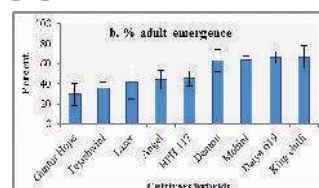


Fig 14. Effect of different Chilli cultivars on adult emergence of *B. tau*

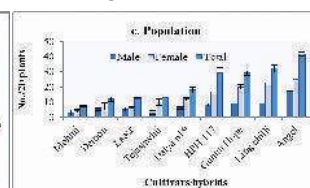


Fig 15. Effect of different Chilli cultivars on sex ratio of *B. tau*

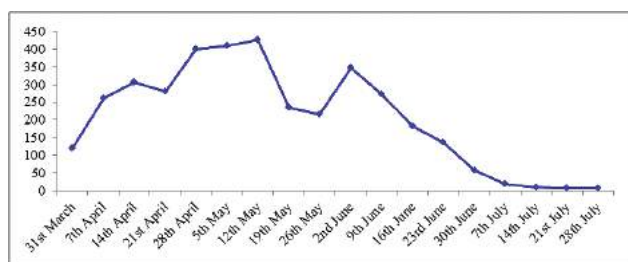
## CAPSICUM

### First report of economic injury due to the *Bactrocera tau* (Walker) (Diptera: Tephritidae) on capsicum in India

Tephritid fly, *Bactrocera tau* (Walker) (Diptera: Tephritidae) was observed feeding on Capsicum for



the first time in the province. The cue lure based trapping revealed that the highest fruit flies adults were attracted during April and May (Fig 16).



**Fig 16. Fruit flies caught by cue lure based trap in capsicum ecosystem**

### Effect of Different Capsicum Cultivars/Hybrids on the Pupal Mortality, Adult Emergence and Sex Ratio of fruit flies

Levels of maggot infestations were ascertained from fruit collected in different cultivars/hybrids of Capsicum (Fig 17). The fruit fly puparia recovered from different cultivars/hybrids of capsicum ranged from 67 to 103. This showed that egg laying occurs more close to ripening stage and can be staggered over a few weeks with varying age/ sizes of maggots during fruit fall. Among them, cv. ‘Indra’ yielded the highest fruit flies puparia/20 fruits (103). The lowest fruit flies puparia/20 fruits were with cv. ‘Picador’ (67). Non-emerged puparia recovered from different cultivars/hybrids of capsicum ranged from 37 to 51.



**Fig 17. Fruit flies infested fruits of capsicum cv. ‘Indra’ and ‘Picador’**

## COLE CROPS

### Insect pest incidence on cole crops

In Mizoram, major insect pests damaging cole crops were cabbage butterfly, tobacco caterpillar,

diamond back moth and aphids (Fig 18). Percent infestation of cabbage butterfly varied from 55 to 75% (Table 13). The highest infestation (75%) by cabbage butterfly was with broccoli compared to cabbage, cauliflower and knol-khol and the lowest was with knol-khol (55%). Percent infestation of tobacco caterpillar varied 25 to 60%. The highest infestation (60%) by tobacco caterpillar was with cauliflower and the lowest was with knol-khol (25%). Percent infestation of diamond back moth varied 15 to 40%. The highest infestation (40%) by diamond back moth was with cauliflower compared to cabbage, broccoli and knol-khol and the lowest was with knol-khol (15%). Percent infestation of aphids varied 22 to 35%. The highest infestation (35%) by aphids was with broccoli and the lowest was with cabbage (25%).



Cabbage butterfly

Diamond back moth



Aphids

Tobacco caterpillar

**Fig 18. Major insect pest of cole crops**

### Biodiversity of fruit flies in Mizoram

Total of eight species of fruit flies (Fig 19) were collected by methyl eugenol and cue lure based parapheromone trap at ICAR, Mizoram Centre, Kolasib, Mizoram. In total, 1220 specimens were collected (Table 14). Of these, 89.84% belonged to *Bactrocera dorsalis*, followed by *B. correcta* (7.143%) and *B. tau* (1.399%).



a. *Bactrocera tau*

b. *Bactrocera correcta*

c. *Bactrocera dorsalis*

**Fig 19. Different species of fruit flies in Mizoram**



**Table 13. Percent infestation and population of major insect pests of cole crops**

Cole crops	Cabbage butterfly		Tobacco caterpillar		Diamond back moth		Aphids	
	Population /10 plants	% infestation	Population /10 plants	% infestation	Population /10 plants	% infestation	Population /10 plants	% infestation
Cabbage	7	70	5	48	2	16	2	22
Cauliflower	7	70	6	60	4	40	3	30
Knol-khol	6	55	3	25	2	15	3	25
Broccoli	8	75	4	40	1	10	4	35

**Table 14. Numbers of insects of the different fruit fly species collected by methyl eugenol and cuelure based para-pheromone trap at ICAR, Mizoram Centre, Kolasib**

Genus	Species	Total	Percentage
<i>Bactrocera</i>	<i>dorsalis</i>	1220	89.838
	<i>correcta</i>	97	7.143
	<i>nigrofemorialis</i>	6	0.442
	<i>diversa</i>	7	0.515
	<i>tau</i>	19	1.399
	<i>cucurbitae</i>	5	0.368
	<i>zonata</i>	2	0.147
<i>Dacus</i>	<i>longicornis</i>	2	0.147

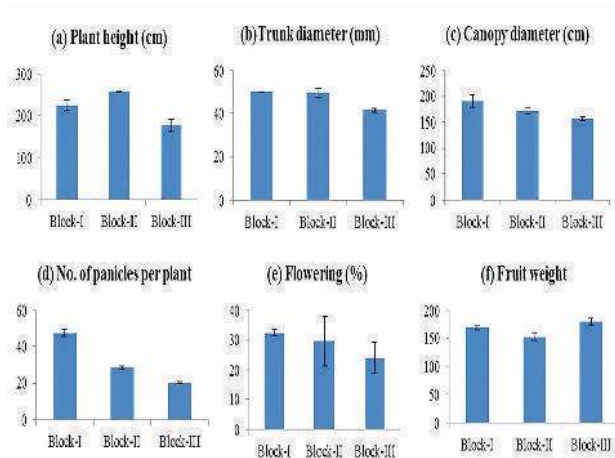
## MANGO

### Canopy management of Mango (*Mangifera indica* cv. Amrapali) under humid sub tropics of Mizoram

Mango variety 'Amrapali' grafted on local seedling rootstocks were subjected to high density planting at ICAR RC NEH Region, Mizoram centre during September 2012. Treatments consisted of three spatial arrangements of plants (Block-I: 2.5x2.5 m, Block-II: 3x2.5 m and Block-III: 2.5x1.5 m), which resulted in the following plant densities: 100 (control), 1600, 1333 and 2666 plants per hectare. After three year of growth, data pertaining to vegetative growth and flowering was recorded (Fig 20). Plant height difference was non-significant among three densities (Fig 21a- 21f). Both Block-I (2.5x2.5m) and Block -II (3x2.5m) recorded significantly greater trunk diameter than Block -III (2.5x1.5m). Similarly both Block-I and Block -II recorded significantly higher canopy diameter than Block -III. Both Block-I and Block -II recorded significantly higher number of panicles per plant than Block -III. There was non-significant difference in the fruit weight of all the three blocks. The data trend shows that plant density has a direct correlation with vegetative growth and flowering.



**Fig 20. Fruiting in high density planting of mango variety Amrapali**



**Fig 21 (a-f). Morphological and reproductive parameters of mango under high density planting**



## TURMERIC

### Effect shading environment on growth and yield of turmeric

The relative shading effect of different local cucurbit landraces (bottle gourd, ridge gourd, pumpkin and bitter gourd) were assessed on turmeric yield (variety: RCT-1). Plant height and leaf chlorophyll content increased significantly, with a marginal increase the number of leaves under cucurbits (gourds and pumpkin) shading over control (without shading). Turmeric rhizome yield was significantly higher (15.2%-17.9%) with the increasing degree of shading from cucurbit canopy (Table 15).

## TREE BEAN

### Identification and pathogenicity of fungi isolated from Tree Bean (*Parkia roxburghii*) decline of North Eastern India: A first report

The present studies comprised of comprehensive survey, isolation and identification of the association of pathogenic fungi from freshly infected quick decline tree and associated the tiny bark beetle. During survey, the most evident symptoms of this disease were wilting half of tree, excessive leaves shedding, gummosis and rotting, cankers and dark black longitudinal discoloration along with numerous tiny holes made by bark beetles. High disease incidence was recorded from all districts of Mizoram, tree bean in range of 50 to 90%. Most of the tree beans were found to be infected with pathogens and infested with tiny bark beetles (Fig 22). From diseased tree as well as from unknown beetle, the most frequently isolated fungi were *Botryodiplodia theobromae*, *Pestalotiopsis disseminata*, *P. guepinii* and *Phoma* spp. The frequency of isolation of *B. theobromae* was significantly higher as compared to *Pestalotiopsis* sp. and *Phoma*. Pathogenicity test confirmed that *B. theobromae*, was the most pathogenic to tree bean causing sudden death or quick decline in northeastern India. The bark beetle may act as a facilitating agent for the entry of the

pathogens. Further conventional and molecular based diagnostics is needed for confirmation on host-pathogen-insect (vector) interaction in development of sudden death or quick decline of tree bean in this region and scheduling an effective management strategy.



Fig 22. Pathogenicity test and symptoms showing on one year old tree bean seedling

## FRENCH BEAN

### Nutrient analysis of French bean landraces

About 52 pole-type common bean landraces collected from the state of Mizoram for quality traits. MZFB-43 (a, b and c) and MZFB-47 (d, e and f) were found distinct; pods of which are purple colour and rich in anthocyanin content (Fig 23). Landraces MZFB-47, MZFB-41, MZFB-83, MZFB-116, MZFB-52, MZFB-28, MZFB-116 and MZFB-85 were found to be the most promising ones with highest N, P, K, Cu, Zn, Mn, Fe and ash content while, total phenol, DPPH and ABTS radical scavenging activity were found maximum in MZFB-97. The study generated information about the nutritional importance of this precious, yet unstudied diversity of landraces which can be conserved, promoted and utilized for selecting and improving superior nutritious common bean lines.

Table 15. Effect of cucurbit integration on growth and yield of turmeric (variety: RCT-1)

Particulars	Plant height (cm)	No. of leaves (per plant)	Leaf chlorophyll content (mg/g)	Yield (t/ha)
Turmeric (Sole crop)	82.9	14.2	22.15	11.05
Bitter gourd - turmeric integration	111.6	16.4	24.22	13.96
Sponge gourd- turmeric integration	117.3	18.3	26.46	16.64
Bottle gourd- turmeric integration	130.2	21.1	28.76	20.94
Pumpkin - turmeric integration	135.3	19.8	29.03	17.51
LSD ( $P < 0.05$ )	7.31	1.87	0.36	1.21



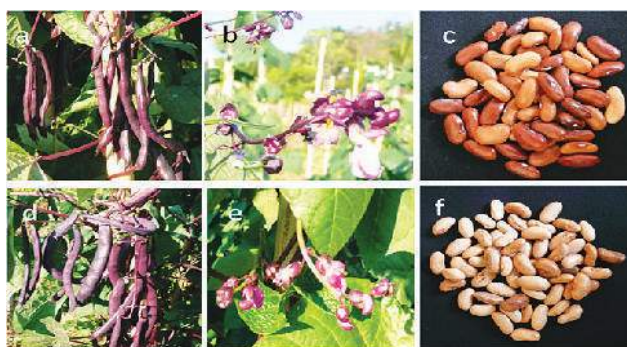


Fig 23. Purple colour MZFB-43 (a, b and c) and MZFB-47 (d, e and f) genotypes

## MUSHROOM

### Utilization of wild banana leaves for cultivation of Oyster mushroom (*Pleurotus florida*) in northeastern hill region of India

The dried leaves of five abundantly available perennial plants, such as wild banana (WB), oil palm (OP), date palm (DP), pine (P) and paddy straw (PS) as check were used as substrate for production of *Pleurotus florida*. Mycelial growth rate, number of primordia, size of stipe and pilus, biological efficiency, mushroom weight and mushroom yield obtained from the cultivation of *P. florida* under different combination substrates were evaluated. The most suitable substrate for mycelial growth was recorded, 25WB+75PS, followed by 100WB and 50WB+50PS. All the yield parameter recorded the highest in combination of 25WB+75PS (282g), followed by 100WB (236.20g) and 50WB+50PS (160g). There were at least five flushes for all the substrates mixing WB+PD and WB alone, and their biological

efficiencies were all higher than that of the control during the 4 months of cultivation period. Analyses of concentrations of nutritional factors like protein, fibre, fat, mineral content of substrates found superior in WB mixed substrates than 100PS (control). Based on the mushroom yield, nutritional factors and biological efficiency of the substrates tested, wild banana (WB) leaves appeared to be the best alternative material for growing *P. florida* which can be either substitute or mixed with paddy straw (PD).

## ANTHURIUM

### Evaluation of antagonist and botanicals against bacterial leaf blight (*Xanthomonas axonopodis* pv. *dieffenbachiae*) of Anthurium and their effect on plant growth parameters

Antagonists and botanical agents were treated the anthurium of variety 'Pistache' by maintaining the spacing of 50×50 cm with 10 plants per replication. The beds without application of any agents were kept as control. The maximum per cent disease control of 66.48 and 59.80% was recorded in *T. viride* and *Pseudomonas fluorescens* treatment, respectively (Table 16). This was followed by *T. harzianum* (56.82%), *Bacillus subtilis* (42.82). Though, neem solution was found the least effective in minimizing the disease. The maximum percent disease incidence (64.7%) was found in control plants. The data also reveal that root dip (37.45%) and soil drenching (40.83%) method do not differ statistically from each other, though found better in compared to Foliar Spray (58.2%) method. Among antagonists, *T. viride* and *T. harzianum* was found statistically significant.

Table 16. Effect of antagonist and botanical against bacterial leaf blight of Anthurium

Treatments	Disease incidence (%)							Overall Mean	Percent disease control
	Conc. (%)	Soil drenching		Sucker Dipping		Foliar Application			
		30 DAT*	60 DAT	30DAT	60 DAT	30DAT	60 DAT		
<i>Trichoderma viride</i>	1%	16.3	23.5	14.6	15.9	29.6	30.2	21.7	66.48
<i>Trichoderma harzianum</i>	1%	23.3	25.5	25.6	27.0	28.7	37.5	27.9	56.82
<i>Pseudomonas fluorescens</i>	1.5%	16.9	24.3	19.6	24.0	32.6	38.6	26.0	59.80
Neem solution	2%	32.7	35.1	41.6	45.6	45.9	50.8	42.0	35.15
<i>Bacillus subtulis</i>	1%	27.2	33.3	31.4	30.2	49.6	50.2	37.0	42.82
Control		60.6	69.1	59.6	68.1	59.6	71.1	64.7	-
S.Em±		2.3	2.8	2.6	1.9	0.9	1.2		
C.D. ( <i>P</i> =0.05)		4.8	3.1	3.6	3.8	2.1	2.7		

\*DAT= Days after Treatment



# NAGALAND

## WEATHER REPORT

The total rainfall received during the period April 2015 to March 2016 was 1354.4 mm (Fig 1). The total rainy days were 88 days (precipitation more than 2.5mm). The mean monthly maximum and minimum air temperature was varied from 23.8° C to 31.9° C and 9.2° C to 25.1° C, respectively (Fig 2). Monthly relative humidity ranged from 40% to 92%. Mean monthly wind speed ranged from 0.029 kmph during the month of December to 2.5 kmph in the month of April. Soil temperature was recorded in the morning (Fig 3) and evening (Fig 4) hours. It showed an increasing trend along with the depth. Highest total monthly evaporation was recorded in the month of March (92.0 mm) and lowest in the month of December (40.2 mm).

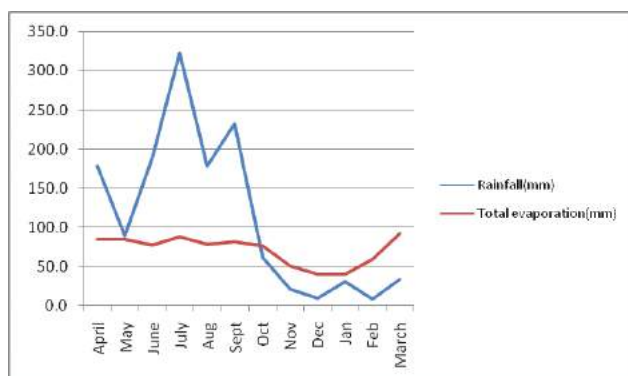


Fig 1. Mean monthly total rainfall and evaporation

## CROP SCIENCES

### RICE

#### High altitudes trial

Rice lines were collected from UPKAS (Almora), ICAR Research Complex for NEH Region (Umiam), SARS Mokokchung and farmers' field across the Nagaland to find out the best lines for Longleng and Wokha district of Nagaland. Experimental trials were conducted during the *kharif* at farmers' field of Wokha and Longleng. The result revealed (Table 1) that the significantly higher rice yield was recorded with Bhalum-3 (24.2 q/ha) followed by VL Dhan-209 (23.1 q/ha) and RCPL-1-412 (22.8 q/ha) at Longleng, whereas the highest grain yield was recorded with rice cv. SARS-1 (40.8 q/ha) at Wokha as compared to other tested lines. Among the local rice, Rukhatang (23.7 q/ha) at Longleng and Chakko Youh (32.6 q/ha) at Wokha was found to be the most potential line at both the places.

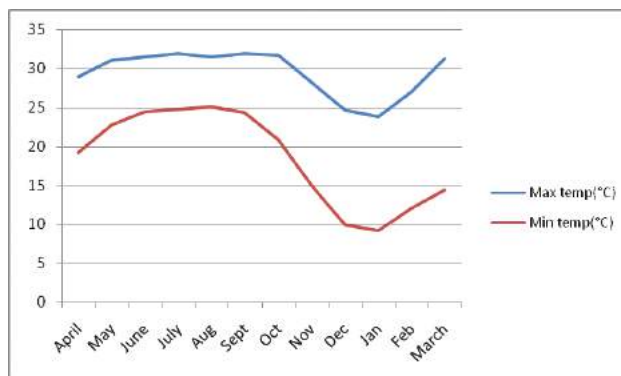


Fig 2. Mean monthly maximum and minimum temperatures

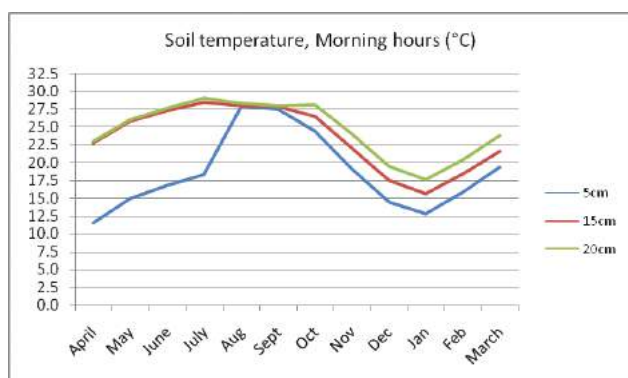


Fig 3. Mean monthly soil temperature during morning hours

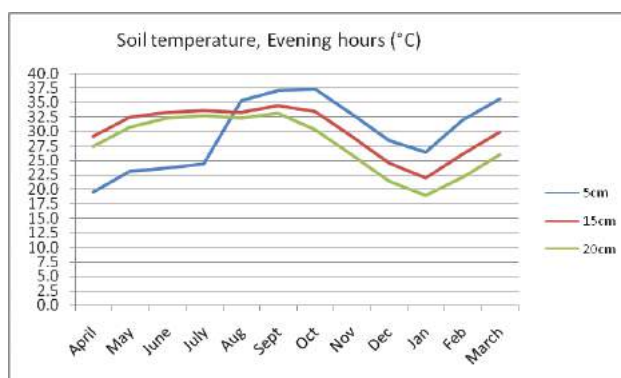


Fig 4. Mean monthly soil temperature during evening hours



**Table 1. Performance of yield attributes and yields of rice cultivar**

Variety	Grains/panicle (no.)		1000-Grain weight (g)		Grain yield (q/ha)	
	Longleng	Wokha	Longleng	Wokha	Longleng	Wokha
RCPL-1-412	110.0	109.2	29.6	21.40	22.75	26.87
Bhalum-3	67.0	103.40	29.0	26.80	24.25	27.30
SARS-1	143.0	231.8	26.5	24.80	17.45	40.78
SARS-2	117.5	63.80	26.5	23.60	17.60	17.98
SARS-5	122.0	109.62	26.0	22.20	18.50	28.43
VL-Dhan-62	82.5	82.60	27.2	22.00	16.15	22.00
VL- Dhan -65	77.0	92.00	29.6	23.20	14.05	24.38
VL- Dhan -154	50.0	72.80	28.1	23.20	9.40	16.80
VL- Dhan -208	76.0	71.00	28.5	23.20	21.45	21.42
VL- Dhan -209	98.5	81.00	28.3	22.60	23.10	19.96
VL- Dhan -221	58.5	36.00	26.5	22.40	11.60	12.60
Azoito	84.0	71.60	24.4	22.60	14.10	18.26
Chakko Youh	114.5	131.80	30.0	21.80	18.60	32.61
Taiho	122.0	105.20	31.5	21.60	16.10	27.32
Ongsho	133.5	91.00	29.2	22.60	16.10	25.76
Rukhatang	124.5	73.80	29.3	21.60	23.65	20.69
Malenken	108.0	79.80	30.2	20.40	22.30	19.28
Mesa	118.0	65.20	30.1	10.20	22.10	19.84
VL Dhan-224	49.5	89.20	23.5	21.20	9.70	20.12
Vepvutsok	110.0	63.80	22.9	20.00	18.40	16.80
SEM±	2.81	2.17	0.70	0.62	0.51	0.56
LSD ( $p=0.05$ )	8.04	6.20	1.89	1.78	1.46	1.60

## MUSTARD

### Adoptative Varietal Trial

Three early maturing Indian mustard varieties viz., PM-25, 26 and 27 and three local check viz., TS-36 and 38 were evaluated during the *rabi* season after harvesting of maize. Results revealed (Table 2) that the maximum seed yield was recorded with *toria* cv. TS-36 as local check (323.2 kg/ha) followed by TS-38 (235 kg/ha) as compared to early maturing Indian mustard i.e. PM-25, 26 and 27 yielded 168.2, 154.8 and 158.8 kg/ha, respectively.

**Table 2. Performance of early maturing Indian mustard varieties**

Variety	Plant height (cm)	Branches plant <sup>-1</sup> (No.)	Siliqua plant <sup>-1</sup> (No.)	Seed yield (kg/ha)
PM-25	112.34	2.34	123.34	168.30
PM-26	116.34	2.20	100.67	154.80
PM-27	123.67	2.20	933.34	158.80
TS-36	66.00	4.67	92.78	323.20
TS-38	74.67	5.34	102.34	235.60
TS-67	68.67	5.67	99.54	121.20
SEM±	1.68	0.11	3.42	6.89
LSD ( $P=0.05$ )	5.30	0.34	10.78	10.72

## RCRT Trial

## GREEN GRAM

### Performance of green gram entries

A total 06 entries of green gram developed at Tripura Centre were evaluated along with local check (Pratap) for their yield potential during the pre-*rabi* season at ICAR farm Jharnapani and results (Table 3) showed that the highest seed yield was recorded with green gram line TRCM-1-2-2 (1242 kg/ha) followed by TRCM 7-2-1 (1164 kg/ha) but lower yield as compared to Pratap as local check (1397.5 kg/ha).

## FRUITS

### Khasi mandarin

#### Status of decline citrus orchards

In decline *Khasi* mandarin orchards the soils pH range from 4.08 to 6.15, soil organic carbon from 0.60% to 2.67%, available N from 169.34 kg/ha to 526.85 kg/ha, available P from 2.02 kg/ha to 49.11 kg/ha and available K from 79.52 kg/ha to 661.36 kg/ha. The soil water holding capacity of these orchards ranges from 28.08% to 73.85%. Enzyme activities viz., dehydrogenase and phosphatase activities range from



**Table 3. Growth, yield attributes and yields performance of green gram lines**

Mungbean lines	Plant height (cm)	Trifoliate leaves (No.)	Branches /Plant (No.)	Seeds /pod (No.)	Pod length (cm)	Pods /Plant (No.)	Days to 50% flowering (No.)	Daysto maturity (No.)	Seed yield (kg/ha)
TRCM 314-1	54.00	23.34	3.38	11.19	3.17	38.00	32.00	53.00	1086.90
TRCM 7-2-1	46.67	20.00	2.52	11.27	3.91	33.33	32.00	53.00	1164.60
TRCM 1-2-2	48.34	19.12	2.19	11.86	3.30	28.09	34.00	53.00	1242.20
TRCM 151-1	47.67	20.45	2.45	10.90	3.90	40.32	34.00	56.00	931.60
TRCM 5-4-2	50.23	20.11	2.35	11.68	3.77	31.26	31.00	56.00	1009.30
Sonamug	38.00	16.78	2.57	10.42	2.78	26.55	29.00	58.00	776.40
Pratap (LC)	45.78	15.23	2.33	11.27	2.97	34.35	29.00	58.00	1397.50
SEM±	1.08	0.46	0.06	0.25	0.08	0.84	0.73	1.25	21.81
LSD (P=0.05)	3.32	1.61	0.18	0.76	0.26	2.59	2.24	3.85	67.21

0.97-13.3 µg (TPF)/g (dw)/h and 4.10-10.74 µg (PNP)/g (dw)/h, respectively. Basal respiration ranges from 0.031-1.077 µg CO<sub>2</sub>/g (dw)/hr. Total nitrogen ranges from 0.16% to 0.38%, phosphorus range from 0.005% to 0.015% and potassium ranges from 0.39% to 2.16% in citrus leaf samples. The plant analysis shows that the orchards were sufficient in K content and deficient in N and P content.

## GUAVA

### Evaluation of guava lines/varieties

The four guava lines viz., RCG-11, RCGH-1, RCGH-4 and RCGH-7 developed at ICAR Research Complex for NEH Region, Umiam along with two standard checks L-49 and Allahabad Safeda were evaluated at a spacing of 5 x 5 m. Results (Table 5) revealed that the line RCGH-1 recorded the maximum plant height (3.04 m), plant girth (35.17 cm) and canopy spread (3.64 m EW and 3.85 m NS) which indicated that the plants were sturdy whereas L-49 recorded the lowest height (2.05 m). The RCGH-4 recorded the maximum fruit weight (171.28 g) and fruit size (6.23/6.97 cm) followed by RCGH-7. Similarly, the highest yield was recorded in RCGH-4 (15.22 kg/tree) followed by Allahabad Safeda (14.16 kg/tree).

The maximum TSS (11.53° B), total sugars (8.52%) with minimum acidity (0.40%) was recorded in RCG-11.

## VEGETABLES

### KING CHILLI

#### Study on incidence of diseases in Naga Kind chilli

In Naga King chilli, damping-off causes a disease incidence of 28 % followed by dieback (22%) and viral mottle virus (21%). Pathogens like *Pythium*, *Fusarium* and *Colletotrichum* were isolated from samples showing symptom of damping off, wilt and anthracnose.

#### In-vitro screening of endophytes against the pathogens

The bacterial endophytes were screened *in vitro* against *Pythium*, *Fusarium* and *Colletotrichum* pathogens of Naga king chilli to measure the bio-efficacy. Among the twenty isolates, KEB15 isolate showed the per cent inhibition of mycelial growth of *Pythium* to an extent of 66.67% over control followed by KEB5 to an extent of 64.07% (Fig 5). In case of *Fusarium*, KEB5 showed the maximum mycelial

**Table 5 Evaluation of guava lines/varieties for growth, yield and quality attributes**

Variety	Plant height (m)	Plant girth (cm)	Canopy spread (m)		Fruits size (L/ W) (cm)	Weight (gm)	Yield (kg/tree)	TSS (°B)	Titratable acidity (%)	Total sugars (%)
			East-West	North-South						
RCGH-1	3.04	35.17	3.64	3.85	4.77/5.47	145.17	9.50	11.03	0.42	8.15
RCGH-4	2.93	32.67	3.07	2.92	6.23/6.97	171.28	15.22	9.63	0.55	6.09
RCGH-7	2.54	30.00	3.11	3.27	5.37/5.20	147.75	8.26	10.37	0.48	7.80
RCGH-11	2.37	29.00	2.81	2.71	4.07/4.27	124.30	13.43	11.53	0.40	8.52
L-49	2.05	28.62	2.32	2.59	5.00/4.77	128.47	10.80	10.00	0.50	7.27
Allahabad Safeda	2.32	28.63	2.32	2.68	4.87/4.47	115.10	14.16	9.83	0.54	6.79



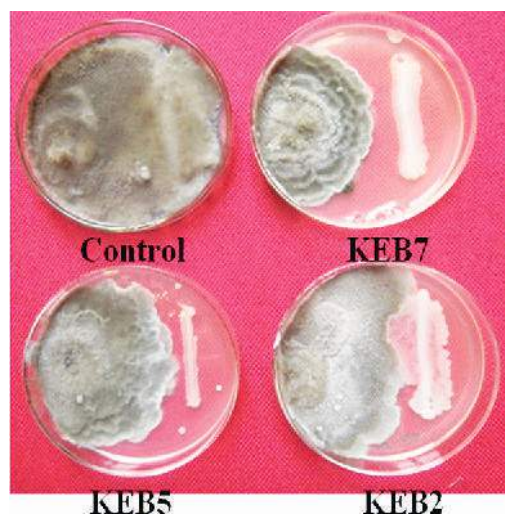


**Fig 5. In vitro screening of endophytic bacteria against *Pythium* spp.**

inhibition of 69.26 per cent over control followed by KEB2 with mycelial inhibition of 60.37% (Fig 6). Isolate KEB7 recorded the maximum mycelial inhibition of 66.30% against *Colletotrichum* over control and followed by 60.33% of inhibition was noticed in KEB2 isolate (Fig 7).



**Fig 6. In vitro screening of endophytic bacteria against *Fusarium* spp**



**Fig 7. In vitro screening of endophytic bacteria against *Colletotrichum capsici***

#### **Isolation and identification and characterization of *Ralstonia* causing bacterial wilt of Naga King chilli**

The wilt infected Naga King chilli sample were kept for the ooze test and found the presence of oozing from the infected stem portion. The ooze solution was used for isolation in TTC (2,3,5-triphenyltetrazolium chloride) media. The pathogen produces the pink colour confirmed as *Ralstonia*. Different biochemical

tests viz., KOH, starch hydrolysis, catalase, oxidase and Nitrate reduction test were showed the positive reaction where as in NaCl test, growth of the bacteria was found @ 2% but not in case of @ 5% @ 10% @ 15% NaCl concentration.

#### **Characterization of Naga King chilli endophytic bacteria for the biocontrol potential**

Twenty isolates were tested for their PGP activities such as IAA, HCN production and Ammonia production, 5 isolates were found positive for HCN production (KEB3, KEB5, KEB7, KEB11 and KEB14), 16 were found positive for Ammonia production (KEB1, KEB2, KEB3, KEB4, KEB5, KEB7, KEB8, KEB10, KEB12, KEB13, KEB14, KEB15 KEB16, KEB17, KEB18 and KEB19) . 17 isolates were found as potential IAA (KEB1, KEB2, KEB3, KEB4, KEB5, KEB6, KEB7, KEB8, KEB9, KEB10, KEB12, KEB13, KEB14, KEB15, KEB16, KEB17 and KEB19) producer.

#### **Molecular characterization of endophytic bacteria and *Fusarium* wilt isolates of Naga king chilli**

To confirm isolates of bacterial endophytes, 16S-23S rRNA intervening sequence specific ITS1F (5' AAGTCGTAACAAGGTAG 3'); ITS2R (5' GACCATATATAACC CCAAG 3') primers were used to get an amplicon size of 560 bp. Amplification of 16S rDNA of 8 isolates with ITS1 and ITS2 region specific primer yielded 560 bp amplicon suggesting that the isolates belong to *Pseudomonas* genus. PCR was performed to identify the *F. oxysporum* using genus specific primers ITS FU F (5'CAACTCCCAAACCCCTGTGA3'); ITS FU R(5' GCGACGATTACCAGTAACGA3'). Four isolates of *F. oxysporum* was amplified at a fragment size of 389 bp in PCR analysis and were identified as *F. oxysporum* (Fig 8).

#### **Bioassay of crude antibiotics of bacterial antagonists against *Fusarium* pathogen by agar diffusion method**

Crude antibiotics of five isolates viz., KEB2, KEB5, KEB6, KEB7 and KEB11 of the endophytic bacterium of Naga King chilli were tested for its efficacy against the *Fusarium* wilt pathogen of chilli. The extracted antibiotic was assayed by agar plate method. Bacterial endophytic isolates were effective in suppressing the linear growth of the mycelium of *Fusarium* pathogen. The crude antibiotic isolated from KEB11 and KEB2 showed maximum inhibition area of 35.14mm and 34.16mm, respectively.



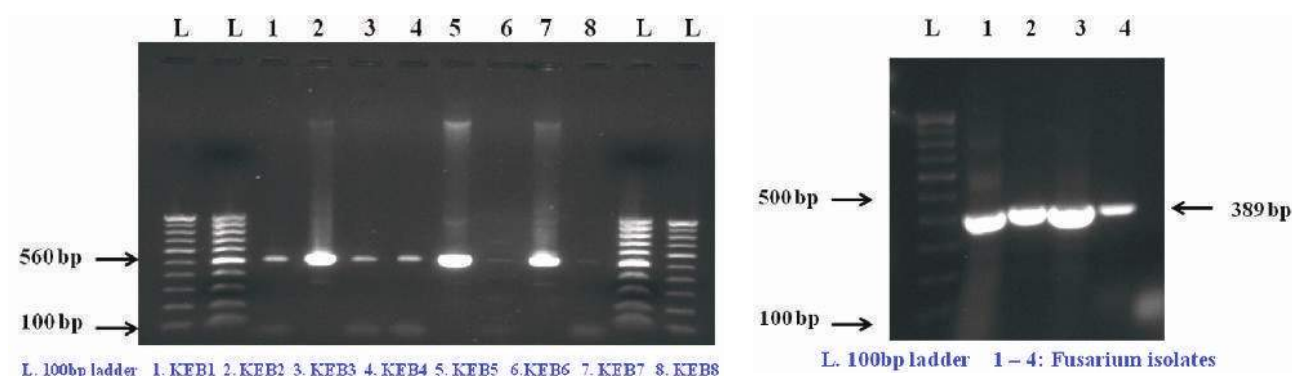


Fig 8. PCR amplification of ITS region of bacterial endophytes and *Fusarium* wilt isolates of Naga King chilli

## FABA BEAN

### First report of faba bean rust caused by *Uromyces vicia-faba* and faba bean yellow Mosaic in India

The occurrence of rust disease on faba bean was observed during January-February, 2016 in Research Farm, Jharnapani, Nagaland as a first report of rust disease on fababean in India (Fig 9). The rust pustules initially light brown later turn into dark brown in colour. After aging, rust pustules become corky encrustation on leaves. Under microscope, the rust spores were observed and confirmed with the presence

of uredospores and teliospores. Uredia are light brown rounded with double layer, where as teliospores are long elongated in nature. Occurrence of yellow mosaic virus disease on faba bean was also reported first time in India at ICAR Research farm, Jharnapani. Development of yellow discolouration on leaves leading to the reduced leaves size and stunted growth of the plant. Fifty nine faba bean lines were screened for root rot and rust disease under field condition. The maximum root rot incidence of 4.88% was recorded in HB-613 line and maximum rust disease incidence was recorded in EC-628957 line (90%).

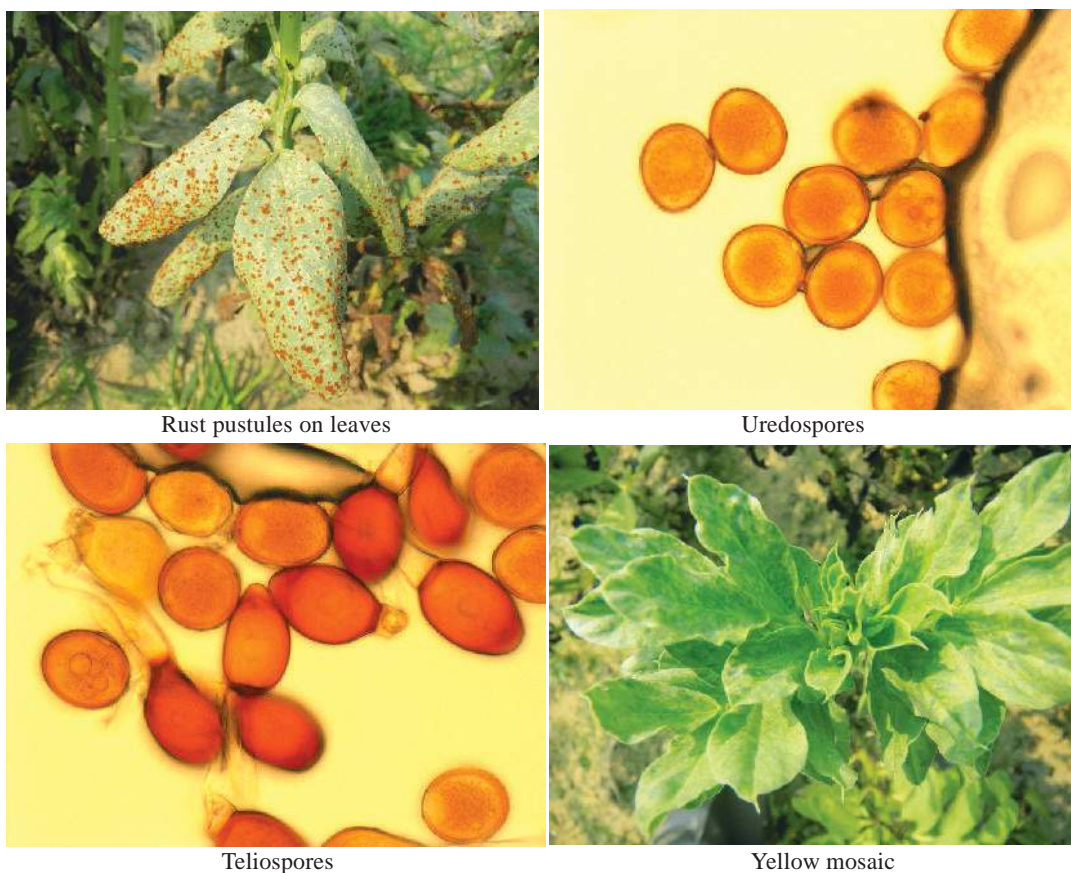


Fig 9. Fababean rust (*Uromyces vicia-faba*) and faba bean yellow Mosaic



## GARLIC

### Evaluation lines/varieties

Among the 21 Garlic lines supplied by DOGR, Pune (Table 6), GN 14-23 recorded maximum plant height (55.50 cm) followed by GN 14-7 (45.67 cm). Maximum leaf number (15 no.), leaf length (35.67cm) and leaf width (1.45 cm) was observed in GN 14-23. Highest pseudostem length (28.75 cm) was recorded in GN 14-23 closely followed by GN 14-25 (27.17 cm).

### Screening for disease and pest resistance

Twenty one garlic lines were found susceptible to stemphylium blight (Fig 10). The maximum PDI of 95.5 was reported from GRL-1337 whereas least



Fig 10. Garlic Stemphylium blight

disease index of 21.0% was reported in GRL-1349. These lines were also screened against viral complex (Fig 11) caused due to multiple infections of virus of onion yellow dwarf, leek yellow stripe virus, common latent virus and garlic virus X. Among all lines, RL-1349 reported maximum disease incidence of 20.60%. Less infection of leaf curling and thrips incidence was also reported in few lines.



Fig 11. Garlic viral complex

## CASSAVA

### Screening of varieties against cassava mosaic virus

Among two cassava varieties screened against cassava mosaic virus disease under field condition variety Shree Vijaya was found free from disease whereas variety Shree Rekha infected by 40% at 30

Table 6 Vegetative characteristics of garlic lines/varieties

Entry	Plant Height (cm)	No of leaf	Leaf length (cm)	Leaf width (cm)	Pseudostem length (cm)	Pseudo dia. (cm)
GN14-27	40.33	11.0	21.47	1.35	24.17	0.42
GN14-15	37.33	6.0	16.52	0.93	12.25	0.23
GN14-23	55.50	15.0	35.67	1.45	28.75	0.43
GN14-17	46.67	8.0	31.83	1.37	21.50	0.45
GN14-13	40.00	8.0	27.83	0.78	19.17	0.37
GN14-11	45.00	8.0	32.92	1.73	9.58	1.08
GN14-25	45.00	9.0	29.50	1.05	27.17	0.73
GN14-7	45.67	12.5	30.67	1.37	26.00	0.55
GN14-5	33.83	6.0	23.33	1.20	10.52	0.24
GN14-1	38.67	8.0	15.08	1.00	23.59	0.34
GN14-19	37.67	8.0	30.08	1.95	7.83	1.05
GN14-21	35.50	8.0	31.17	2.13	9.67	0.85
GRL-1349	21.83	10.0	15.08	1.27	13.75	1.03
GRL-1335	39.67	8.0	29.50	1.88	9.33	0.80
GRL-1345	45.50	12.0	22.50	1.23	23.20	0.43
GRL-1351	55.00	12.0	34.67	1.62	10.00	0.60
GRL-1332	48.67	14.0	32.00	1.47	22.50	0.40
GRL-1337	44.00	12.0	29.17	0.75	19.67	0.33
GRL-1330	44.83	12.0	25.92	0.88	21.58	0.55
GRL-1340	38.33	6.0	24.58	0.75	13.75	0.40
GRL—1328	31.17	12.0	16.58	1.22	14.59	0.60



days after planting (DAP) and 53.33% was observed at 60 and 90 DAP.

### Diseases under *jhum* cultivation its analysis and management

The different treatment combinations with antagonists included *Trichoderma harzianum* and *Pseudomonas fluorescens*, soil amendment (mustard oil cake), botanical and ITK (sprinkling ash) were studied for the management of diseases under *jhum* condition. The combination of antagonists as seed treatment and soil application with MOC recorded no incidence of disease in ginger (0.00%) with yield of (1.90 t/ha). Combination of seed treatment and soil application of *T. harzianum* and *P. fluorescens* resulted high yield (7.10 t/ha) in colocasia with only 8.33 per cent of blight disease incidence. Anthracnose disease incidence in beans recorded lowest (0.4%) in the treatment combining seed treatment with the antagonists and soil application of MOC with yield of 0.8 t/ha. The treatment of seed and soil application with the bio agents resulted in least incidence of blast disease (2.60%) with an average yield of 1.10 t/ha.

## INTEGRATED FARMING SYSTEM

### Comparative evaluation of IFS models suitable for small and marginal farmers

A total of four different integrated farming system (IFS) models were established (Table 7) viz., Model 1: Horticulture + Piggery + Fisheries, Model 2: Agriculture + Horticulture + Duckery + Fishery, Model 3: Agriculture + Horticulture + Piggery + Fishery, Model 4: Agriculture + Horticulture + Poultry + Fishery + Azolla + Mushroom. The vermicompost unit was included in all the models. Each IFS models was allocated a minimum area of 0.4 ha (1.0 acre). In model 1, pig recorded maximum profit followed by tuber crops (colocasia and elephant foot yam). In model 2, paddy registered maximum profit followed by fruit crops. In model 3, pig recorded maximum profit followed by fruit, vegetables and maize. In model 4, paddy, banana and poultry registered the maximum profit. From the results Model 2 i.e. Agriculture + Horticulture + Duckery + Fishery registered higher net profit of Rs.26608/- followed by Model 3 (Rs.22795/-) as compared to Model 4 (Rs.14915) and Model 1 (Rs.13190/-).

Based on the results, pig and rice followed by toria/ linseed was found best in terms of productivity and profitability in IFS. Along with pig and rice followed

**Table 7 Economics of different farming system models**

Models	Components	Gross income (Rs)	Cost of cultivation (Rs)	Net income (Rs)
Model 1	Horticulture	8170	3350	4820
	Fishery	720	600	120
	Piggery	29250	21000	8250
	<b>Total</b>	<b>38140</b>	<b>24950</b>	<b>13190</b>
Model 2	Agriculture	17000	4380	12680
	Horticulture	4528	1920	2608
	Fishery	2700	1200	1500
	Duckery	2320	1700	620
	Vermicompost	10200	1000	9200
	<b>Total</b>	<b>36748</b>	<b>10200</b>	<b>26608</b>
Model 3	Agriculture	9920	3520	6400
	Horticulture	8645	2270	6375
	Fishery	-	-	-
	Piggery	28750	21980	6770
	Vermicompost	3750	500	3250
	<b>Total</b>	<b>51065</b>	<b>35225</b>	<b>22795</b>
Model 4	Agriculture	10550	3520	7030
	Horticulture	6350	2380	3970
	Fishery	-	-	-
	Poultry	1400	2100	-700
	Mushroom	2500	935	1565
	Azolla	500	150	350
	Vermicompost	3000	300	2700
	<b>Total</b>	<b>24300</b>	<b>9385</b>	<b>14915</b>

by linseed/toria, planting of banana/Assam lemon/ Amrapalli mango in the borders and intercropping with radish/mustard/ colocasia/ elephant foot yam will increase the productivity. Out of different species of fish, silver carb and rohu were fast grower and can give maximum fish yield. The cultivation of pumpkin, bitter gourd, ridge gourd, beans and bottle gourd above the pond using bamboo trellis should be promoted to utilize the space and to get additional income. The weeds/grasses, crop residues and waste materials from vegetable and animal components were used for vermicompost preparation.

## ANIMAL SCIENCE

### Poultry Seed Project

The parent stock of Vanaraja and Srinidhi were maintained at farm. A total of 82,440 numbers of eggs were produced from which 39,044 numbers of chicks were produced in the hatchery unit established at the centre. Altogether 39,044 chicks distributed to the beneficiaries at subsidized rate in Nagaland, Arunachal, Assam and Meghalaya at day old or after rearing for 3-4 weeks at brooding unit (Table 8). A total of 173



**Table 8. Production status of fertile eggs and chicks during 2015-16**

Breed	Egg produced	Egg set	Chicks hatched	Fertility	Hatchability on TES	Hatchability on FES	Chicks distributed	Revenue (Lakh)
Vanaraja	55487	35685	15086	66.72	42.28	63.36	—	—
Srinidhi	26953	48984	23678	69.81	48.34	69.24	—	—
<b>Total</b>	<b>82440</b>	<b>84669</b>	<b>38764</b>	<b>68.51</b>	<b>45.78</b>	<b>66.83</b>	<b>39044</b>	<b>14.91</b>

farmers were covered under TSP of Poultry Seed Project and given assistance by providing 8613 nos. of grown up chicks of Vanaraja and Srinidhi varieties among the beneficiaries (Fig 12).

**Fig 12. Vanaraja and Srinidhi maintained by the beneficiaries**

### Mega Seed Project on Pig

Parent stock of Ghungroo, Hampshire and crosses of Ghungroo and Hampshire breeds of pigs were maintained under the project. A total of 844 numbers of piglets were born, of which 541 piglets were distributed to beneficiaries (>150), different NGOs and

KVKs in different parts of Nagaland as well as in the neighboring states (Table 9). The feedback from all the corners of the state is very encouraging and demand of piglets produced under the project is increasing enormously.

Artificial insemination in pig was popularized in Nagaland to enhance the production of piglets from superior breeding stock under Mega Seed Project on Pig (Table 10). The performance appraisal of artificial insemination program from adopted organized farm and farmers' field were conducted. The conception rate was recorded to be 58.23% in the MSP farm following double insemination with average litter size 8.13. The low conception rate could be attributed to outbreaks of FMD among the parent stock. However, in field condition the conception rate was increased from previous years (74.5 %) with litter size averaging 7.15. Farmers' visits to the farm were conducted by different KVKs at the MSP farm for creating awareness about improved techniques of breeding and management.

**Table 9. Piglet production status during 2015-16**

Parent stock	Piglet born	Piglet distributed	Adult animal culled	Revenue from sale of semen(in Rs.)	Total Revenue (Rs. in Lakhs)
63(58F:5M)	844	541	11	13570	16.39

**Table 10 Performance of AI conducted at farm and field level**

Location of AI adopted farm	No. of insemination	No. of animals conceived	Conception rate	Service per conception	Litter size
<b>Mega Seed Project farm</b>	79	46	58.23	1.72	8.13 (3-12)
Dimapur town	61	48	78.69	1.27	6.89 (4-11)
Kohima	54	41	75.93	1.32	8.31 (5-10)
AICRP on Pig farm, SASRD Medziphema	20	14	70.00	1.43	6.28 (5-11)
Molvom	18	12	66.67	1.5	5.66 (4-9)
Jharnapani village	27	20	74.07	1.35	6.9 (4-12)
Kukidolong	10	6	60.00	1.67	7.16 (5-9)
Ruzephema	6	4	66.67	1.5	8.25 (6-9)
Medziphema Town	4	4	100.00	1	7.75 (5-9)
<b>Total in field condition</b>	200	149	74.50	1.34	7.15 (3-12)



## SIKKIM

### WEATHER REPORT

In Sikkim, maximum rainfall (671.7 mm) was received during May whereas minimum rainfall (1.4 mm) was recorded in January (Table 1). The maximum mean temperature (28.2° C) was observed in July and the minimum (7.5° C) in January. The maximum relative humidity of 99.3 % was observed during May and the minimum of 39.2% in March.

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 study revealed that among the cropping sequences, rice-fenugreek (leafy vegetable)-maize (green cobs) recorded the maximum system productivity (82.2 t/ha) followed by rice-vegetable pea-maize (green cob). Similarly, production efficiency (25.3 kg/ha/day) was also higher in rice-fenugreek (leafy vegetable)-maize (green cobs) followed by rice-vegetable pea-maize (green cobs) and lowest under rice-buckwheat

**Table 1. Monthly weather data of the year 2015**

MONTH	TEMPERATURE (°C)		RELATIVE HUMIDITY (%)		RAINFALL (mm)	EVAPORATION (mm)	RAINY DAYS (Nos.)	BRIGHT SUNSHINE (hrs)
	MAX	MIN	MAX	MIN				
January	17.2	7.5	93.3	44.2	0.0	8.0	0	2.79
February	18.5	8.4	91.2	42.9	2.8	7.9	03	3.69
March	22.8	11.8	85.2	39.2	69.9	9.4	13	4.27
April	25.7	14.2	86.3	40.5	159.4	10.2	15	4.91
May	26.4	17.1	99.3	55.9	671.7	9.2	26	3.69
June	27.8	20.1	92.3	63.6	543.5	7.9	27	1.36
July	28.2	20.5	92.1	62.9	541.7	8.3	29	2.40
August	27.4	20.2	91.6	67.9	514.7	8.8	30	2.63
September	26.7	18.9	87.3	69.7	363.1	8.8	27	2.92
October	25.9	14.9	89.6	47.5	16.7	9.0	07	5.89
November	20.9	13.0	89.4	48.2	1.4	8.2	03	2.96
December	17.9	9.0	87.3	45.3	5.8	5.3	01	2.01

### AGRONOMY

#### Effect of cropping system on system productivity and production efficiency

Diversification of rice through inclusion of leguminous crops was tested in a fixed plot field in Completely Randomized Block Design (CRBD) comprising seven cropping systems (Fig 1) viz., rice-maize, rice-fenugreek (leafy vegetable)-maize (green



**Fig 1. Diversification of rice based cropping system**

#### Effect of Biochar on crop productivity

Impact of Biochar on crop productivity was assessed in factorial randomized block design, assigning three levels of Biochar viz., control, 1 t/ha and 2 t/ha as a factor A and five levels of FYM (control, 100% RDN, 75% RDN, 50% RDN and 25% RDN) as factor B. The study revealed that among the different treatment combinations application of 2 t/ha along with 100% RDN through FYM recorded higher grain yield of maize (3.82 t/ha). However, maximum yield of vegetable pea (5.62 t/ha) was recorded with the application of 2 t/ha and 75% RDN through FYM.

#### Diversification of maize-based cropping system through *in situ* moisture conservation practices for improving water and crop productivity

In Sikkim, cropping intensity is low due to non-availability of soil moisture during winter season as very low or no rainfall is received, hence, farmers generally grow maize as sole crop. Hence, *in situ* moisture conservation practices during winter season



through residue retention may play vital role for improving the crop productivity and enhancing the cropping intensity in the state. Keeping these in view an attempt has been made to diversify the maize-based cropping system by incorporating the legumes and *in situ* moisture conservation practices. The study revealed that among the cropping sequences, maize + cowpea-vegetable pea recorded maximum values of system productivity (18.0 t/ha) and production efficiency (49.4 kg/ha/day) followed by maize + cowpea - rajma (Fig 2). With respect to the moisture conservation practices, *in situ* retention of maize stalks + weeds biomass proved it superior over the other methods of moisture conservation (Fig 3).

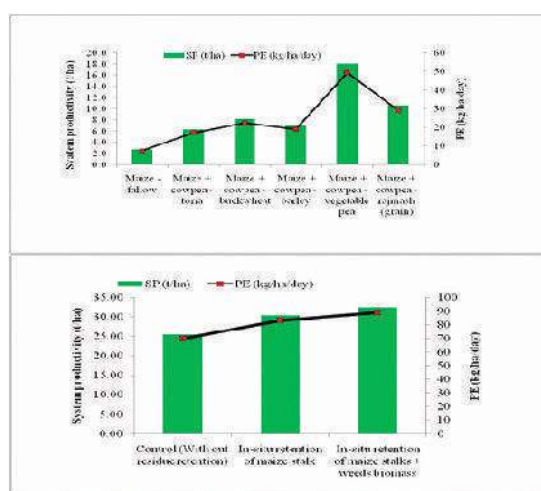


Fig 2. System productivity under different moisture conservation practices



Fig 3. Maize Stover + Weed biomass mulching

### Resource conservation techniques for improving productivity and resource-use efficiency of maize-pea cropping system

Inclusion of legumes in conservation agriculture for diversification of cereal-based cropping systems will help to overcome the problem of declining factor productivity. It is also assumed that the adoption of no-till practice will also help in timely seeding of either

of the crops in system mode, and hence, lead to increase in productivity of maize-based cropping system. Keeping these in view a fixed plot field experiment was started during 2014 to study the influence of resource conservation techniques on productivity and profitability of crops and cropping system. The experiment was carried out in split plot design consisting three tillage practices viz., conventional, reduced and zero tillage in main plot and four organic sources of nutrients viz., farmer practices, recommended dose N through organic sources, 75% of RDN of organic source + maize stalk/pea stover, 50% RDN of organic sources + maize stalk/pea stover and replicated thrice (Fig 4). The result showed that zero tillage with 100% RDN through organic sources recorded maximum system productivity (14 t/ha) and production efficiency (28.9 kg/ha/day) over the other tillage practices with organic sources of nutrients.

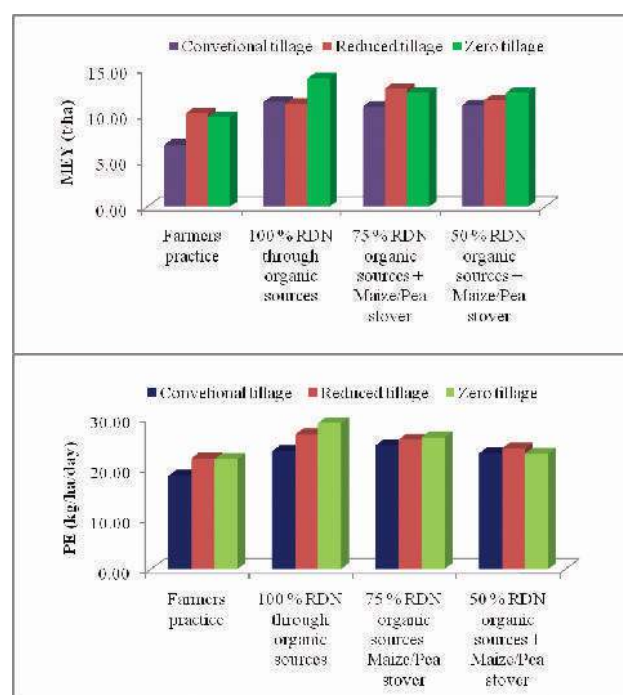


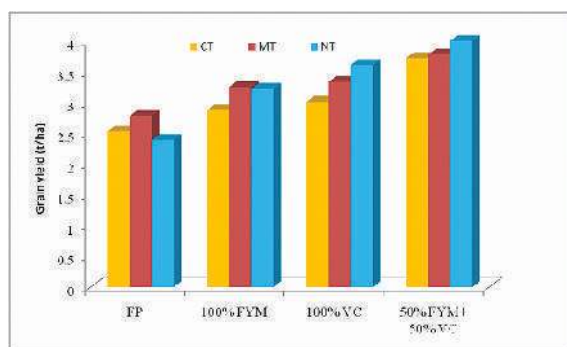
Fig 4. Maize equivalent yield and production efficiency under different tillage and nutrient management practices

### Effect of tillage practices and organic sources of nutrients on productivity of rice-vegetable pea cropping system

Rice-vegetable pea cropping system was evaluated under different tillage practices and organic nitrogen sources. The results revealed that significantly influenced by different tillage and organic nutrient sources, the highest grain yield of rice was recorded



with NT (3.31 t/ha) followed by RT (3.28 t/ha) and lowest in CT (3.03 t/ha). With regard to organic sources of nutrients, application of 50% FYM + 50% VC + Biofertilizer recorded significantly higher grain yield (3.83 t/ha) over other organic sources (Fig 5). Similarly, green pod yield of vegetable pea was also found to be significantly influenced by tillage practices and organic nutrient sources. The highest pod yield was recorded under no-till (4.96 t/ha) followed by RT (4.46 t/ha) and lowest with CT (4.10 t/ha). With respect to the system productivity, among the tillage practices, maximum system productivity (10.8 t/ha) was recorded with no-till and substitution of organic manures also had significant effect and application of 50% FYM + 50% VC + Biofertilizer recorded higher system productivity (10.34 t/ha) over farmer practices (8.25 t/ha). It was also found that under double no-till technology turnaround time of about 12-15 days was reduced for sowing of vegetable pea. Double no-till technology also conserved soil moisture as compared to conventional and reduced tillage practices. During the study, about 18-20% higher soil moisture was noticed under double no-till practice as compared to conventional method of tillage.

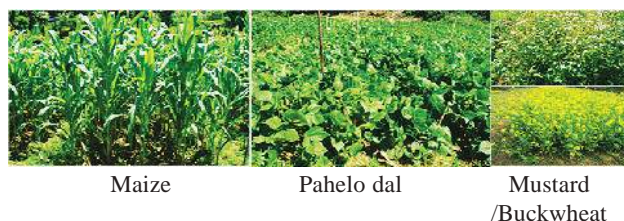


**Fig 5. Grain yield of rice under different tillage and organic nutrient management practices**

### Development of climate resilient maize-based cropping system for mountain ecosystem under organic management

Farmers practice mono cropping of maize in the state due to which the cropping intensity of Sikkim is very low (118%) as compared to the national average of about 140%. Hence, an attempt has been made to increase the cropping intensity up to 300% in rainfed ecosystem through intensification of maize-based cropping sequences with inclusion of leguminous crop. Three cropping sequences viz., CS<sub>1</sub>- maize-fallow (FP), CS<sub>2</sub>- maize-urid bean (*pahelo dal*)-buckwheat and CS<sub>3</sub>- maize-urid bean (*pahelo dal*)-mustard were

kept in main plot and four organic sources of nutrients (Fig 6) viz., control (farmers' practices); 50% FYM + 25% VC + 25% MC + biofertilizers; 50% MC + 25% FYM + 25% VC + Biofertilizers and 25% FYM + 25% MC + 25% VC + 25% PM + Biofertilizers in subplots with three replications. The results revealed that among the organic sources of nutrients application of 25% FYM + 25% MC + 25% VC + 25% PM + Biofertilizers recorded higher grain yield (3.88 t/ha) of maize and pahelo dal (0.73 t/ha) over the other sources on nutrients. The grain yield of maize was higher in CS<sub>2</sub> (3.64 t/ha) followed by CS<sub>3</sub> (3.6 t/ha). Similarly, maize responded to the mulching applied in *Rabi* season crops and recorded significantly higher grain yield (3.67 t/ha) over without mulching (3.56 t/ha).



**Fig 6. Climate resilient Maize- Pahelo dal – Buckwheat cropping system for rain fed conditions**

### Effect of local land races of rice (*Oryza sativa* L.) under different planting methods in mid hills of Sikkim Himalayas

In Sikkim, farmers generally grow local landraces (scented) by traditional methods which not only enhanced the use of resources but also recorded lower productivity. In order to evaluate the effect of local land races (scented) on productivity of rice under different methods of planting in Sikkim, an experiment was laid out in split plot design, assigning two methods of rice production viz., system of rice intensification (SRI) and conventional planting (CP) in main plots and three local cv. viz., Kalo Nunia, Bhrimphul, and Krishna Bhog allocated in subplots. All the treatments were replicated thrice. The results revealed that SRI recorded 20.2 per cent higher grain yield over the CP. Among the local cv., Krishna Bhog recorded significantly higher grain yield (2.94 t/ha) over others (Fig 7).

### Screening of sunflower (*Helianthus annuus* L.) varieties under organic management condition

In order to meet the demand of edible oil in the state, alternative oilseed crops such as sunflower (*Helianthus annuus* L.) is an option for the farmers in



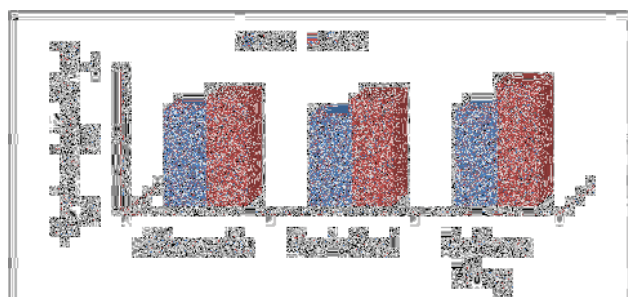


Fig 7. Grain yield of different rice cultivars

new areas. The oil content in sunflower is higher as well as the productivity may also be higher with its appropriate cultivation. In order to study that, varietal evaluation of sunflower was conducted at research farm of ICAR Sikkim Centre during *rabi* season. Among the different varieties tested, DRSH-1 recorded highest grain yield (1.96 t/ha) followed by KBSH – 44 (Table 2).

Table 2. Yield of different sunflower varieties

Variety	Days to 50 % flowering	Head diameter (cm)	Seed yield (t/ha)
DRSF - 108	99	18.9	1.65
DRSH - 1	112	21.3	1.96
KBSH - 44	105	20.1	1.83

#### Varietal evaluation of Finger millet under organic management condition

Varietal evaluation of Finger millet comprising of 15 varieties *viz.*, GPU-45, VL-324, VL-149, GPU-66, KMR-204, PR-202, INDAF-8, HR-911, VL-708, KMR-301, GUP-48, VL-352, KMR-201, GPU-28, INDAF-9 was carried out in mid hills of Sikkim during *kharif* season of 2015 at KVK East Sikkim. Among the varieties, VL-324 recorded maximum grain yield (1.91 t/ha) followed by INDAF-8 (1.76 t/ha) (Fig 8).

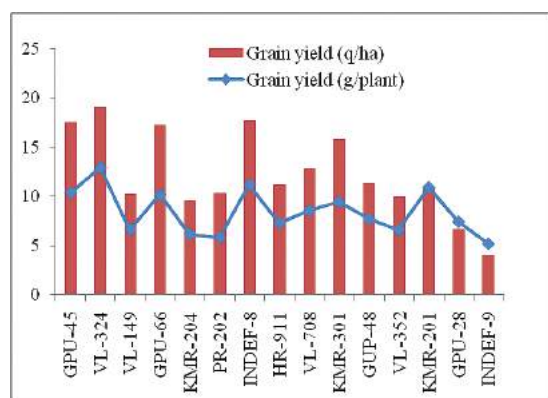


Fig 8. Grain yield of different finger millet varieties

## SOIL SCIENCE

### Performance of upland direct seeded rice variety under different sources of organic nutrients

Field experiments were conducted during three consecutive years 2013-2015 during *kharif* to evaluate the performance of four upland direct seeded rice varieties (Bhalum 2, Bhalum 3, RCPL-412 and Rajendra Bhagwati) under different sources of organic nutrients on yield, nutrient availability, soil health and carbon sequestration. The study consisted FRBD having 5 treatments *viz.*,  $T_1$ =Control,  $T_2$ =FYM 100%,  $T_3$ =FYM 75% + NC 25% + BF,  $T_4$ =FYM 50% + VC 25% + NC 25% + BF,  $T_5$ =VC 75% + NC 25% + BF. The pooled analysis showed that  $T_4$  recorded highest grain yield (Bhalum 2-35.97 q/ha, Bhalum 3- 38.53 q/ha, RCPL 412-43.54 q/ha, Rajendra Bhagwati- 27.37 q/ha) during the years. Pooled analysis also showed that N (129.1 kg/ha), P (14.3 kg/ha) and K (134.2 kg/ha) uptake was highest in RCPL-412.  $T_4$  resulted in significantly increase in soil organic carbon content as compared to other treatments (initial 0.92% to final 1.04%). Three years data showed that water productivity ( $\text{kg/m}^3$ ) was higher in RCPL-412 followed by Bhalum 3, Bhalum 2 and Rajendra Bhagwati.

### Soil organic carbon dynamics and fertility in response to organic nutrient sources under maize-based cropping system

Field experiment was conducted on clay loam soil during two consecutive years 2014 and 2015 (pre-*kharif*) to evaluate SOC dynamics and fertility status in maize-based cropping system (Fig. 9). Five treatments, *viz.*,  $T_1$ = Control;  $T_2$ = 75% N through FYM + green manure;  $T_3$ = 50% N through FYM + 25% VC + GM ;  $T_4$ = 33% N FYM + 33% N VC + GM;  $T_5$ = 25% N FYM + 25 % N VC + 25% N poultry manure + GM were laid out in FRBD design and replicated thrice. Initially the soil had 0.79% organic carbon, 193.2, 13.3 and 403.2 kg/ha available N, P and K, respectively with pH 6.2. The two year pooled analysis showed that  $T_4$  resulted in highest grain yield for RCM 1-3 (3.93 t/ha) and RCM 1-76 (4.27 t/ha). Application of different sources of organic nutrients reflected improvement in SOC (initial value 0.79% to final 0.85%). The varying fertility levels significantly influenced the plant height and dry matter accumulation at all the stages of crop growth.  $T_4$  registered significantly higher available N, P and K content in soil as compared to other treatments. The



grain and stover yield were influenced significantly due to varying fertility levels in different treatments. The higher available N, P and K in T<sub>4</sub> could be due to increased activity of microorganisms leading to greater mineralization of applied and native nutrients.



**Fig 9. Experimental field of soil organic carbon dynamics and fertility in response to organic nutrient sources under maize-based cropping system**

#### **Effect of organic nutrition on nutrient availability and yield attributes of buckwheat as a climate resilient crop**

Field experiment was conducted on clay loam soil during two consecutive years 2014 and 2015 (*rabi*) to evaluate effect of organic nutrition on nutrient availability and yield attributes of buckwheat. The pooled analysis showed that T<sub>4</sub> (FYM 5 t/ha + neem cake 0.5 q/ha + seed treatment with biofertilizers 200 g/kg seed) recorded highest seed yield (15.12 q/ha) along with B:C ratio 2.03 and harvest index 35.12. Results also showed an increased in soil pH ranged from 0.05 to 0.13 units in all treatments along with soil organic carbon from 0.07% to 0.25%. Soil available phosphorus (Bray P<sub>i</sub>) decreased from initial 22.6 kg/ha to 16.80 kg/ha in T<sub>4</sub> treatment indicating P uptake capacity of buckwheat from soil. Pot study revealed that lack of difference in buckwheat biomass between all the treatments may be a compensatory mechanism to uptake greater P uptake. Soil-P availability and concentration of rhizosphere tartrate was significantly higher ( $p < 0.005$ ) in no FYM pot than added FYM pot suggesting organic-anion root exudation has a role in buckwheat rhizosphere P dynamics (Table 3).

#### **Effect of different organic nutrient sources on changes in soil enzyme activity in maize-Pahelo dal cropping system**

Effect of different organic nutrient sources on soil enzymatic activities were studied in North Eastern sub

**Table 3. Effect of buckwheat on soil P availability and organic acids (pot study)**

Variable	Added FYM	Without FYM	p value
Soil-P availability/ $\mu\text{g}$ (g dry soil <sup>-1</sup> )	13.94b	15.3a	<0.005
Buckwheat shoot biomass /g dm plant <sup>-1</sup>	0.36a	0.35a	0.275
Buckwheat root biomass /g dm plant <sup>-1</sup>	0.27a	0.28a	0.251
Rhizosphere tartaric acid conc./ $\mu\text{g g}^{-1}$	0.27b	0.51b	<0.005

Mean ( $\pm$  SD) soil P availability, dry buckwheat plant biomass, and rhizosphere tartaric acid concentration at the time of buckwheat harvest

temperate hilly agro-ecosystem. Comparing with control treatment, addition of poultry manure (PM), farmyard manure (FYM) and vermicompost (VC) increased SOC (initial 0.89%) by 15%, 27% and 23%, respectively (FYM @ 10 t/ha, VC @ 2.5 t/ha, PM @ 2 t/ha). Dehydrogenase activity was higher in the FYM treatments followed by VC and PM treatments than control. Protease and cellulase activity was increased in all the treatments significantly except control. Alkaline phosphatase and urease activity was more influenced by application of FYM compared with VC and PM. Phosphatase activity was increased which may be attributed to microbial stimulation by organic C and soil pH. Differences in all enzymatic activities narrowed down in residual treatments compared to control having little change in the trend in maize-Pahelo dal cropping system.

#### **Effect of biochar on soil health and productivity of maize-pea cropping system in acidic soil of Sikkim**

Application of *Lantana* spp. biochar had shown significant increase in soil pH (initial 5.4 to 6.7) followed by *Ageratum* spp. (6.5), *Neyrardia* spp. (6.3), *Artemisia vulgaris* (6.1), *Bidens* spp. (6.0), *Chromolaena odorata* (5.9) (Fig 10). Application of 5 t/ha biochar and 100% RDN through FYM recorded higher grain yield of maize (4.57 t/ha). However, maximum yield of vegetable pea (6.13 t/ha) was recorded with the application of 2.5 t/ha biochar and 100% RDN through FYM. Application of 5.0 t/ha biochar along with 100% RDN through FYM increased SOC significantly (0.81 to 2.23) as compared to other treatments. Higher application rates of biochar



significantly reduced root nodules but increased nodules biomass along with decreased SPAD (chlorophyll content) values. Soil moisture investigation at 0-15 cm and 15-30 cm depth showed higher soil moisture content (SMC) under biochar applied with 5.0 t/ha as compared to biochar at 2.5 t/ha and no biochar application in both the layers.



Fig 10. Biochar application in an experimental field

## HORTICULTURE

### Year round organic leafy vegetable production technology under low cost plastic tunnels

In Sikkim, due to heavy rainfall it is difficult to produce quality organic leafy vegetables under open conditions. Studies conducted to grow year round organic leafy vegetables under low cost plastic tunnels and open conditions revealed that leafy vegetables viz., coriander, fenugreek and spinach can be successfully produced year round under low cost plastic tunnels.

The increase in coriander yield was observed from April to September with maximum (2 kg/m<sup>2</sup>) during August and September under low cost plastic tunnels. The crop duration varied from 36 days (August) to 66 days in October sown crop. Fenugreek also showed similar yield trends during rainy season with earliest maturity (27 days) in May and late maturity (57 days) in December sown crop. Spinach yield was maximum (4.5 kg/m<sup>2</sup>) in November sown crops followed by October and December sown crops (3.8 kg/m<sup>2</sup>). However, no marketable yield of leafy vegetables was obtained under open conditions due to peak rainy season from May to August. In general, leafy vegetables yield was significantly higher under low cost plastic tunnels during rainy season; however, the yield of leafy vegetables grown under open conditions was at par with low cost plastic tunnels yield during winter months (Fig 11).

### Flagship Program on Temperate Horticulture

#### Kiwifruit

Organic package of practices has been standardized for maximization of 'A' grade Kiwifruit (Fig 12) production and studies have been undertaken on hand pollination techniques and its effect on per cent fruit set, fruit growth, fruit yield and fruit quality. Hand pollination showed good response in producing high yield of good quality fruits. The best time of hand pollination was observed at 10-12 am to get the maximum fruit set. Pollen viability was observed up

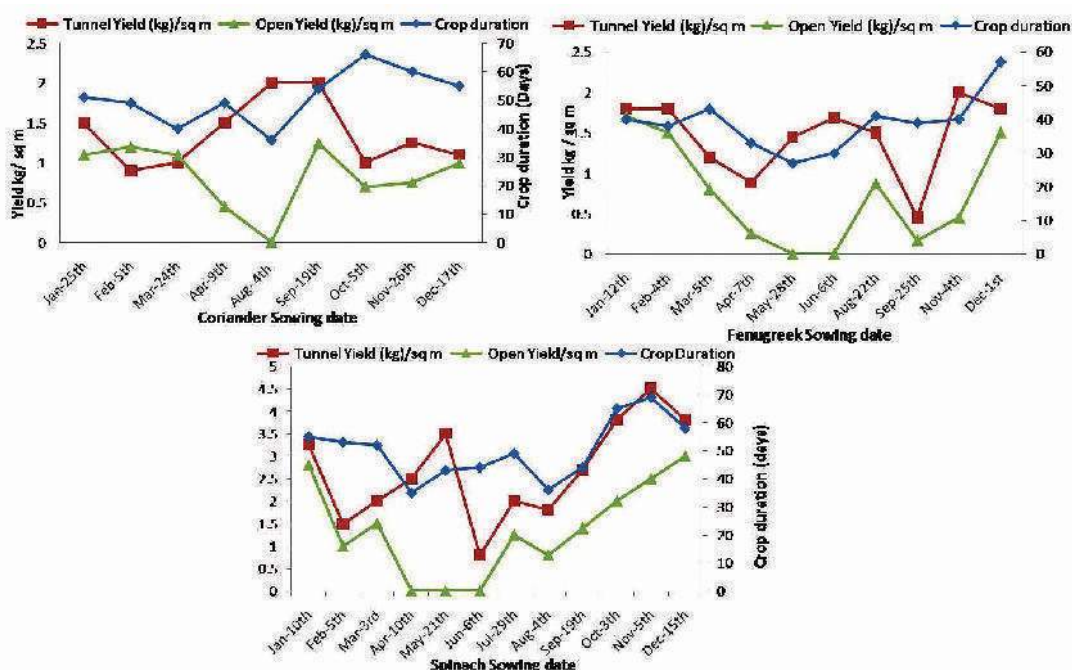


Fig 11. Yield of coriander, Fenugreek and Spinach in different sowing dates



to 72 hrs for hand pollination, however, maximum (100%) and 90% fruit set was observed within 24 hrs and after 48 hrs of anther removal respectively. Time of hand pollination and organic nutrient management showed



**Fig 12. Kiwifruit bearing tree**

significant effect on fruit weight (100-120 g) of kiwifruit variety Monty and Bruno over control (50-60 g) and TSS content varied from 17-21°Bx. Besides, kiwifruit plant multiplication by semi-hardwood cuttings under low cost farmer friendly structure has also been standardized at ICAR Sikkim Centre. Sterilized growing medium composed of perlite, vermiculite, cocopeat and vermicompost (1:1:1:1 ratio) is being used for propagation through semi-hardwood cuttings under jute bag made low cost tunnels. Cuttings were taken from semi-mature growth of the current season. Cuttings of 0.5-1.0 cm thickness with relatively short internodes and about 15-20 cm in length were most ideal. Base of cuttings wounded and dipped in 400 ppm IAA for 24 hr and then planted in growing media and in moist soil under greenhouse. Relative Humidity (70-80%) was maintained by regular spraying of water on jute bags after shoot emergence to prevent desiccation.

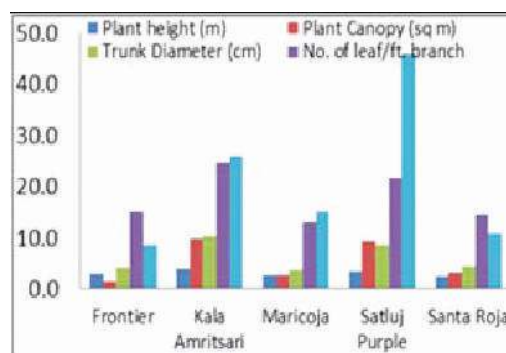
### Plum and Pomegranate

Two year evaluation studies after planting showed significant variations for vegetative growth parameters in plum and pomegranate. Plum cultivars Kala Amritsari (Fig 13) showed maximum plant height (3.9 m), plant canopy (9.8 m<sup>2</sup>) and trunk diameter (10.4 cm), however, plant height was minimum in Santa Rosa and plant canopy observed minimum in Frontier under uniform cultural practices (Fig 14). Maximum trunk diameter (23.8 mm) and plant height (1.83 m) was observed in Kandhari, however, minimum was in



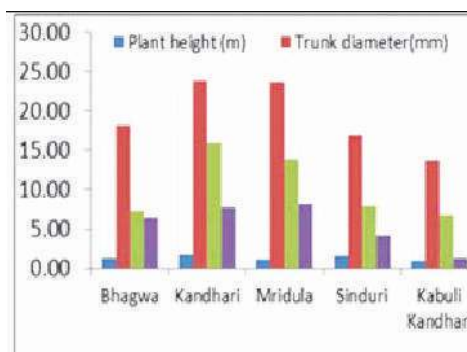
**Fig 13. Plum bearing tree**

Kabuli Kandhari as 13.8 mm and 0.89 m, respectively. Plant canopy maximum (8.2 m<sup>2</sup>) and minimum (1.3 m<sup>2</sup>) was noted in Mridula and Kabuli Kandhari, respectively (Fig



**Fig 14. Growth parameters of plum varieties**

15). With the organic package of practices, Satluj Purple and Kala Amritsari have produced fruiting in two years.



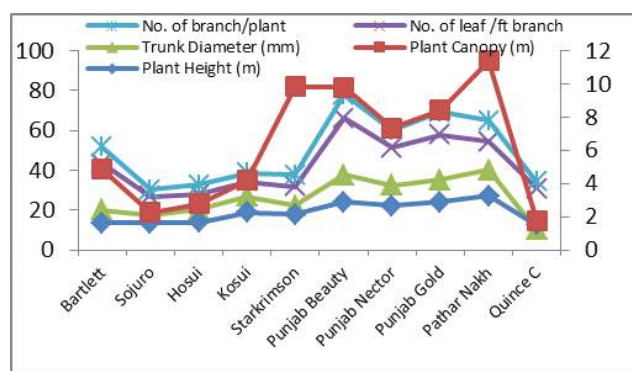
**Fig 15. Growth parameters of pomegranate varieties**

### Evaluation of pear germplasm suitable for cultivation under Sikkim conditions

Evaluation of nine pear cultivars (Asian pear: Punjab Nectar, Punjab Gold, Punjab Beauty, Patharnakh; Japanese pear: Kosui, Hosui, Sojuro; European pear: Bartlett, Starkrimson, Quince C) after three years of planting under uniform management practices showed significant variations for vegetative growth parameters viz., plant height, trunk diameter, number of leaves per ft. branch, number of branches per plant and plant canopy measurements. Low chill Pathar Nakh attained maximum plant height (3.25 m) and maximum trunk diameter (40.07 mm) followed by Punjab Beauty 2.90 m and 37.57 mm, respectively. However, the rootstock Quince C attained the minimum plant height (1.52 m) and trunk diameter (10.20 mm). Maximum plant canopy (8.14 m<sup>2</sup>) was observed in Pathar Nakh followed by Starkrimson (7.68 m<sup>2</sup>) and minimum plant canopy noted in Quince C (0.27 m<sup>2</sup>) followed by Sojuro (0.62 m<sup>2</sup>). Highest no. of leaves per ft. branch (28.57) was observed in Punjab Beauty followed by Bartlett (23.11) and minimum was in Hosui and Kosui (7.45) (Fig 16).



Highest no. of branches/plant was noted in Punjab beauty (11.78) followed by Punjab Gold (11.53) and minimum (3.26) was found in Quince C. Standardization of organic nutrient management and scheduling of biopesticide and biofungicide spray has also been carried out. Application of well-decomposed and dried cattle manure @ 20 t/ha in two split doses (*i.e.*, dormant stage in December and active vegetative growth stage in July), neem cake @ 2 t/ha, dolomite @ 2 t/ha, and vermicompost @ 2 kg/plant showed better growth response in all the pear varieties. Spray of petroleum-oil based spray mixed with neem oil in equal concentration @ 5 ml/l during April-May and July-August is effective for control of aphids, leaf miner *etc.* and spray of copper oxychloride @ 0.25% during April-May and July-August at 15 days interval is effective for the management of blight disease.



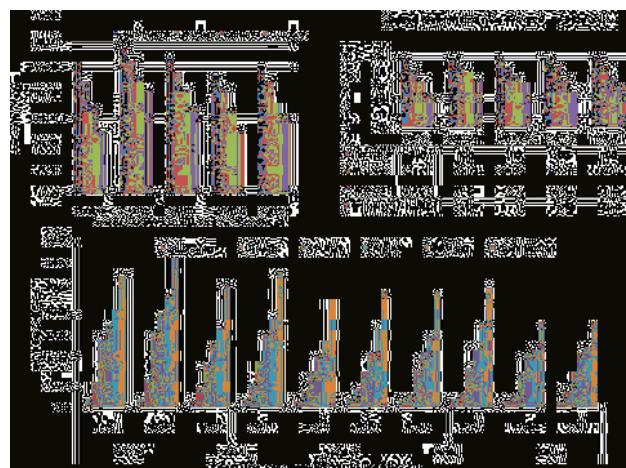
**Fig 16. Evaluation of pear germplasm suitable for cultivation under Sikkim conditions**

#### Evaluation of nano fertilizers on mandarin

Nano nutrient formulation @ 2 ml/litre sprayed on 05 years old Sikkim Mandarin plants grafted on different rootstocks at 45, 90 and 135 days after fruit set reduced fruit drop significantly as compared to control. Maximum fruit set (206 nos.), fruit length (54.81 mm), fruit width (61.97 mm) and highest per cent fruit retention (72.02%) was recorded in Sikkim mandarin grafted on Rangpur lime followed by Rough lemon (65.26%). The per cent fruit retention in Sikkim mandarin grafted on Grapefruit (63.68%) was at par with Rough lemon (Fig 17).

#### Evaluation and screening of chow-chow/squash (*Sechium edule*) germplasm under varied climatic conditions

ICAR Sikkim Centre has a collection of 86 chow-chow accessions (Fig 18). Morphologically different types and colours of fruits were observed *viz.*, round,



**Fig 17. Effect of nano fertilizers on mandarin**

oblong, spiny, very spiny, without spine and creamy white to green, dark green fruits. High range of fruit phenotypic variations were observed among the chow-chow accessions for several parameters under study such as fresh fruit weight, dry fruit weight, fruit length, fruit width, spine density per unit area and spine length in spiny types, peel thickness, seed weight, seed length, seed width and total soluble solid (TSS) contents. The fresh fruit weight ranged from 93 g to 1250 g, dry weight 7.09 g to 16.47 g/100 g fresh fruit, fruit length-37.5 mm to 178 mm, fruit width-47.2 mm to 102.7 mm, spine density-3.20 to 62.56 per square inch and spine length-0.5 mm to 7.17 mm in spiny types, peel thickness-0.14 to 0.51 mm, seed weight-10 g to 26 g, seed length-26.31 to 91.46 mm, seed width-9.52 to 47.31 mm and TSS from 2° Bx to 7.1° Bx were the variations recorded. The yield of chow-chow accessions varied from 0.5 to 62 kg per plant.

#### Regional trial on advance breeding lines of horticultural crops – Guava

Five guava varieties *viz.*, RCGH-1 (Sour type × Red fleshed local), RCGH-4 (Red fleshed × Allahabad Safeda), RCGH-7 (Lucknow-49 × Pear shaped),



**Fig 18. Chow-chow/squash (*Sechium edule*) germplasms of sikkim**



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. Evaluation studies on vegetative growth responses have been initiated for their suitability in Sikkim conditions and standardization of organic nutrient management and scheduling of biopesticide and biofungicide spray has also been started during second year of planting. Two year evaluation studies showed that maximum height (2.2 m), plant canopy (2.0 m<sup>2</sup>) and trunk diameter (4.3 cm) was observed in RCGH-1 while minimum height in Lucknow-49 and RCGH-7 (1.2 m) and minimum canopy spread (1.3 m<sup>2</sup>) was noted in RCGH-4. Minimum trunk diameter (2.9 cm) was observed in Lucknow-49. Maximum no. of branches/plant, no. of leaf/branch, leaf length and leaf width was observed in RCGH-1 (Fig 19).

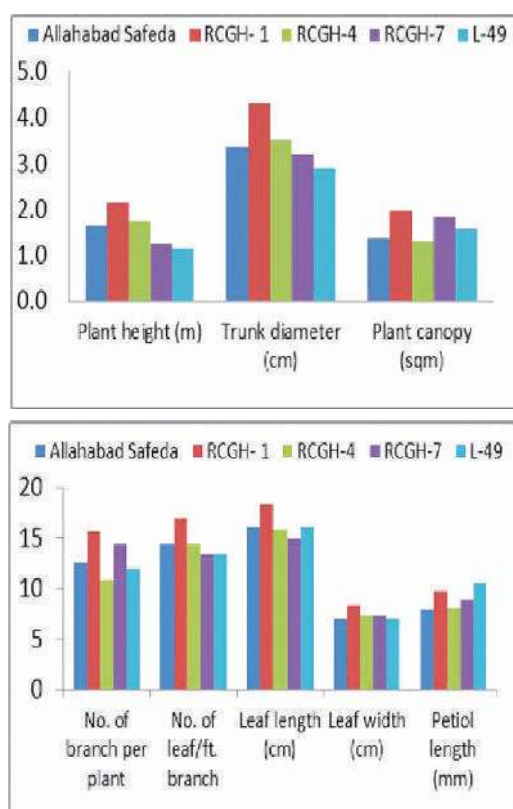


Fig 19. Different growth parameters of guava genotypes

## AGRO FORESTRY

### Carbon sequestration potential and bio-economic appraisal of large cardamom-based agroforestry systems in mountain region

An experiment was conducted in large cardamom-based AFS during 2015 at ICAR Sikkim Centre. Large cardamom cv. Sawney was planted in combination with multipurpose tree species as well as mixed forest system. Growth performance of two year old plants of large cardamom recorded higher average plant height and more bearing tillers/clump under *Alnus nepalensis*-based AFS followed by mixed forest system and minimum average plant height and bearing tillers/clump was recorded under *Ficus hookerii* (Table 4).

### Effect of large cardamom-based different agroforestry systems on soil properties

An experiment was initiated in large cardamom-based AFS during 2015 at ICAR Sikkim Centre to evaluate nutrient dynamics in large cardamom under different agroforestry systems. First year data showed that plant available NPK were significantly higher in *Alnus*-based agroforestry system followed by mixed forestry system, *Leuceana*, *Schima wallichii*, *Terminalia* spp. and *Ficus* spp. But accumulation of soil organic carbon content was higher in mixed forestry system followed by *Ficus*-based agroforestry system. Accumulation of boron was higher in *Alnus*-based agroforestry system (Table 5).

### Productivity of mustard and buckwheat intercropping in Sikkim mandarin as influenced by different mulching

Productivity of buckwheat and mustard were assessed with different types of mulching in Sikkim mandarin-based agroforestry system. Both the crops were assigned to main plot while three mulching treatments viz., without mulch, maize stover mulch and tree leaf mulch were assessed in subplot. The experiment was conducted in split plot design with three replications. The first year study showed that

Table 4. Growth performance of large cardamom with different multipurpose tree species

Growth Parameters of largecardamom	<i>Schima wallichii</i>	<i>Ficus hookerii</i>	<i>Terminalia myriocarpa</i>	<i>Alnus nepalensis</i>	<i>Leaueana leucocephala</i>	Mixed Forest
Plant height (cm)	132±0.05	117±0.05	123.4±0.70	153.3±0.12	143.5±0.08	147.06±0.08
Immature tillers/clump	5.10±0.8	5.18±0.72	4.10±0.43	6.55±0.70	5.33±0.72	6.41±0.65
Mature tillers/clump	4.16±0.33	5.6±0.73	5.12±0.72	6.19±0.42	4.3±0.61	6.15±0.06
Bearing tillers/clump	4.01±0.35	3.1±0.24	5.5±0.43	6.26±0.079	4.10±0.71	6.10±0.40



**Table 5. Nutrient dynamics under different large cardamom based AFS**

Name	pH	O. C. (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
<i>Schima wallichii</i>	5.23	1.39	371.50	20.40	420.40
<i>Ficus hookerii</i>	5.34	1.45	350.10	19.60	428.40
<i>Terminalia sp</i>	5.37	1.41	353.70	17.50	405.60
<i>Alnus nepalensis</i>	4.93	1.02	395.20	23.60	430.80
<i>Leuceana leucocephala</i>	5.01	1.38	376.40	21.40	416.70
Mixed Forest	5.53	1.53	384.20	18.90	419.70
SE m±	0.02	0.01	2.13	0.45	0.68
LSD (0.05)	0.06	0.02	6.23	1.30	1.93
	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	B (mg/kg)
<i>Schima wallichii</i>	1.23	37.41	2.34	15.64	5.45
<i>Ficus hookerii</i>	2.52	37.26	2.56	19.85	5.35
<i>Terminalia sp</i>	1.69	31.67	2.84	28.90	5.61
<i>Alnus nepalensis</i>	2.54	29.48	1.95	37.65	6.68
<i>Leuceana leucocephala</i>	1.95	26.48	1.59	30.45	4.15
Mixed Forest	1.37	34.48	3.02	27.45	5.68
SEm±	0.01	0.22	0.02	0.34	0.01
LSD (0.005)	0.04	0.63	0.05	1.00	0.02

mustard recorded higher grain yield (6.58 q/ha) over buckwheat (5.83 q/ha). Both the mulching showed significant effect on grain yield over without mulch. Tree leaf mulch recorded 28.5% higher yield than without mulch. Similarly, maize stover mulch also recorded 20.7% higher grain yield over without mulch.

## PLANT PATHOLOGY

### Organic management of major tomato diseases under protected and unprotected conditions in Sikkim

Experiments were conducted in protected conditions to study the effect of different organic treatments against various diseases in tomato. A total

of 10 treatments were used viz., cow urine 10%, garlic 5%, onion 5%, mugwort 5%, *Trichoderma viride* 0.25%, *Pseudomonas fluorescens* 0.25%, copper oxychloride 0.25%, copper hydroxide 5%, Metalaxyl 0.1% and control with no spray. Late blight (*Phytophthora infestans*) and root rot (*Rhizoctonia solani*) were observed. The results of the study under poly house, rain shelter and high tunnel (Table 6) revealed that copper oxychloride was the most effective in reducing the disease with lowest late blight (22, 18, 22.33%) and root rot (1.66, 1.00, 3.67%) in poly house, rain shelter and high tunnel, respectively. This was followed by copper hydroxide @ 0.25% with late blight severity of 25.66, 21.33 and 27.66% and root rot incidence of 4.00, 2.00 and 7.33%, respectively

**Table 6. Effect of different organic treatments on late blight and root rot of tomato under protected conditions**

S No	Treatments	Late blight (PDI)			Root rot (PDI)		
		Poly house	Rain shelter	Tunnel	Poly house	Rain shelter	Tunnel
1	Cow urine 10%	91.66	93.66	96.33	13.33	13.66	22.73
2	Garlic 5%	93.66	95.00	95.00	15.00	14.33	23.28
3	Onion 5%	93.33	94.33	94.66	15.00	16.00	24.08
4	<i>Artemisia vulgaris</i> 5%	94.66	95.66	97.33	14.00	15.00	23.28
5	<i>Trichoderma viride</i> 0.25%	95.00	97.00	94.00	7.00	8.33	14.14
6	<i>Pseudomonas fluorescens</i> 0.25%	94.33	97.00	94.66	11.00	8.33	19.03
7	Copper Oxychloride 0.25%	22.00	18.00	20.33	1.66	1.00	3.67
8	Copper hydroxide 0.25%	25.66	21.33	27.66	4.00	2.00	7.33
9	Metalaxyl 0.1%	13.00	13.66	15.66	0.33	0.66	4.79
10	Control	96.33	97.66	96.33	19.00	20.66	27.01
	CD @ 5%	4.84	3.42	4.01	1.80	3.59	3.09



for poly house, rain shelter and high tunnel. None of the botanicals and biocontrol agents was effective against both late blight and root rot in tomato. The late blight disease severity was more than 90% in control and botanicals and bio-control agents treated plots. However, both the biocontrol agents were effective against root rot with lowest per cent root rot of 7.00, 8.33 and 14.44 for *Trichoderma harzianum* under poly house, rain shelter and high tunnel, respectively. The yield of tomato treated with copper oxychloride was highest (20, 18.3, 17.8 t/ha) followed by copper hydroxide (19.1, 16.2, 16 t/ha), under poly house, rain shelter and high tunnel, respectively. The copper oxychloride recorded highest yield increase over control followed by copper hydroxide. The low level of disease suppression by plant extracts and biocontrol agents may be due to their lower inhibitory activity against *P. infestans* and rapid spread of pathogen under congenial environment. However, the severity of disease was found to be minimum in the plots treated with standard fungicide metalaxyl @ 0.1%.

## AGRICULTURAL ENTOMOLOGY

### Foraging bumble bees of Sikkim and neighboring areas for sustainable large cardamom production

Large cardamom is one of the most important cash crops in Sikkim. The sustenance of the population of bumble bee (major pollinator) is of utmost importance for the large cardamom ecosystem and higher production and productivity. Enhancement of foraging plants is extremely necessary along with DNA fingerprinting of this pollinator for conservation of bumble bee. Besides large cardamom, 11 another foraging plants viz., Gerbera, marigold, *Hibiscus* spp., *Hibiscus efloraifindia*, *Gardenia* spp., *Lilium* spp., *Abutilon* spp., Phlox, Balsam, *Nerium* spp. and *Petunia* spp. have been identified as foraging plants of bumble bee. The efficacy of hand pollination was studied in large cardamom and it was found that the hand pollination was at par in terms of no. of capsules per spike, no. of seeds per capsules, weight of capsules and length of capsules with open pollinated crops (Table 7).

### Organic management of storage pests of maize

#### Evaluation of some non-edible oils and substances against grain moth of maize in storage

Five non-edible substances viz., neem oil, lemongrass and petroleum based horticultural oil @ 7 ml/kg of grain, spinosad 45 SC @ 0.1% solution and

parad tablet @ 1 tablet/kg were evaluated for their efficacy as grain or seed protectants against grain moth in maize in storage based on grain damage %. The number of infested grains was recorded after 3 and 6 months of storage. Germination test of all treated seeds was done after 3 and 6 months of treatment with untreated and uninfested seeds as control. It was observed that among five treatments, grain damage % was recorded minimum in lemon grass oil (1.75% after 3 months and 8.25% after 6 months) and spinosad treated seeds (1.75% after 3 months and 7.25% after 6 months of storage) but lemon grass oil negatively affected the germination per cent of seeds (32.5 % after 6 months). Spinosad 45 SC @ 0.1% was found to be effective to reduce the infestation of seed/grain retaining the germination per cent (95.00 % after 6 months of treatment) followed by parad tablet (12.5% and 18.5% grain damage after 3 months and 6 months, respectively) and germination % (88.75%) (Table 8).

**Table 7. Study on effect of hand pollination on large cardamom**

Type of pollination	No. of capsules /spike	Quantitative parameters of capsules		
		Weight/ capsule (g)	Length (cm)	No. of seeds / capsule
Open pollination	13.62	2.38	2.36	28.37
Hand pollination	11.87	2.37	2.34	28.00
Without pollination	1.87	2.00	1.69	23.00
LSD (P=0.05)	2.43	0.149	0.166	3.93

#### Evaluation of some locally available botanicals as seed/grain protectants against weevils of maize in storage

Five locally available botanicals viz., Angeri (*Lyonia ovalifolia*), *Lantana camara*, *Artemisia vulgaris*, Karkus (Vernacular-Nepali) @ 10 g powder/kg and lemon grass @ 10g dry leaves/kg were evaluated for their efficacy as seed/grain protectants against weevils in maize in storage based on periodical mortality and population growth. The number of dead and live adults was noted 7 days after the release and the adults (dead and live) were discarded. The observations on number of adults (live + dead) in each repetition were made after 3 and 6 months of storage. Germination test of all treated seeds was done after 3 and 6 months of treatment with untreated and uninfested seeds as control. Among the five treatments, adult mortality was maximum in Karkus treated seeds



**Table 8. Evaluation of the efficacy of non-edible substances against Angoumois grain moth as seed/grain protectants**

Treatments	Grain damage % after 3 months	Grain damage % after 6 months	Germination % after 3 months	Germination % after 6 months
Neem oil (1500 ppm) @ 7 ml/kg water)	6.0(14.10)	13.0(21.10)	51.25(45.72)	41.25(39.93)
Petroleum oil-based agro spray @ 7 ml/kg	8.0(16.35)	15.0(22.75)	42.50(40.66)	36.25(37.00)
Lemon grass oil @ 7 ml/kg	1.75(7.39)	8.25(16.62)	36.25(37.00)	32.5(33.60)
Spinosad 45 SC0.1% solution	1.75(7.53)	7.25(15.58)	95.00(77.29)	95.00(79.14)
Parad tikri1 tablet/kg	12.5(20.64)	18.5(25.40)	93.12(75.34)	88.75(70.76)
Control	44.5(41.83)	86.25(68.50)	96.47(81.26)	95.00(79.14)
LSD (P=0.05)	3.23	3.89	7.15	8.86

Data within the parentheses are angular transformed values

@ 10 g/kg (31.25%) with less population growth (9.25 adults after 6 months) followed by Angeri (*Lyonia ovalifolia*) @ 10g/kg (26.25% adult mortality and 12.25 adults emerged after 6 months) retaining the germination per cent (92.50% after 6 months of treatment in case of Karkus and 95.00% after 6 months of treatment in Angeri) (Table 9).

### Organic management of snails in major agricultural and horticultural crops

Survey was conducted in some areas of East and South districts of Sikkim to determine the occurrence of snails and their intensity of damage in some important agricultural and horticultural crops in 2015. Among the horticultural crops cultivated in the surveyed areas chow-chow was mainly affected by the snails followed by large cardamom, ginger and some leafy vegetables. Among the field crops maize was infested to some extent. The snail observed in the surveyed areas is Giant African snail, *Achatina fulica*. It appears in the month of April with the occurrence of rainfall and gradually the population increases. Population is maximum in June and July after that it

starts to decline. Occurrence is rare after October with the reduction of rainfall and temperature. In chow-chow when it moves through the stem of the plant it feeds on the bark of the stem and leaves a mucous layer which results in drying of the plants. An experiment was conducted to find out the effective barrier to prevent the snail incidence. Different circles were made with different materials viz., lime, ash, sand, salt and saw dust and three snails were released at the centre of each circle. The observation on movement of snails across the boundary was recorded for each treatment 10 times and each of the treatment was replicated four times. The most effective result was obtained in the circle made by salt where the snails could not cross the boundary. The circles made by lime and ash were also on par result with salt.

### Host preference of fruit fly and its eco-friendly management

The preference of fruit fly to different vegetable crops was studied in *kharif* 2015. Seven different crops viz., bitter melon, bottle melon, ridge melon, cucumber, chow-chow, zucchini, tomato and Red cherry pepper

**Table 9. Evaluation of the efficacy of some locally available botanicals against *Sitophilus* spp. as seed/grain protectants**

Treatments	% Adult mortality after 7 days of treatment	Adult emerged after 3 months of treatment	Adult emerged after 6 months of treatment	Germination % after 6 months	Grain damage %
Angeri ( <i>Lyonia ovalifolia</i> ) 10 g/kg	26.25(5.20)	8.00(2.98)	12.25(3.63)	95.00(78.82)	43.50(41.25)
Karkus 10 g/kg	31.25(5.65)	5.00(2.67)	9.25(3.18)	92.5(77.71)	38.25(38.19)
<i>Lantana camara</i> 10 g/kg	16.25(4.13)	18.50(4.39)	21.75(4.76)	96.25(80.52)	60.25(50.96)
<i>Artemisia vulgaris</i> 10 g/kg	10.0(3.28)	23.75(4.96)	35.75(6.05)	97.5(82.22)	71.25(57.60)
Lemon grass 10 g/kg	20.0(4.56)	11.75(3.55)	15.75(4.07)	91.25(73.62)	44.75(41.98)
Control	0.00(0.00)	38.00(6.23)	55.75(7.51)	97.50(82.22)	89.50(71.38)
LSD (P=0.05)	0.91	0.56	0.51	NS	4.83

Data within the parentheses are angular and square root transformed values



were studied. Maximum fruit fly, *Bactrocera tau* (identified at ICAR-NBAIIR, Bangalore) infestation was observed in bottle gourd (56.42%) followed by ridge gourd (44.82%), cucumber (42.64%), bitter gourd (36.14%), zucchini (28.26%), chow-chow (18.72%), Red cherry pepper (14.68%) and tomato (12.42%). Collection and destruction of fallen fruits were found effective for management of fruit fly. From one fallen fruit of bottle gourd maximum 172 flies were recorded after emergence. Installation of parapheromone traps @ 20 traps/ha was found effective to trap male adults (average 14.64 adults per day). The bagging of the fruit just after setting with perforated polythene is highly effective to avoid fruit fly infestation.

### Pollinators' complex of some important crops of Sikkim Himalaya

Pollinator is the main agent responsible for transfer of pollen from male to female line. The collection of information regarding pollinator's complex of some important crops is of utmost necessity in organic state like Sikkim. Study has been completed for crops like large cardamom, mustard, buckwheat, sunflower and Pigeon pea. During this year the pollinator's complex of pea, maize, bitter gourd, chow-chow, Kiwifruit have been studied. Out of six insect visitors in chow-chow *Vespa* spp., *Apis cerana indica* and bumble bee are some frequent visitors. In maize, among the visitors *Apis cerana indica* and bumble bee are major (Fig 20). In Kiwifruit, the frequency of visit of pollinators is very less; the visitors included *Apis cerana indica*, *Eristalis* spp. and a Dipteran fly. In pea, out of 10 visitors, *Bombus breviceps*, *Apis cerana indica*, *Eristalis tenax* and *Eristalis* spp. were some important and frequent visitors. In bitter gourd, *Bombus breviceps*, *Apis cerana indica*, rice skipper, cabbage butterfly, *Danaus chrysippus*, *Xylocopa* spp. and blister beetle were recorded as important pollinators.



**Fig 20. Pollinators' complex of some important crops of Sikkim Himalaya**

## ANIMAL SCIENCES

### Augmentation of the reproductive performance of Singharey (Sikkim local) goat

Institutional Project on goat titled "Augmentation of the reproductive performance of Singharey (Sikkim local) goat by natural and melatonin intervention" is in progress. In this project, effect of slow release of melatonin on the reproductive performance was evaluated with three different doses viz., (control (G1), 10 mg (G2), 20 mg (G3) and 40 mg (G4) per animal). It was observed that G2 and G3 group of goats showed early induction of estrus and increased twinning percentage compared to other groups.

### Reproductive disorders of dairy cattle in relation to mineral deficiency in different agro-climatic zones of Sikkim

Various reproductive traits were evaluated through direct interview with farmers and per-rectal examination of dairy animals. It is found that the postpartum interval was quite high at higher altitude of North Sikkim ( $5.46 \pm 0.68$  months) as compared to West and lower part of North district of Sikkim (Table 10).

**Table 10. Reproductive traits of dairy cattle**

S.I. No.	Reproductive Traits	North District		West Sikkim
		Up to 1818 m amsl	>1818-4242 m amsl	
1.	Age at first service (Month)	26.90 $\pm 1.01$	25.40 $\pm 1.00$	30.00 $\pm 1.12$
2.	Age at first calving (M)	37.00 $\pm 1.20$	36.30 $\pm 1.10$	39.00 $\pm 1.20$
3.	Inter Calving period (Days)	475.00 $\pm 24.3.00$	465.00 $\pm 16.38$	538.00 $\pm 26.30$
4.	Post-partum anestrus (Month)	4.38 $\pm 0.75$	4.25 $\pm 1.00$	5.46 $\pm 0.68$
5.	Calving to conception interval (Days)	230.00 $\pm 10.00$	224.00 $\pm 6.00$	245.00 $\pm 5.00$
6.	No of services per conception	1.80 $\pm 0.18$	1.68 $\pm 0.45$	1.50 $\pm 0.21$

### Various reproductive disorders in Dairy cattle of North and West District of Sikkim

Various reproductive disorders of dairy cattle of North and West District of Sikkim were diagnosed (Fig 21) and their incidences were worked out through direct per-rectal palpation of the dairy animals and history obtained from farmers. It was found that





**Fig 21 : Examination of dairy animals at field level through ultra-sonography for diagnosis of various reproductive disorders**

anoestrus was one of the major infertility problems across the districts i.e. 36% in North Sikkim and 25 percent in West Sikkim (Table 11).

**Table 11. Reproductive disorders of dairy cattle**

S No.	Reproductive Disorders	North district (%)		West district (%)
		Up to 1818 m amsl	>1818-4242 m amsl	
1.	Anoestrus	30.40	36.00	25.00
2.	Repeat Breeding	12.10	9.50	13.50
3.	Uterine infection	6.80	4.10	7.10
4.	Abortion	3.10	4.01	3.00
5.	Prolapse	3.00	2.00	4.00
6.	Dystocia	3.10	2.00	4.60

## EXTERNALLY FUNDED PROJECT

### National Mission for Sustaining Himalayan Ecosystem (NMSHE)

Under NMSHE project data collection, monitoring and climate resilient technologies have been demonstrated at two locations in Sikkim. Two locations have been selected for implementation of the project (Fig 22) viz., i) Tympyem, East Sikkim (Mid altitude), and ii) Lachen, North Sikkim (High altitude). The base line survey of both the selected locations has been initiated in the month of December 2015.

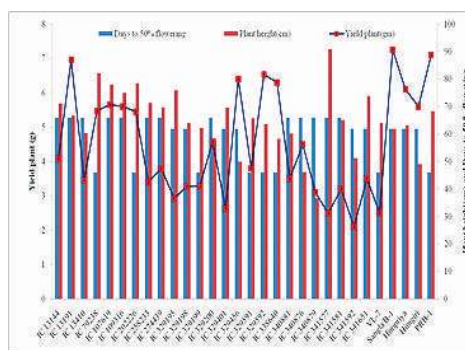


**Fig 22. Demonstration of climate resilient technologies in Sikkim**

### AICRN on Potential Crops (All India Coordinated Research Network on Potential Crops)

#### Buckwheat germplasm evaluation under organic management in mid hills of Sikkim

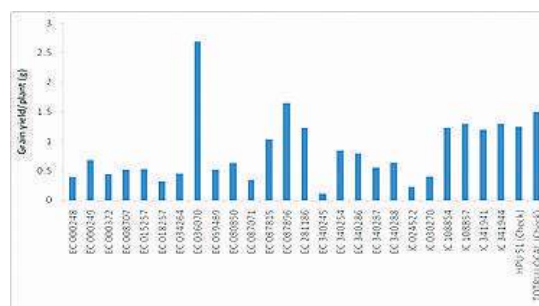
Under AICRNPC, buckwheat germplasm was evaluated in organic management condition at mid hills of Sikkim. A total of 25 accessions along with five varieties of buckwheat were tested at ICAR Sikkim Centre for suitability under organic condition. Among those tested, IC and variety, Sangla B-1, recorded maximum grain yield per plant (7.26 g) followed by PRB-1 (7.1 g). IC 13191 recorded the highest yield (6.97 g) among IC though the yield was less than released varieties (Fig. 23).



**Fig 23. Screening of different buckwheat germplasms**

#### Evaluation of Adzuki bean germplasm under organic management

Twenty five accessions of Adzuki bean along with two checks (HPU 51 and Totru Local) were tested under organic management condition in mid hills of Sikkim. Among the collection, EC 036070, recorded maximum grain yield per plant (2.69 g) over others and local checks (Fig 24).



**Fig 24. Screening of different Azuki bean germplasms**

#### *Perilla* germplasm evaluation in mid hills of Sikkim

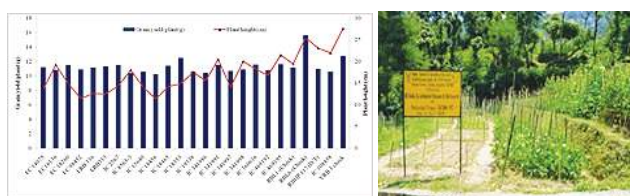
Twenty eight accessions of *Perilla frutescens* received from ICAR Umiam were grown for



morphological diversity in an on-farm field experiment at Research Farm, Sikkim Centre. Wide variation in various agronomic traits like plant height, days to 50% flowering, maturity and seed weight per plant *etc.* were recorded among different accessions. RCP-01 (28) recorded maximum yield per plant (10.6 g) over others.

### Rice bean germplasm evaluation in mid hills of Sikkim under organic management condition

Twenty accessions along with five varieties of rice bean were grown for morphological diversity in an on-farm field experiment at Research Farm, Sikkim Centre. Among the landraces wide variations in various agronomic traits were recorded (Fig 25). Among landraces, IC 18553 recorded higher grain yield (12.5 g) over others but it remained lower than released variety RBL1 (15.6 g) and VRB3 (12.7 g).



**Fig 25. Evaluation of Rice bean germplasm under organic management conditions**

### Rashtriya Krishi Vikas Yojana (RKVY)

During the year, different part of North, South, East and West Sikkim was surveyed and collected the local germplasm of different crops from various locations crops viz., maize (13), rice (23), sorghum (02), French bean (05), Bee (04), Beans (10), Amranthus (02), Foxtail millet (02) and Porsomillet (03). With regards to germplasm evaluation, ten previously collected germplasm of maize; twenty six germplasm of rice, two germplasm of sorghum, ten germplasm of french bean, two germplasm of foxtail millet and two germplasm of porsomillet were evaluated at ICAR Research Farm. Apart from that, nutritional profiling of collected germplasm is also being carried out to find out the most nutritive indigenous germplasm of different crops.

### AICRP on Spices

#### Mealy bug, *Paraputo theaecola* (Green), a new record in large cardamom

Mealy bug, *Paraputo theaecola* (Green), has been recorded in Kerala in small cardamom, *Elletaria* spp. as a destructive pest. It has been recorded for the first

time in large cardamom in 2014 at ICAR Research Complex, Sikkim Centre, Tadong. The specimen of mealy bug has been identified at ICAR-NBAIR, Bangalore, Karnataka. The body of mealy bug is round, orange brown and covered by thin layer of white mealy wax allowing body segmentation to be visible. Damage is caused by sucking the sap from the roots, rhizomes and fruits. Due to continuous loss of sap, the infested plants get debilitated and most common symptoms are slow plant growth, lack of vigor, browning of leaves, reduction of capsule size and deformed capsules and subsequent death of the plant. The mealy bug was not evident unless the rhizome is examined by uprooting the plant from the soil. White, waxy substance and adult females were noticed in the rhizome of the infested plants (Fig 26 to 28). The incidence of the pest is observed more in August and September months. The highly mobile crawlers are the dispersal stage. The spread of infestation happened mostly through irrigation water, re-use of previously infested plots for transplanting and crawlers moving from infested plants to other plants.



**Fig 26. Infestation of mealy bug**



**Fig 27. Infestation of mealy bug in capsules**



**Fig 28. Mealy bug infested plant**

### Poultry Seed Project

The Poultry Seed Project of ICAR Sikkim Centre supplied 53407 numbers of Vanaraja day old chicks produced from its own hatchery unit during the financial year 2015-16. Out of this, a total of 47708 numbers of chicks were distributed to the tribal farmers of Sikkim under TSP project funded by Directorate of Poultry Research, Hyderabad and ICAR Research Complex for NEH Region, Umiam Meghalaya. The farmers are highly benefitted by rearing Vanaraja birds in terms of selling eggs and meat. Farmers sold the birds for meat purpose which could fetch market price at par with local chicken. By rearing one bird up to 3-4 months, farmers could earn about Rs. 700/- from selling of live bird and annually farmer could earn Rs. 1500-1800/- from the selling of eggs and culled bird at the end of laying. This has created huge demand for the supply of Vanaraja chicks in Sikkim.



### **Characterization of Tibetan Sheep under Network Project on Animal Genetic Resources**

Population of a fairly least recognized sheep breed of Sikkim has been enumerated i.e., 235 only. Morphometric characterization has been done i.e., height at withers in adult male and female;  $77.20 \pm 0.98$  cm and  $64.80 \pm 0.85$  cm; body length  $74.27 \pm 1.88$  cm and  $72.00 \pm 0.94$ ; weight  $46.14 \pm 0.75$  kg and  $45.32 \pm 0.66$  kg, respectively. Quality trait of wool is sub-white, full of gloss, equal and long fiber, high compactness, high elasticity and big pull with average annual wool yield 700 gm; staple length 11.86 cm, staple diameter 29.08cm, bundle strength 12.71. Clear migratory route of the sheep has been identified on transhumance tract of Dokpas. Sheep migrate up to the height of 5515 meters amsl in winter season and during summer coming down to 4393 meters amsl and approximately remain six month in cold desert and six month on alpine pasture. A clear cut seasonal weight dynamics has been observed with weight loss up to 14.83 during lean season. Partial morphometry of sheep and socioeconomic status of shepherds of

West Kameng and Tawang District of Arunachal Pradesh has been performed.

### **Study on pig performance under low cost climate resilient deep litter housing model under Sikkim Himalaya condition (NICRA)**

Preliminary study showed that indigenous (Lepcha) pig (Fig 29) performed better under deep litter housing system as compared to Hampshire. The average weight at five month of age of indigenous pig and Hampshire was  $25.00 \pm 2.33$  kg and  $19.50 \pm 0.83$  kg, respectively. Attainment of sexual maturity is quite early in case of local (Lepcha) pig (between 7 to 8 months) compared to other exotic breed like Hampshire crosses (12 to 14 months). Morphometrically, the small snout length of indigenous pig is more suitable for deep litter housing system since they dig less when compared to Hampshire.



**Fig 29. Indigenous (Lepcha) pig**

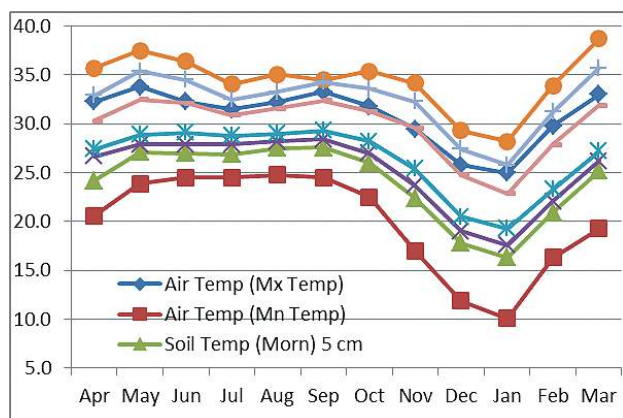


## TRIPURA

### WEATHER REPORT

The total rainfall (2510.2 mm) received during 2015-16 was about 10% more than the normal rainfall with 95 rainy days compared to 111 normal rainy days. The highest rainfall (610 mm) received in a single month was July with 19 rainy days (Fig 1a). Maximum and minimum air temperature varied from 25 - 34° C and 10 - 25° C, respectively. Relative humidity varied from 62 - 88% (morning) and 61 - 78% (evening). Mean monthly Sunshine hour varied from 3.0 hours during August to 7.4 hours during November. Evaporation loss out of total rainfall was 1428 mm (57%).

Agromet Advisory Service unit received 96 forecasts from IMD, from which 88 bulletins were issued by the centre. About 95% of our rainfall forecasts were found to be 'Correct' and 'Usable' during winter; while 100% during Post Monsoon season.



**Fig 1a. Monthly variation of air temp and soil temperature at Lembucherra**

### CROP IMPROVEMENT PROGRAMME

#### Rice

Selection and advancement of generations continued in IRR lines or crosses to identify high yielding genotypes. Evaluation and Selection continued in the segregating populations of new cross combinations RCPL 1-128×Naveen, Bhalum 3×Naveen, Fulbadam×Swarna, KataktaraxNaveen,

Fulbadam×Naveen and KataktaraxSwarna. Selection and advancement also continued in the segregating material from IRR involving 12 high yielding varieties crossed with 62 tropical japonica selected from 300 tropical japonica germplasm collected from worldwide. Some of the lines were back crossed to improve the yield. In some of the crosses gene donors for different biotic and abiotic stress resistance genes as third parents were used, such as BPH Bph20 & 21, Bph18, blast Bi2, Pi1 and Pikh, BLB Xa21, xa13, xa5, RTD, Sub1, saltol1, new blb, blast, salinity, basmati lines drought gene/QTLs to improve the traits, were evaluated and selections were carried out for further use in our breeding programme.

Out of the 20 nominations made to different AICRIP trials, the following 12 TRC entries were promoted and tested in AICRIP AVT1 & AVT 2 during 2015. The performances of the promoted entries are given in Table 1a.

Rice genotype 'TRC 2013-2 / IET 23947 (Fig 1b and 1c)' qualified for VIC (Variety Identification Committee), CVRC for the states of Uttarakhand, Haryana, West Bengal, Madhya Pradesh, Maharashtra and Kerala under irrigated or rainfed shallow lowland ecosystem.

During all the testing years (2013-2015) in AICRIP, IET 23947 has recorded consistently superior performance by not only out yielding national, regional and local checks but also other qualifying entries of the trials with an impressive yield margin in states of Uttarakhand, Haryana, West Bengal, Madhya Pradesh, Maharashtra and Kerala under irrigated or rainfed shallow lowland ecosystem.



**Fig 1b. Field view of TRC 2013-2**



**Table 1a. Performance of the promoted entries of rice**

Promoted entries	Yield (kg/ha)	NC	RC	Promoted to:
TRC 2013-2 (IET 23947)	4902	4680	4090	AVT 2 E TP in R IV
% Increase Over		+4.74	+19.85	
TRC 2014-13 (IET 24702 )	5328	4691	4023	AVT 1 E TP, All zone, Rank: 4th
% Increase Over		+13.58	+32.44	
TRC 2014-3 ( IET 24353 )	5086	4582	4704	AVT 1 IME, in R III
% Increase Over		+11.00	+8.12	
TRC 2013-11 (IET-24195)	4418	3980	2467	AVT1 E H under low altitude, Rank: 1st
% Increase Over		+11.01	+79.08	
TRC 2014-6 (IET-24196)	4762	3952	3060	AVT1 E H under medium altitude
% Increase Over		+20.50	+55.62	
TRC 2014-8 (IET-24197)	4333	3952	3060	AVT1 E H under medium altitude
% Increase Over		+9.64	+41.60	
TRC 2014-7 (IET-24214)	6942	5463	6070	AVT1 M H at low altitude (Northern hills). Rank: 1st
% Increase Over		+27.07	+14.37	
TRC 2013-9 (IET-24216)	5841	5201	4295	AVT1 M H at medium altitude (Northern hills). Rank: 1st
% Increase Over		+12.31	+36.00	
TRC 2013-8 ( IET-24215)	7379	5726	5272	AVT1 M H at medium altitude (Southern hills). Rank: 2nd
% Increase Over		+28.87	+39.97	
TRC 2014-14( IET-24665)	6242	5354	4932	AVT1 Aerobic, Rank: 1st
% Increase Over		+16.59	+26.56	
TRC 2014-11( IET-24630)	4016	3662	3827	AVT1 Aerobic, Rank: 3rd
% Increase Over		+9.67	+4.94	
TRC 2014-12 ( IET-24659)	6113	5354	4932	Promoted to AVT1 Aerobic in R V
% Increase Over		+14.18	+23.95	

**Fig 1c. Paddy and milled rice of TRC 2013-2****A brief account of rice TRC 2013-2 /IET 23947**

Overall performance of IET 23947 has been outstanding all through the testing years in general and in the proposed states. IET 23947 recorded an overall mean grain yield of 4978 kg/ha (averaged over three years for all the proposed states) (Table 1b). The entry surpassed national check, regional check and local check with a yield margin of 8.6%, 26.4% and 9.6% respectively. In addition, IET 23947 has out

yielded qualifying entries by a margin ranging 10.5% to 4.6%. It is important to note that IET 23947 maintained yield superiority over all the checks in all the years and occupied place among top ranking entries 19 times out of 29. IET 23947 recorded mean yield of 6358 kg/ha and superiority over NC, RC, and LC by a margin of 18.78%, 28.55% and 23.69%, respectively in Haryana; whereas, its superiority over the qualifying varieties were up to 31.64%. IET 23947 recorded mean yield of 4578 kg/ha and superiority over NC, RC, and LC by a margin of 4.2%, 14.9% and 11.1%, respectively in Uttarakhand, whereas, its superiority over the qualifying varieties were up to 31.1%. IET 23947 recorded mean yield of 5345 kg/ha and superiority over NC, RC, and LC by a margin of 15.4%, 5.82% and 8.82%, respectively in West Bengal, whereas, its superiority over the qualifying varieties were up to 9.8%. IET 23947 recorded mean yield of 4544 kg/ha and superiority over NC, RC, and LC by a margin of 7.0%, 70.5% and 9.0%, respectively in Madhya Pradesh, whereas, its superiority over the qualifying varieties were up to 6.5%. IET 23947 recorded mean yield of 4847 kg/ha and superiority over NC, RC, and LC by a margin of 4.76%, 18.4% and 8.08%, respectively in Maharashtra, whereas, its superiority over the qualifying varieties were up to 8.55%. IET 23947 recorded mean yield of 4630 kg/ha



**Table 1b. Summary of mean grain yield (kg/ha) in co-ordinated trials E TP (2013-2015)**

Year of testing	Name of the trial	No. of locations tested	Proposed variety IET 23947	NC	RC	LC	IET 23339	IET 23392	IET 23979	IET 23354	IET 23951
2013	IVT E TP	9	4279.9	4148.6	3372.1	3848.7	4256.0	4214.9	3757.9	4206.0	3728.4
2014	AVT1-E-TP	8	5054.0	4380.6	3854.6	4753.1	4875.4	4545.3	4423.3	4910.4	4633.5
2015	AVT2-E-TP	12	5450.4	5043.7	4419.6	4920.6	4982.1	5182.9	5118.8	5005.1	5611.3
	Weighted mean		4977.8	4583.0	3938.7	4541.7	4727.3	4706.6	4504.6	4731.0	4757.2
% increase of over	2013			+3.2	+26.9	+11.2	+0.6	+1.5	+13.9	+1.8	+14.8
	2014			+15.4	+31.1	+6.3	+3.7	+11.2	+14.3	+2.9	+9.1
	2015			+8.1	+23.3	+10.8	+9.4	+5.2	+6.5	+8.9	-2.9
% increase of over	Weighted mean			+8.6	+26.4	+9.6	+5.3	+5.8	+10.5	+5.2	+4.6
Frequency in the top group (pooled over 3 years)			19/29	14/29	4/29	10/29	13/29	11/29	6/29	13/29	14/29

and superiority over NC, RC, and LC by a margin of 4.1%, 11.8% and 5.4%, respectively in Kerala, whereas, its superiority over the qualifying varieties were up to 14.4%.

### INGER nurseries

Four INGER nurseries were conducted during 2015 (Table 2). International Irrigated Observational Nursery (IIRON Module 1, 2015) with 56 entries, IIRON Module 2, 2015 with 30 entries, International Rainfed Lowland Observational Nursery (IRLON, 2015) with 42 entries and IURON 2015 with 30 entries. Performance of top entries in the trials is listed in Table 2.

### Stress tolerant rice for farmers in Africa and South Asia (STRASA) Phase 3

During 2015 under STRASA, the following trials were conducted and the best performing entries are listed in Table 3.

Twelve promoted entries were under evaluation in different trials of AICRIP during 2015. Breeder seed

production of 5 rice varieties (Tripura Khara Dhan 1, Tripura Khara Dhan 2, Tripura Hakuchuk 1, Tripura Hakuchuk 2, Tripura Aus Dhan) released by SVRC, Tripura was taken up during 2015 wet season and 2700 kg Breeder seeds were produced.

### Functional genomics of drought tolerance and allele mining of selected genes in rice

Under this newly sanctioned project started in 2015 in which functional genomics of drought tolerance studies are initiated on Mapping populations Kataktara × Naveen, Kataktara × Swarna and Fulbadam × Swarna, which are in F5. Genotyping with SSR markers is initiated.

### Pulse

Selections were made in F8 and F9 of the cross SPS 5 × IPM 99-125. Promising entries were entered in replicated yield trial at station. Two promising entries were nominated to AICRP MULLaRP. Selections were also carried out in F3 bulk of IPM 03-1 × SPS 5 (Mungbean x Urdbean) received under

**Table 2. INGER nurseries conducted during 2015**

Trial	IIRON Module 1		IIRON Module 2		IRLON		IURON	
Rank	Entry	Yield (kg/ha)	Entry	Yield (kg/ha)	Entry	Yield (kg/ha)	Entry	Yield (kg/ha)
1	128/25	5620	106/30	7780	104/12	4680	12	4440

**Table 3. STRASA trials and best performing entries of rice**

Sl. No.	Trial	No. of Entries & Design	Best performing entry
1	Upland AYT 80-100 rainfed	17 entries + 3 checks	IR92521-146-3-3-2 (4319 kg/ha)
2	Vandana, Anjali & Kalinga NILs	33 NILs + 3 checks	VANDANA (3521 kg/ha)
3	Swarna sub1 + Drought (Control)	33 + 3 checks	IR 96321-558-563-B-2-1-3 (5512 kg/ha)
4	G X E Trial	57 entries + 6 checks	Kongkoi (7908 kg/ha)
5	Multi Environment Trial	10 entries + 4 checks	IR92978-192-1-2 (R-306) (7096 kg/ha)



MULLaRP. Selections were also made in F8 bulk of VRM (Gg) 1 × *Vigna umbellata*, F8 bulk of VBN3 (blackgram) × *V. silvestris* and F2 of VBN (Gg)3 × IPM 205-7, received from NPRC, Vamban. In lentil, Tripura Lentil Selection 1 was nominated to AICRP MULLaRP. In field pea, segregating entries from nine different crosses were evaluated and advanced. In lentil, selections were made from segregating population LIF3N-E-2014, LIF-3-N-2014 and LIPBWF6-2014, LIF4N -2015 received from ICARDA and F4 population of 9811193 × EC 208362 and ILL-6002 × ILL 9997 received from IIPR, Kanpur. In Rajmash, seven bulks received from MAREC, HPKV, Sangla and Kinnaur were evaluated and single plant selections were made.

#### AICRP MULLaRP

Sixteen coordinated trials (IVT & AVTs) were conducted during the period under report and 318 entries of mungbean, urdbean, lentil, field pea and chickpea were evaluated in replicated trials. Details of trials are given in Table 4.

**Table 4. Trial details of 318 entries of pulse crop**

Sl. No.	Name of trial	Name of crop	No of entries	Season
1	IVT	Mungbean	7	Summer 2015
2	IVT	Mungbean	25	Kharif 2015
3	IVT	Urdbean	25	Kharif 2015
4	IVT	Field pea(Tall)	17	Rabi 2015-16
5	IVT	Field pea (Dwarf)	12	Rabi 2015-16
6	IVT	Lentil (Small Seed)	21	Rabi 2015-16
7	IVT	Lentil (Large Seed)	18	Rabi 2015-16
8	AVT 2+1	Mungbean	16	Summer 2015
9	AVT 2+1	Mungbean	10	Kharif 2015
10	AVT 1	Urdbean	6	Kharif 2015
11	AVT 1	Field pea(Tall)	8	Rabi 2015-16
12	AVT 1	Lentil (SS)	6	Rabi 2015-16
13	AVT 1	Lentil (Large Seed)	14	Rabi 2015-16
14	Pathology	Mungbean	52	Kharif 2015
15	Entomology		47	Kharif 2015
16	Physiology	Chickpea	34	Rabi 2015-16

#### Legume International Nurseries

Under Biodiversity and Integrated Gene Management Program (BIGMP) of ICARDA, following nurseries were conducted during *rabi* 2015-

**Table 5. Nurseries conducted under BIGMP of ICARDA**

Crop	Year	Trials and no. of entries			
Lentil	2016	LIEN-SS36 entries	LIF <sub>4</sub> N21 entries	LIEN-E36 entries	LISN250 entries
Chickpea	2016	CIEN-LS36 entries	CIEN-S36 entries	CIF <sub>4</sub> N33 entries	CIEN-W36 entries

16 (Table 5). Individual plant selections were made from the earlier selected promising entries such as 52110, 52125, 52210, 52101, 52107, 52114, 52103, 52121, 52111, 52104 and 52127 for late sown conditions. Efforts are on for selecting superior entries which can perform well when sown even in the first week of December.

#### Special trial under “Promotion of Pulses in NEH States”

During *rabi* 2015-16, the coded entries provided by IIPR, Kanpur were evaluated for their performance study under NEH states. Nine lentil varieties, 10 field pea varieties and 14 chickpea varieties were evaluated.

#### AICRN on Potential Crops

Under AICRN on Potential Crops 3 trials were conducted during 2015-16. The trials are Screening nursery on Grain Amaranth (25 accessions + 4 checks) and Screening nursery on Adzuki bean (25 accessions + 2 checks) during *kharif*. In *rabi*, screening nursery on buckwheat (25 accessions + 5 checks) was undertaken. The trial on grain amaranth failed due to heavy rain after sowing.

#### Seed production

The quantity of seed produced by Tripura centre during 2015-16 under ICAR Seed Project and Breeder Seed Project of different crops are given in Table 6.

### NATURAL RESOURCE MANAGEMENT

#### Studies on effect of nutrient management system on lentil growth and productivity

Among six different nutrient management systems, application 10 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> + 40 kg K<sub>2</sub>O/ha + 200 kg Lime/ha + 3 times foliar spray of Urea + ZnSO<sub>4</sub> + Boron produced maximum number of pods/plant and seed yield as compared to early and late sown of lentil.

#### Studies on effect of different sowing date on performance of lentil

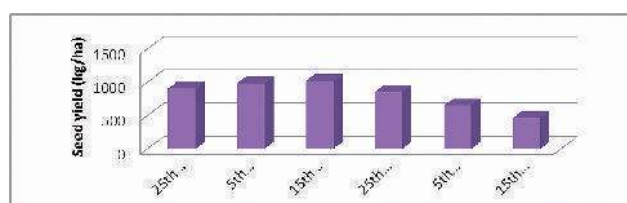
Six dates of sowing viz. S<sub>1</sub>= 25<sup>th</sup> October, 2014, S<sub>2</sub>= 5<sup>th</sup> November, 2014, S<sub>3</sub>= 15<sup>th</sup> November, 2014, S<sub>4</sub>= 25<sup>th</sup> November, 2014, S<sub>5</sub>= 5<sup>th</sup> December, 2014 and



**Table 6. Quantity of seed produced of different crops**

Crop/ Variety	Breeder Seed (kg)	TL seed produced in participatory mode (kg)
<b>Cereals (Rice)</b>		
Gomatidhan (TRC 2005-1 / IET 21512)	6500	340000
Tripura Khara 1 (IET 22837)	710	2300
Tripura Khara 2 (IET 22835)	340	1100
Tripura Jala 1 (IET 22167)	230	900
Tripura Chikan Dhan (IET 22112)	1600	7400
Tripura Sarat (IET 22113)	1240	1200
Tripura Nirog (IET 22580)	1210	2400
Tripura Hakuchuk 1 (TRC 2013-4)	600	1300
Tripura Hakuchuk 2 (TRC 2013-5)	630	900
Tripura Aush (TRC 2013-12)	420	1250
<b>Pulses</b>		
TRCP-8 (Fieldpea)	1060	-
Tripura Maskolai 1	100	1000
Tripura Mung 1	40	800
<b>Oilseeds</b>		
Tripura Siping (produced at IIOR)	65	-
TRC Toria 1 (TRCT -1-1-5-1)	50	-

S<sub>6</sub> = 15<sup>th</sup> December, 2014 were tested to identify the optimum sowing time of lentil in Tripura. Among the sowing dates, lentil sown on 15<sup>th</sup> and 5<sup>th</sup> November produced maximum yield (Fig 2).



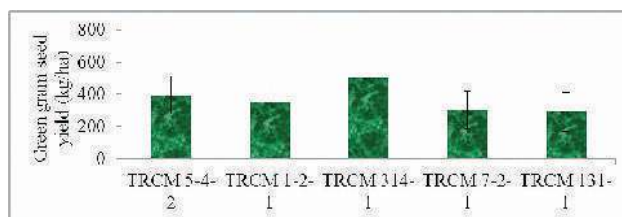
**Fig 2. Yield performance of lentil varieties on different sowing dates**

### Agronomic evaluation of green gram varieties for Tripura

An experiment was conducted to identify the suitable green gram varieties for Tripura. Among five green gram varieties (TRCM 5-4-2, TRCM 1-2-1, TRCM 314-1, TRCM 7-2-1 and TRCM 131-1), TRCM 314-1 produced significantly higher seed yield as compared to all other varieties (Fig 3).

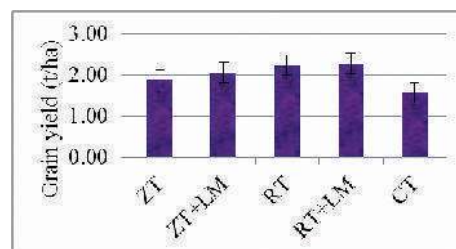
### Effect of conservation tillage on maize productivity

Field experiment was conducted to study the effect of conservation tillage on productivity of maize. The



**Fig 3. Yield performance of different green gram varieties**

experiment consists of five treatments: zero tillage, zero tillage + Live mulch, reduced tillage, reduced tillage + live mulch and conventional tillage. In treatments, where live mulch was used, the two rows of cowpea variety Kashi Kanchan were sown in between two rows of maize. The results revealed that, maize grown under reduced tillage system with live mulch of cowpea produced significantly higher yield (Fig 4 & Fig 5).



**Fig 4. Effect of tillage and live mulch on grain yield of maize**

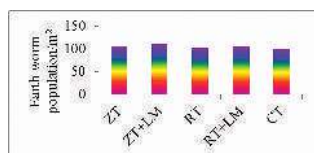


**Fig 5. Overview of maize grown under different tillage**

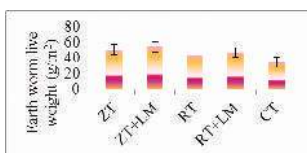
### Effect of conservation tillage on earth worm population and live weight under maize-maize-lentil/mustard cropping system

The experiment consists of five treatments: zero tillage, zero tillage + Live mulch, and reduced tillage, reduced tillage + live mulch and conventional tillage. The results revealed that, ZT+LM recorded maximum number of earthworms/m<sup>2</sup> (Fig 6). Live weight of Earthworm was significantly higher under ZT+LM and ZT as compared to CT (Fig 7).





**Fig 6. Effect of tillage and live mulch on earthworm population**



**Fig 7. Effect of tillage and live mulch on earthworm live weight**

### Agronomic evaluation of groundnut varieties for Tripura

Four groundnut varieties were evaluated. The variety 'Avishkar' matured one month earlier than rest of the three varieties, however, highest pod yield (2188 kg/ha) was produced by HNG-10.

### Effect of conservation tillage along with improved nutrient management on rice

Cultivation of rice under reduced tillage system along with improved nutrient management (25 % N through GLM + N<sub>60</sub> P<sub>9</sub> K<sub>17</sub> B<sub>2</sub> Zn<sub>5</sub> + cellulose decomposing organism and 30% residue incorporation) had showed higher growth and produced more rice yield than others (Fig 8 & 9).



**Fig 8. Rice grown under reduced tillage system**



**Fig 9. Rice grown under zero tillage system**

### Evaluation of Nagaland rice varieties

Seven rice varieties received from Nagaland Centre were evaluated for their performance in Tripura. Among the rice varieties, C<sub>2</sub>-74-3-3-2 produced highest rice grain yield.

### Agronomic evaluation of vegetable soybean varieties

Four soybean varieties were evaluated for their adaptability. Among the four varieties, JS-97-52 produced highest seed yield as compared to other varieties under evaluation.

### Residual effect of live mulch and tillage on yield of mustard and lentil under maize-maize –lentil/ mustard cropping system

Mustard (Pusa Mustard 25) and Lentil (HUL-57) was sown after harvest of maize (Fig 10). Highest yield on mustard and lentil was recorded on zero tillage with live mulch; while lowest was on zero tillage.



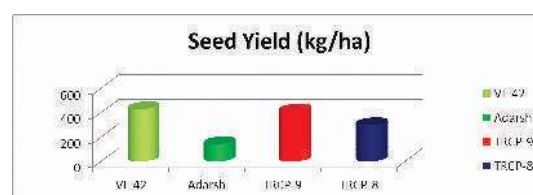
**Fig 10. Performance of mustard and lentil**

### Effect of conservation tillage and resource conserving method of weed control on productivity of upland *Toria*

Highest seed yield was recorded on zero tillage with brown manuring (662.39 kg/ha) while least yield was recorded on conventional tillage with glyricidia leaf mulch (384.62 kg/ha).

### Agronomic evaluation of field pea varieties for Tripura

Four field pea varieties (VL-42, ADARSH, TRCP-9 and TRCP-8) were sown in the month of December and harvested during first fortnight of March, 2016. Among all cultivars, VL-42 showed significantly higher seed yield as compared to other varieties (Fig 11).



**Fig 11. Yield performance of different field pea varieties**



### Agronomic evaluation of winged bean

Winged bean was evaluated for adaptability in Tripura agro-climatic condition. Highest pod yield was observed on AWB 13-4 (7.65 t/ha) whereas lowest was recorded on AWB-1 (4.54 t/ha) and varieties yielded higher when supplied with 20:40:40 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O/ha over control (Fig 12 & 13).

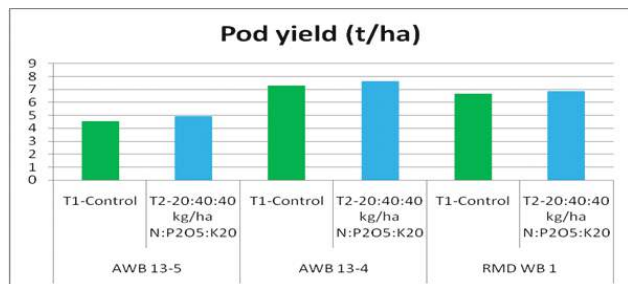


Fig 12. Yield of three winged bean varieties



Fig 13. Winged bean trailed on bamboo made support

### Participatory evaluation of different lentil varieties/lines

Fourteen varieties/lines of lentil were sown on two different dates viz. 16<sup>th</sup> Nov, 2015 and 1<sup>st</sup> Dec, 2015 for evaluating the effect of sowing dates on growth and yield. Among the lentil lines sown on 16<sup>th</sup> Nov, 2015; the variety BM-7 produced significantly highest seed yield whereas the variety ILL-10897 recorded the lowest seed yield. Lentil varieties sown on 1<sup>st</sup> Dec'2015 yielded lower than varieties sown on 16<sup>th</sup> Nov'2015 (Fig 14 & 15).

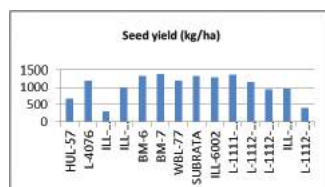


Fig 14. Performance of lentil lines sown on 16<sup>th</sup> November, 2015

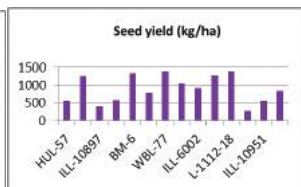


Fig 15. Performance of lentil lines sown on 1<sup>st</sup> December, 2015

### AICRP trials of Mushroom

A total of six entries namely PL-15-01 to PL-15-06 of *Pleurotus* mushroom were evaluated under AICRP mushroom project (Fig 16). Four replications of each entry were maintained and the observations were taken for the various parameters like date of opening, time of pin head formation and yield data. Among the six entries PL-15-05 and PL-15-06 showed the first pin head formation followed by PL-15-02, PL-15-03, PL-15-01, PL-13-05 and PL-15-04 and the highest yield was recorded for the entry PL-15-05 during reported year.

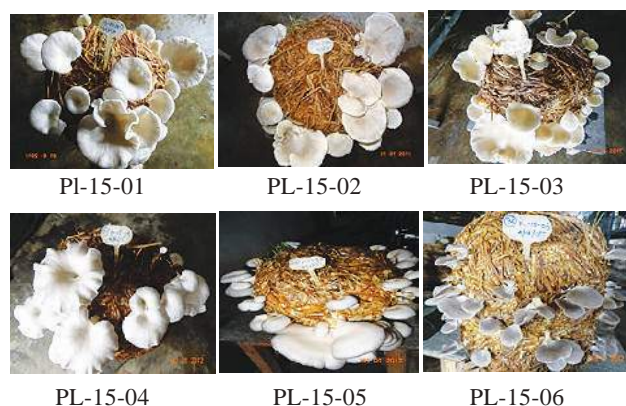


Fig 16. Six entries of *Pleurotus* mushroom under AICRP mushroom

### Isolation of phosphate solubilizing microorganism from maize field under different organic manurial regimes

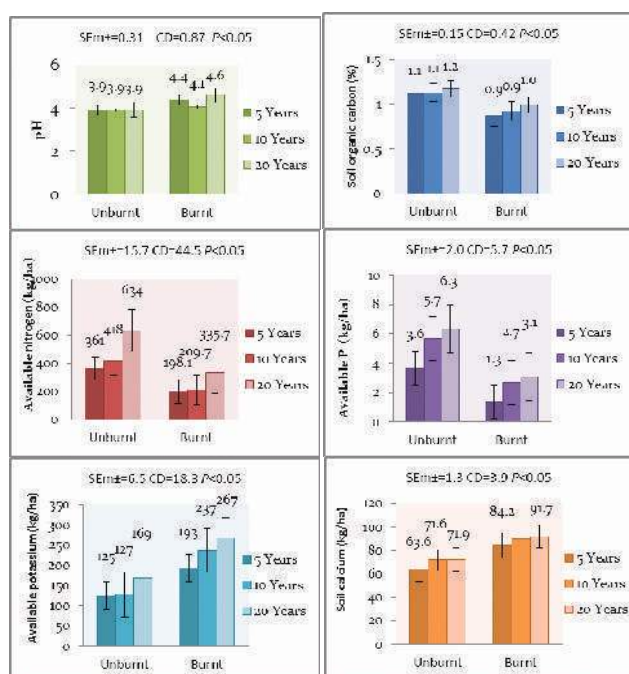
A survey was conducted in farm experimental plots to isolate phosphate solubilising microorganism (PSM) thriving under various manurial regimes, viz., FYM, vermicompost and poultry manure. Soil samples were collected at a depth of 0 - 15 cm and air dried on an open bench for 72 h. A total of 43 PSM isolates were extracted from soil on Pikovskaya's agar medium, containing insoluble tricalcium phosphate (TCP). Twelve isolates showed highest phosphate solubilization index (PSI) ranged from 2.18 - 3.0. These isolates belong to genus *Pseudomonas*, *Bacillus* as identified by their morphological and biochemical properties, respectively.

### Effect of fallow periods on chemical properties on *jhum* soils of Mizoram

Soil samples were obtained from Mizoram nearly spanning entire *jhum* cycle and fallow periods. The fallow periods in *jhum* cycle were five, ten and twenty



years. The soil was found to be acidic. The changes in chemical properties suggest that slight decrease in pH in soil surface layer occurred during the fallow periods (Fig 17). The changes in the content of organic carbon increased with the rise in fallow period. Both organic carbon (1.2%) and available nitrogen (634 kg/ha) was the highest value in twenty years fallow site. The surface layer accumulated much organic matter during the long fallow period. The levels of available phosphorus, exchangeable calcium, potassium and pH of the soil were lowest during the five year fallow period. Exchangeable calcium was noticeably abundant in the long fallow period. Burned soils had lower organic matter and nitrogen than unburned soils, higher calcium and potassium, and nearly unchanged pH and available phosphorus were recorded.

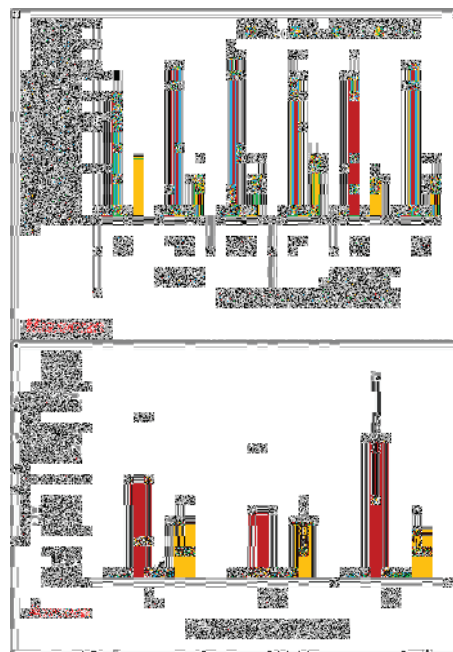


**Fig 17. Effect of burning on chemical properties of soil under different fallow periods (5, 10, 20 years). Bars represent  $\pm$  SD of mean (of ten replicates)**

### Effect of burning and fallow periods on minor elements of soil from *jhum* fields

Soil samples were obtained from Mizoram, Assam nearly spanning entire *jhum* cycle and fallow periods. The fallow periods in *jhum* cycle were five, ten and twenty years. The quantity of minor elements occurred in the trend as iron>manganese>zinc>copper in all the sites in general (Fig 18). Conversion practices had a least significant effect on the quantum of minor elements. While the quantity of iron and copper

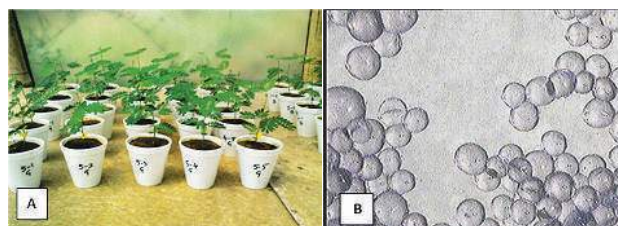
increased with the increase in fallow period, manganese and zinc had a negative correlation with fallow period.



**Fig 18. Profile of minor elements under the *Jhum* regime of various sites.**

### Effect of alginate encapsulation of microbial consortia on growth parameters of *Leucaena leucocephala*

The effectiveness a microbial consortia in conjunction of arbuscular mycorrhizal fungi (AMF) in crop growth and phosphorus translocation in *Leucaena leucocephala* via. encapsulation in alginate was explored with an objective to develop encapsulated form of biofertilizer for agricultural use in harsh ecosystem (Fig 19). Table 7 in general reveals that all the parameters under investigation increased with the application of immobilized microbial consortia above control. The trend of phosphorous (P) translocation was: immobilised consortia > non-immobilised consortia > control. Maximum P was



**Fig 19a. Experiment of immobilized microbial consortia tested on *Leucaena leucocephala* and B) stereoscopic micrograph of alginate microcapsules (x 40)**



**Table 7. Effect of immobilized microbial cells on plant growth and phosphorous (P) translocation**

Treatment	Dry weight(g)				Total P per leaflet/leaf(μg)	
	Shoot		Root		Non AMF	AMF
	Non AMF	AMF	Non AMF	AMF		
IRPR*	0.32	0.50	0.19	0.20	0.82	0.94
S-IRPR	0.28	0.31	0.18	0.19	0.30	0.76
NIRPR	0.30	0.40	0.19	0.20	0.62	0.84
Control	0.25	-	0.17	-	0.21	-

\* IRPR = co-immobilised bacterial cells of *Rhizobium* +PSB+ RP; S-IRPR = sterile co- immobilised bacterial cells of *Rhizobium* +PSB+ RP; NIRPR= Non-immobilised bacterial cells of *Rhizobium*+ PSB+RP , RP= Rock phosphate, PSB= Phosphate solubilising bacteria

translocated by immobilised bacterial cells in conjugation of AMF @ 0.94 μg/leaflet/leaf with minimum with control (devoid of microorganism) @ 0.21 μg/leaflet/leaf. Alginate polymer alone had insignificant influence on the parameters tested as compared to the control.

### Growth and Yield evaluation of North-East rice cultivars under excess iron stress

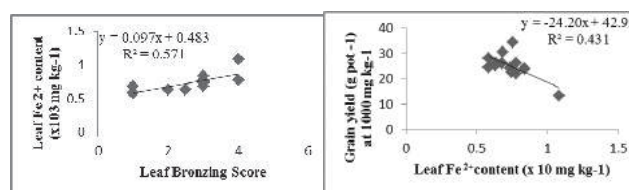
An investigation was carried out to determine the growth and yield of rice cultivars under excess iron stress using thirteen rice cultivars viz. Maibetikala, Chandina, Hathia, Signal, Garumaruti, Abhinara, Mamireang, Chakki Badam, Chinari, Lalgura, Katakchara, Kanatara and Naveen from Northeast. Rice seeds were planted in earthen pots (6" x 12" size) filled with washed fine sand soil. Ferrous iron was applied into the pots as  $\text{Fe}_2\text{SO}_4 \cdot 7\text{H}_2\text{O}$  in concentrations of 300 ppm (considered as critical limit) and 1,000 ppm along with basic nutrient supplements twice a weeks starting from 14 days after germination (DAG) until 30 DAG.

#### Expression of Leaf symptoms

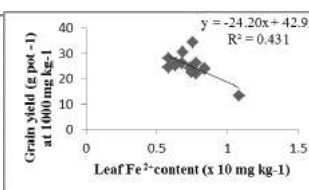
Among the subjected cultivars, Chakki Badam, Chinari and Lalgura expressed mild symptoms. Relatively low leaf bronzing scores were observed in cultivar Katakchara, Kanatara and Naveen. Regression analysis further showed positive relationship between the mean iron content in the leaves and mean bronzing scores ( $R^2 = 0.57$ ) (Fig 20).

#### Percentage dry biomass and grain yield reduction

Significant differences were observed in dry biomass and grain yield among the rice cultivars (Fig 21). The shoot dry weight reduction due to iron toxicity ranged from 7.5 to 49.4 %. The highest dry matter



**Fig 20. Relationship between mean iron content in the leaves and bronzing score of 13 genotypes of rice after exposure to 1000 mg/kg  $\text{Fe}^{2+}$**



**Fig 21. Relationship between mean iron concentration in the leaves and yield of 13 genotypes of rice after exposure to 1000 mg/kg  $\text{Fe}^{2+}$**

accumulation under iron toxic conditions was recorded in Lalgura and Naveen. The grain yield reduced by 18.93 % due to iron toxicity. The grain yield was not significantly reduced in Chakki Badam, Chinari, Lalgura and Naveen when compared with other rice cultivars.

### Antioxidative responses of two rice cultivars to short term iron toxicity during de-etiolation

The iron-induced increase in SOD activity was recorded higher in Phougak compared to KD-2-6-3 both in lamina as well as sheath tissues. Total SOD activity significantly increased after 24 hr greening period followed by sudden increase after 72 hr of greening in sheaths. Conversely, while Phougak showed a transient increase in total SOD activity in laminae during 24 hr and 72 hr of greening the cultivar KD-2-6-3 showed increase in SOD activity only during 24 hr greening which declined after 72 hr of greening. Ferrous iron had little impact on APX activity in sheaths, but it increased in laminae after 24 hr of greening in both the cultivars and to a lesser extent after 72 hr of greening in Phougak and declined in case of KD-2-6-3. To conclude, the cultivar Phougak



resisted iron stress due to its early preparedness to combat the oxidative stress through enhancement of the antioxidative enzyme activities than of KD-2-6-3 in non-stressed conditions.

### Physiological basis of tolerance to iron toxicity in rice germplasm of Northeast India

An attempt was made to understand the tolerance mechanism associated with selected rice germplasm from Northeast to iron toxicity viz., **A:** Pyzum, **B:** Shahsarang and **C:** Arize (after 5 days treatment of 1,000 mg L<sup>-1</sup> Fe<sup>2+</sup>) showing differential leaf symptom expression, Root oxidising potential and antioxidative enzyme (Fig 22 and 23) activities were analyzed.

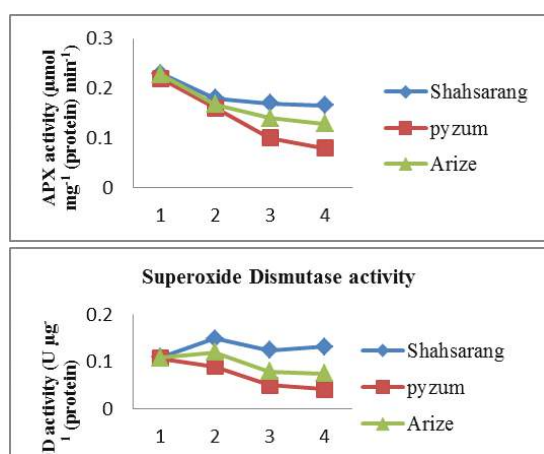
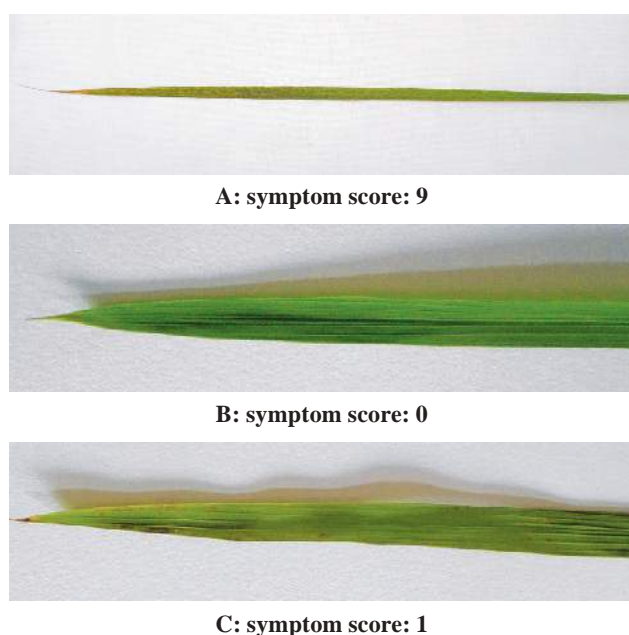


Fig 22. Antioxidative enzyme activities of three rice cultivars

Rice cultivar employ different tolerance mechanism against iron toxicity ie. Shoots and root

based mechanisms. While the dominant tolerance mechanism of Arize was determined to be exclusion manifested through stronger oxidizing potential of Fe<sup>2+</sup> (Fig 2), the iron tolerance in Shahsarang 1 was attributed mainly to shoot-based mechanisms (enhanced antioxidative activities).

Ten upland rice germplasm from Tripura were evaluated for phosphorus use efficiency. Among the cultivars studied, Lalgura was found to be highly efficient in phosphorus utilisation and uptake exhibited through high grain yield and grain phosphorus content even at 0 phosphorus input. A study on morpho-physiological responses of foliar application of different concentration of nano ZnO in TRCM-131-1 mung is ongoing.

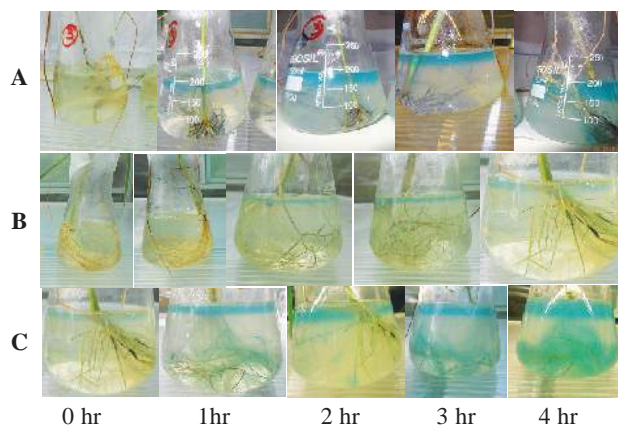


Fig 23. Time course of root oxidizing power of rice cultivars were indicated by color change in Methylene-blue agar solution

## HORTICULTURE

### Standardization of rejuvenation techniques of old Mango trees

Rejuvenated old and senile mango trees of cv. Himsagar attained height of 3.6 to 6.2 m and spread 3.2-5.6 m (N-S) X 3.1-5.1 m (E-W) in the 3<sup>rd</sup> year (Fig 24a). Average shoot length ranged from 1.5 - 2.9 m and shoot girth ranged from 45 – 60 mm. Panicle emergence was recorded in 65% of the rejuvenated trees with panicle size 25 cm × 22 cm (length × girth). The growth parameters indicated that tree growth was better with pruning height of 2.5 m, followed by 3.5 m. Top grafting on sprouted shoot emerged on the rejuvenated wild trees show that wedge grafting during April-May gave maximum grafting success (73.3-85.4%) in 2013-14 (Fig 24a). Grafted shoot length was 2.5 m and diameter 60.4-69.4mm. Trees top grafted





**Fig 24a. New shoot growth on rejuvenated mango trees**

with cv. Amrapali produced panicle in 2<sup>nd</sup> and 3<sup>rd</sup> year. Infestation of stem borer (60-70%) was recorded to be more during rainy season i.e. June to August under Tripura condition.

#### **Effect of shoot pruning and foliar feeding of nutrients on Litchi**

The experiment was carried out on the young bearing trees of litchi cv. Shahi to standardize the combination of shoot pruning intensity and foliar feeding of nutrient (Fig 24b). Shoot pruning treatments of 20 cm in combination with single spray of zinc (0.1%) at one month before panicle emergence followed by boron (0.5%) at one week before flowering was effective for better flowering and fruit



**Fig 24b. Standardization of management practices for Litchi**

set. Single spray of urea (1%) at green fruit stage, again boron (0.1%) at fruit maturity stage was effective for fruit growth and quality. Sprays gave better response in terms of early shoot emergence and shoot maturity in comparison to tree without pruning as well as only the shoot tip removal treatments. Similarly, this treatment combination was also found to be effective for higher shoot length (56.5-61.4 cm) and diameter (19.8-21.8 mm), panicle length (41-46.4 mm) and fruit set (16.5-17.9%). Fruit chemical parameters show that fruit weight ranged from 16.8-18.6g, length 3.3-3.8mm, diameter 2.4-2.8mm, pulp 73.6-74.8% and TSS 19.6-21.5%. Foliar sprays of zinc, boron and urea significantly reduced fruit cracking (5.1-5.6%) and increased yield/tree (34.6-37.8 kg). This treatment was closely followed by the 30 cm shoot pruning. Old litchi trees are under rejuvenation process for validation of the shoot pruning and foliar feeding trial. Trees in the 2<sup>nd</sup> year attained 3.7-4 m height with spread 2.5-3.5 m (in E-W and N-S). New shoot length and girth are 1.5-2.5m and 25-30 mm, respectively.

#### **All India Coordinated Research project on Vegetable Crops**

Evaluation of different brinjal entries under Tripura agro-ecological conditions showed that higher yield was recorded in 2015/BRLVAR-3 (26.87 t/ha) in IET (Long), 2015/BRRVAR-2 (19.61 t/ha) in IET (Round), 2014/BRLVAR-3 (33.1 t/ha) in AVT-I (Long), 2014/BRRVAR-3 (25.56 t/ha) in AVT-I (Round), and 2013/BRLVAR-1 (39.62 t/ha) in AVT-II (Long). In tomato, entries 2015/TOLCVRES-5 (36.75 t/ha) in IET (TOLCV) and 2014/TOLCVRES-4 (36.25 t/ha) in AVT-I (TOLCV) were high yielder. In Dolichos bean, entries 2014/DOLPVAR-3 in AVT-I yielded 7.0 t/ha.

#### **All India Coordinated Research project on Tuber Crops**

Major and minor tubers crops like swamp taro, sweet potato and colocasia have been collected and tuber crop based integrated farming system has been established in the farmer's field. The different components to be integrated are tuber crops, piglets, goats and chicks along with vegetable and fruit crops. Colocasia and sweet potato has been planted in the rice fallow land after *Aman* season. Quality planting materials of different tuber crops (Elephant Foot Yam – 500 kg, Colocasia 400 kg, Dioscorea 350 kg, Tapioca cuttings 6000 Nos.) have been produced.



## All India Network Research Project on Onion and Garlic

Survey for supply and demand of onion was carried out. On an average household consumption is 1.9-2.2 kg/month, procurement by hotels and eateries is 110-560 kg/month, the sale by the retailers is 770-800 kg/month and the procurement of onion at whole sale level is in the range of 300-360 tons/month. Total entries evaluated are 16 in IET, 11 in AVT-I, 13 in AVT-II and 9 in AVT-II hybrid. Drip and sprinkler irrigation system was installed in the onion demonstration plots (Fig 25). Bulb weight ranged from 64-124 g. Incidence of purple blotch, botrytis blight and thrips were predominant on *rabi* onion in Tripura.



Fig 25. Sprinkler and drip irrigation system installed in onion field

## Molecular diagnosis of banana Sigatoka disease in Tripura

The Sigatoka disease complex of banana involves three related ascomycetous fungi, *Mycosphaerella fijiensis*, *M. musicola*, and *M. eumusae*. In this study, a rapid and robust species-specific molecular- based diagnostic tool has been developed for detection of *M. fijiensis*, *M. musicola*, and *M. eumusae*. Different banana leaf samples were collected from different places of Tripura i.e Kulfung, Jolaibari, Shantirbazar, Bagafa, Garjee, Matabari, Jirania, Mohanpur and Lembucherre. Total 9 samples have been collected. DNA samples

were diagnosed by the three specific primers i.e MFactF, MMactF2 and MEactR. Among the three primers MMactF2 has shown the positive result in all the 9 samples (Fig 26). MMactF2 is specific primer for *M. musicola*.



Fig 26. PCR result showing the distinct bands with primer MMactF2

(Note: The amplicons of expected size of around 350 bp in all the samples. M: Promega 1 Kb ladder; lanes 1-9:- Banana samples)

## ANIMAL SCIENCE

### Performances of Murrah buffalo in Tripura agro climatic conditions

The highest lactational yield for 305 days was 1576.3 litres with the highest peak milk production of 12 litre per day during 3<sup>rd</sup> year period (2015- 16). Though silent heat feature in Murrah buffalo was recorded at farm (Fig 27), bull parading detected estrus in she buffaloes at farm. One female buffalo calf (30.0 kg birth weight) and one male buffalo calf (33.0 kg birth weight) born during 2015- 16 at ICAR livestock



Fig 27. Buffalo under shower system to cool the body heat in summer

Table 8. Blood haemoglobin level and biochemical constituents in Murrah buffaloes

Hb (gm%)	Glucose (mg/dl)	Total Protein (gm/dl)	Cholesterol (mg/dl)	Ca (µg/ml)	P (µg/ml)	Fe (µg/ml)	Cu (µg/ml)	Zn (µg/ml)	Mn (µg/ml)
11.64 ± 0.54	57.82 ± 7.07	13.33 ± 0.90	71.55 ± 7.19	67.55 ± 8.53	7.64 ± 1.57	7.23 ± 1.08	1.00 ± 0.13	Not detectable	Not detectable



farm, Lembucherra, West Tripura. There was no incidence of diseases in buffaloes during 2015- 16. Table 8 shows the blood haemoglobin level and biochemical constituents in Murrah buffaloes during 2015- 16.

### Phenotypic characterization and egg quality of Tripura indigenous ducks under farming system

To distinguish Tripura indigenous ducks (Fig 28) phenotypically from Khaki Campbell (Fig 29) and investigate egg quality of Tripura indigenous ducks as well as Khaki Campbell a study was conducted. Twenty one phenotypic variables (such as BW, body length, neck length, kill bone length, breast circumference, bill length, bill colour, bill shape, shank colour, plumage colour etc.) collected on 69 adult ducks covering Tripura indigenous ducks and Khaki Campbell were analyzed using multivariate test-Wilks' lambda to build a best fit predictive model for goodness of group membership and thus recognize the most probable six predicted variables. The relative importance of the predicted variables in discriminating two groups was assessed using canonical discriminant function coefficients. Based on these canonical discriminant function coefficients, the following equation for the discriminant function (DF) was generated using six best predicted variables:

$$DF = 0.517 * \text{Sex} + 1.619 * \text{BodyLength} - 0.802 * \text{Wing Length Up} - 0.775 * \text{Hine Circumference} + 0.470 * \text{Billshape} + 0.393 * \text{Shank Colour}$$

Using this equation, given someone's scores on these variables, we calculated their scores on the discriminant function and then 'cut score'. If an individual variety's score on the DF was above - 0.7095, then it was probably the Variety 1: Local. If their DF score was below -1.167, then it was probably the Variety 2: Khaki Campbell. The egg quality of Tripura indigenous ducks did not differ ( $p > 0.05$ ) from the egg quality of Khaki Campbell ducks as shown in Table 9.

### Plasma anti- mullerian hormone (AMH) level is independent of pituitary FSH and/ or LH action

The aim was to investigate whether plasma anti-mullerian hormone (AMH) profile was affected by pituitary follicle stimulating hormone (FSH) and/ or luteinizing hormone (LH) during folliculogenesis stage in animals. An experiment was designed to elucidate the responsiveness of plasma AMH to GnRH challenge in cattle, she buffaloes and she goats at livestock farm. Three Holstein Fresian crossbred cattle, three Murrah she buffaloes and three Black Bengal does selected for the study were non-pregnant (empty) and non-cyclic with average age of 8.32, 9.14,



Fig 28. Tripura indigenous ducks

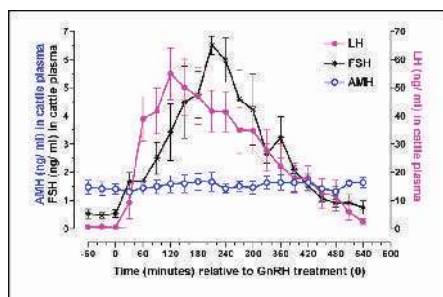


Fig 29. Khaki Campbell ducks

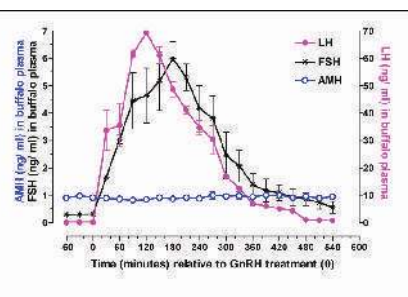
Table 9. The egg quality of Tripura indigenous ducks as well as Khaki Campbell ducks

Variety	Egg wt.(gm)	Shapeindex	Egg shell thickness (mm)	Shell %	Albumin index	Yolk index	Haugh unit
Tripura indigenous ducks	58.68± 0.77	73.50± 0.35	0.30 ±0.01	10.55 ±0.13	13.68 ±0.41	42.32±0.63	81.90± 0.81
Khaki Campbell ducks	60.10 ±0.62	73.26 ±0.34	0.28 ±0.00	10.06 ±0.05	13.27 ±0.33	41.20±0.90	81.09±0.79

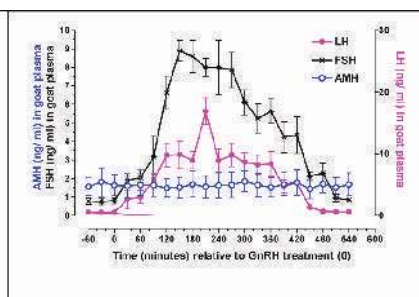




**Fig 30a. Plasma AMH, FSH and LH profiles in cattle (n=3) after GnRH challenge. Time 0 represents the time of GnRH administration intravenously @ 0.25 µg/ kg body weight**



**Fig 30b. Plasma AMH, FSH and LH profiles in she buffaloes (n= 3) after GnRH challenge. Time 0 represents the time of GnRH administration intravenously @ 0.25 µg/ kg body weight**



**Fig 30c. Plasma AMH, FSH and LH profiles in she goats (n= 3) after GnRH challenge. Time 0 represents the time of GnRH administration intravenously @ 0.25 g/ kg body weight**

4.1 years, respectively. These animals were administered intravenously (i.v.) with GnRH @ 0.25 mg/ kg body weight (Receptal®, M/s. Intervet, India). The serial blood samples were collected in heparinised tubes at -60, -30, 0 min (0 being the time of GnRH administration) and then every 30 min interval for 9 h post GnRH administration. Plasma FSH, LH and AMH concentrations were quantified using commercially available ELISA kits.

The mean ( $\pm$  SEM) plasma FSH, LH and AMH profiles in cattle, she buffaloes and she goats in response to GnRH challenge test are presented in Fig 30a- 30c. Nonparametric one-way repeated measure, i.e. Friedman test revealed that plasma FSH and LH concentrations changed significantly ( $p < 0.01$ ) over time after GnRH administration in cattle/ she buffaloes/ she goats. Plasma AMH levels remained unchanged ( $p = 0.896, 0.494, 0.291$  for cattle, she buffaloes and she goats, respectively) after GnRH challenge test in cattle, buffaloes and goats indicating that plasma AMH level was not affected by pituitary FSH and/ or LH.

### Evaluation of performance of dual type chicken

Dual variety chicken was developed at Division of Poultry Science, ICAR, Tripura Centre by crossing of Tripura Black, Coloured Broiler and Dahlem Red and evaluated for their performance (Table 10).

### Evaluation of fertility and hatchability of different chicken germplasms

A total of 31546 eggs of different breeds/varieties/ lines of chicken were set for hatching at the hatchery unit. A total of 17,346 chicks of different varieties /

**Table 10. Evaluation of mean performance of dual type chicken at Institute and farmer's fields**

Traits	Institute Farm	Farmer's field
Day old BW (g)	41.39 $\pm$ 0.62	40.05 $\pm$ 0.35
4 Wk BW (g)	243.67 $\pm$ 8.34	239.88 $\pm$ 13.27
8 Wk BW (g)	547.09 $\pm$ 17.04	433.44 $\pm$ 16.64
12 Wk BW (g)	1007.09 $\pm$ 32.49	715.88 $\pm$ 24.32
20 Wk BW (g)	1806.04 $\pm$ 54.46	1455 $\pm$ 23.58
40 Wk BW (g)	2653.72 $\pm$ 82.26	2078 $\pm$ 24.56
E.P. up to 40 WK	46.15	-
Age of first egg (Days)	165	174
Egg wt 40 WK (g)	55.88 $\pm$ 0.39	50.12

lines of chicken were produced. The overall average percent fertility was estimated 77.36 % in different breeds/varieties/ lines of chicken. The highest percent fertility was found in Coloured broiler (82.69%) and lowest percent fertility was found in NB Cross (69.93%). The overall average percent hatchability on total egg set (TES) and fertile egg set (FES) were estimated; 54.98 % and 71.07 %, respectively. The highest hatchability on total egg set (TES) and on fertile egg set (FES) was found 61.89% and 77.85% respectively in Coloured broiler. The lowest hatchability on total egg set (TES) and on fertile egg set (FES) was found 38.70% and 54.94%, respectively in Dahlem red.

### Supply of poultry germplasms:

During the period, a total of 14,193 chicks of different varieties / lines of poultry were distributed to the farmers of Tripura (Table 11).



**Table 11. Details of supply of different types of rural poultry germplasm**

S. N.	Name of the germplasm	Nos.
1.	Dual Type	6298
2.	ND Cross (50%)	4119
3.	Coloured Broiler	2,783
4.	NB Cross (50%)	816
5.	Tripura black	95
	Dahlem Red	82
	<b>Total</b>	<b>14,193</b>

## FISHERIES

### Demonstration of composite culture using stunted fingerlings

Composite culture was demonstrated using stunted fingerlings of Indian major carps and Chinese carps (Fig 31) at a stocking density of 7500 fingerlings/ha. The species composition was catla and silver carp each at 20%, rohu 30% and mrigal, grass carp and bata each at 10% feeding was done regularly using rice bran and mustard oil cake (1:1) at 5% body weight of the fish. The water quality parameters recorded on monthly intervals were DO 6.8-8.8 ppm, total alkalinity 50-100 ppm, pH 5.8-7.7, ammonia 0.63-1.5 ppm. The soil quality parameters were pH 4.4-6.61, OC 0.12-0.65%, available N 4.28-6.43 mg% and available P 1.6-3.6 mg%. The production of fish recorded over of one year was 2055 kg/ha. The avg. rate of survival of fish was 75%.



**Fig 31. Fish produced using stunted fingerlings**

### Demonstration of duck cum fish farming using stunted fingerlings

Duck cum fish farming was demonstrated at a stocking density of 250 ducks and 7500 fingerlings/ha (Fig 32 & 33). The species composition was catla 40%, rohu 30% and mrigal 30%. No feeding was done. The fish were made solely dependent on the plankton produced from the duck excreta. The density of the

plankton was 2.8-6.5 ml/50-L. The water quality parameters recorded on fortnight intervals and DO was 6.0-9.6 ppm, alkalinity 50-100 ppm, pH 5.8-7.3 and ammonia was 0.98-2.82 ppm. The avg. soil pH was 4.1-6.43, OC 0.22-0.59%, available N 4.84-7.39 mg% and available P 2.6-4.2 mg%. The production of fish recorded over a period of 10 months was 1168 kg/ha. The avg. survival was 73.3%.



**Fig 32. A haul of fish produced through duck integration**



**Fig 33. Visit of State officials to the demonstration model of ICAR**

### Demonstration of kanla (*Notopterus notopterus*) culture

Kanla, popularly known as bronze featherback is a high valued indigenous self-recruiting species. The fish has ornamental value beside food value and medicinal value. In this study, the production of the fish was demonstrated at a stocking density of 1500 fingerlings/ha using minnows (*Amblypharyngodon mola*, *Esomus danricus*, *Puntius spp.* etc) as forage fish. No feeding was done, however, aeration was provided frequently. Fertilization was done following recommended practices. Batch harvesting was followed from 3<sup>rd</sup> month onwards after stocking. Total number of fish harvested in a year due to self-recruitment was 42750 (Fig 34). The avg. size of fish at harvest was 55g and the total production of fish was 2351 kg/ha. The protein content in kanla was 18.5%, Ca 250 mg, P 270 mg, Cu 0.055mg, Zn 1.8 mg, Fe 2.8 mg and Mn 0.045 mg/100g. This was very good





**Fig 34. Grading of kanla**

to control minnows, tadpoles and aquatic insects in the ponds and to enhance the overall productivity of the culture system.

#### **Fingerling production and distribution**

358500 fingerlings of Indian major carps and exotic carps were produced experimentally at the ICAR farm. 255000 fingerlings were distributed among 380 farmers under NICRA, TSP and other projects.

#### **Survey of Assam and Tripura districts for Epizootic Ulcerative Syndrome (EUS)**

A survey was conducted covering 2 districts of Assam and eight districts of Tripura for EUS. It was observed that in district Nalbari and Kamrup, 90% of the farms surveyed had infection with EUS (Fig 35). The farmers were suffering huge economic loss due to the recurrence of EUS every year. To control the infections, farmers were applying antibiotics which is a serious ecological concern. Almost all the species of composite fish culture like Rohu, Catla, Mrigal, grass carp were being affected. In addition to that Anabas, Puntius, Channa species were also seriously affected.



**Fig 35. Infected *Cirrhinus mrigala* collected from Guwahati**

Similarly in Tripura, 95% of the farms surveyed were being affected with EUS (Fig 36). In Tripura, the farmers were not able to apply any therapeutic measures. As a result of which mass mortality was being recorded. Huge financial losses were recorded in these farms, as the fishes which they normally sold at Rs. 200/Kg were disposed off at Rs. 30/Kg. Samples of fish, soil and water were collected and brought to ICAR, Tripura Centre. The *Aphanomyces invadans*, causative agent of EUS was isolated from the infected fishes. Twenty different isolates of *A. invadans* are currently being maintained in our centre for further molecular characterization.



**Fig 36. Infected *Labeo gonius* in Kumarghat of Tripura**

#### **Herbal supplementation diet on immune response in *Labeo rohita* against *Aphanomyces invadans***

The epizootic ulcerative syndrome (EUS), caused by the fungal pathogen, *Aphanomyces invadans*, is one of the fish diseases of international significance in capture and culture fisheries. In this study, the effect of diet supplemented with the root powder of *Withania somnifera* (Indian winter cherry/ Indian ginseng) against *A. invadans* in Indian major carp, *Labeo rohita* ( $45.82 \pm 3.85$ g) was investigated to find out the innate immune response and disease resistance. In the infected fish, fed with herbal diet, there was significant improvement in immunity and disease resistance of the fish. Protein, albumin, GPT, ALP, NBT level and bactericidal activity were highest at a dose of 2 g/kg, however, GOT, RBC, WBC and haemoglobin contents in the fish were highest at a dose of 3 g/kg after fourth week. The survival was highest at a dose of 3 g/kg. This study suggests that 2-3 g/kg enriched diet enhances innate immunity and confers disease resistance which could be applied to develop prophylactic strategies for sustainable aquaculture.



### Chitosan enhances the immunity in *L. bata* to *E. tarda* infections

Effect of chitosan as an immunostimulant was evaluated on the immune response of *Labeo bata*. Various haematological and immune parameters were evaluated. It was seen that overall the chitosan fed fishes had higher haemoglobin content than the control fishes throughout the experimental period. Total erythrocyte and leukocyte count was significantly higher ( $P \leq 0.05$ ) in dose 1 and dose 2 chitosan fed fishes during the whole experimental period. After challenge with *E. tarda* the chitosan fed fishes had higher erythrocyte count than the control fishes. The mean protein, albumin and globulin of *L. bata* fed chitosan were always higher than the control fishes throughout the experimental period. The glucose concentration of control fishes was always higher than chitosan fed fishes. Dose 2 and dose 3 chitosan fed fishes had higher MPO and lysozyme activity during almost all the experimental period except for 7<sup>th</sup> day sampling period when control group had significantly higher ( $P \leq 0.05$ ) MPO activity than the chitosan fed group. Ten days post challenge with *E. tarda* all the chitosan fed groups had significantly higher NBT activity than control. Serum bactericidal activity of control fishes was always lower than chitosan fed fishes. It was observed that chitosan as an immunostimulant could elevate the immune status of *bata* rendering protection against *E. tarda*. Dose 2 chitosan fed fishes performed better than the other 2 dose. So it can be said that 50gm chitosan per Kg feed can improve the immune status of *bata* protecting it from bacterial infections.

### Immune response in *Labeo bata* to *Edwardsiella tarda* infections

An attempt was made to understand the pathogenicity mechanism of edwardsiellosis in *Labeo bata*. *L. bata* was artificially infected with a pathogenic isolate of *E. tarda* (Fig 37). It was seen that post infection, there was a significant decrease in total

protein, albumin, globulin, respiratory burst and serum bactericidal activity (Table 12). A significant increase in lysozyme, myeloperoxidase and glucose was observed post infection. The results obtained here helps us to understand the pathogenesis of *E. tarda* in *L. bata*.

**Table 12. Effect of *Edwardsiella tarda* infection on haemato-biochemical and immunological parameters**

Parameters	0 Day	1DPC	10 DPC
RBC Count (millions/cumm.)	2.55±0.06 <sup>a</sup>	1.28±0.12 <sup>b</sup>	1.83±0.17 <sup>c</sup>
WBC Count (thousands/cumm.)	32.80±1.51 <sup>a</sup>	28.40±4.98 <sup>b</sup>	29.85±4.87 <sup>b</sup>
Mean Protein (g/dl)	3.96±0.54 <sup>a</sup>	3.61±0.34 <sup>b</sup>	3.61±0.67 <sup>b</sup>
Albumin (g/dl)	1.48±0.22 <sup>a</sup>	0.97±0.05 <sup>b</sup>	1.08±0.08 <sup>b</sup>
Globulin values (g/dl)	2.71±1.22 <sup>a</sup>	1.66±0.63 <sup>b</sup>	1.73±0.32 <sup>b</sup>
Glucose values (mg/dl)	46.90±0.41 <sup>a</sup>	47.57±0.35 <sup>b</sup>	46.45±0.46 <sup>b</sup>
NBT (OD at 540 nm)	0.37±0.01 <sup>a</sup>	0.18±0.019 <sup>b</sup>	0.34±0.04 <sup>a</sup>
MPO values (OD at 450 nm)	0.73±0.03 <sup>a</sup>	0.36±0.06 <sup>b</sup>	0.50±0.03 <sup>c</sup>
Lysozyme values (µg/ml)	3.87±0.12 <sup>a</sup>	4.15±0.24 <sup>b</sup>	3.52±0.22 <sup>a</sup>



**Fig 37. Typical Edwardsiellosis after injection of fish with pathogenic strain of *E. Tarda***



# NATIONAL INNOVATION IN CLIMATE RESILIENT AGRICULTURE (NICRA)

## Theme 1: Identification of stress tolerant rice, maize and tomato genotypes for North Eastern Hill ecosystem

### Rice

Nine promising heat tolerant rice genotypes were selected and for developing mapping population, these lines were crossed during *kharif* 2015 with two newly released upland rice varieties *viz.*, RCPL 1-115 and RCPL 1-412. A total of 45 rice germplasms/line/varieties collected from various sources *viz.* VPKAS Almora, ICAR RC Barapani, SARS Mokokchung and farmers' field across Nagaland were tested under upland rainfed conditions for testing their ability to withstand moisture stress (Fig 1). The soil moisture content during the period of experimentation varied between 7.28 and 21.08 %. Among the tested germplasms/lines/varieties, variety Bhalum-3 recorded maximum grain yield (1633 kg/ha). The minimum yield was recorded in case of *Mannia* local (250 kg/ha).



**Fig 1. Screening of rice germplasms under rainfed condition for moisture stress in Nagaland**

Studies were conducted to identify water stress tolerant upland rice cultivars using rainout shelter facility at Umiam. Stress was imposed for 15 days each at two stages (1<sup>st</sup> one at active tillering: 23 DAS and 2<sup>nd</sup> one at grain filling: 94 DAS). It was observed that under water stress conditions, RCPL 1-412 and IURON 514 performed poorly as their yield reduction was more than 30% compared to 6-7% reduction in Bhalum 1 and Bhalum 3.

The comparative performance of elite cold tolerant local cultivars (50 nos.) under rainfed upland condition of Sikkim was studied. The highest yield was recorded in culture no. 2303 (16.95 t/ha). Same entries were kept under severe drought conditions (in pot) at the beginning of anthesis. Among the 50 entries, grain filling was observed in 17 entries only and the highest

number of grain filling per panicle was recorded in case of Tabrey (125.25) cultivar.

Five rice varieties *viz.* RC Maniphou-4 (RCM-7), RC Maniphou-6 (RCM-5), RC Maniphou-7 (RCM-9), AKUTPHOU and TAOTHABI with different seedling ages (25, 35, 50 and 60 days old) were tested for submergence tolerance under Manipur weather conditions (Fig 2). Among these varieties, RC Maniphou-7, when transplanted 60 days old seedling, recorded the highest grain yield (5.08 t/ha) under half submergence condition for 5 days. Number of grains per panicle was also found to be the highest (169) in case of RC Maniphou-7 under the same duration of submergence and seedling age of transplanting. Irrespective of duration of submergence (5, 10 and 15 days), the tested varieties failed to show any tolerance to the induced submergence.



**Fig 2. Submergence Tolerance Study on Rice, Kharif-2015**

To identify temperature tolerant rice varieties in Mizoram, the performance of different varieties was evaluated at low, medium and high altitude. Variety *Gomati* produced significantly higher grain yield at low and high altitude (4.79 and 4.3 t/ha, respectively). However, at medium altitude, RCM-9 produced significantly higher grain yield (45.1 q/ha). At low, medium and higher altitude, under upland conditions, significantly higher grain yield was recorded (2.59, 3.6 and 3.68 t/ha, respectively) in case of *Bhalum 3* (Fig 3).

### Maize

Maize landraces (124 nos.) were characterized using morphological characters in CTGC. Wide variations for various morphological traits were recorded among different landraces. All genotypes were grouped in three different clusters; promising genotypes from different cluster will be used in maize improvement programme. Five screened maize genotypes (RCMGP 40, RCMGP 47, RCMGP 63, RCMGP 105 and RCMGP 124) were selected for inbred development and were advanced to F3 in 2015 (Fig 4)





**Fig 3. Evaluation of rice varieties under high-altitude WRC conditions at Champhai, Mizoram**

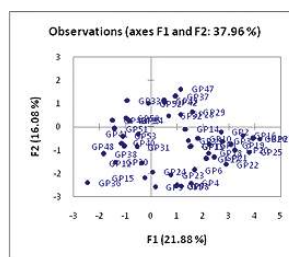


**Fig 4. Maize landraces growing in CTGC**

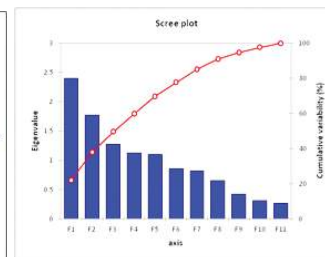
Fourteen local genotypes were tested for cold tolerance under Manipur conditions. Among the tested germplasms, *Tharathei*, *Khamathei* white, *Chechata* and *Vaiminphei* were found to be well suited for cold conditions over other tested germplasms under the minimum and maximum temperature range of 2.9 to 23.5<sup>o</sup> C and 13.6 to 32.6<sup>o</sup> C, respectively. In a similar study, 45 maize germplasms/line/varieties collected from various authentic sources *viz.*, VPKAS Almora, ICAR RC Barapani and farmers' field across Nagaland were tested for their performance in terms of productivity under rainfed conditions during *kharif*, 2015. In terms of grain yield, the maximum yield was recorded in case of maize *cv.* Longchang Local (3755.6 kg/ha) and the minimum with Hukphang local (488.9 kg/ha). With respect to protein content, Tuli local-1 (14.9 %) recorded the highest protein content and the lowest values of protein content was recorded in case of Changki local (6.6 %) (Fig 5a and 5b). Based on proline content, all the lines of maize were found to be moisture tolerant/drought resistant except *Akhoya* local. The maximum values of proline content ( $\mu$  mol/gram fresh weight) was recorded with Longchang local (3.98) and the minimum in *Akhoya* local (0.19). However, this study needs validation under field conditions of Nagaland.

## Tomato

Tomato genotypes (24 nos.) were evaluated for their relative germination rate (RGR), relative germination energy (RGE), relative germination index



**Fig 5a. Principal component scatter plot of maize landrace**

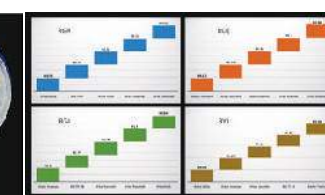


**Fig5b. Scree plot of maize landraces**

(RGI), relative vitality index (RVI) and relative PEG injury rate under in-vitro drought condition induced by application of PEG @ 30 g/l of water (Fig 6). Apart from this, plants were also grown under elevated temperature and restricted irrigation conditions. ArkaAnanya and ArkaSaurav have been found to be tolerant to moisture stress during germination stage. Arka Rakshak, Arka Ananya, Arka Meghali, RC Manikhamenshinba-I, MCTR 4 and Megha Tomato-3 have been found to be promising under elevated temperature and restricted irrigation (Fig 7).



**Fig 6. Comparative Performance of ArkaAnanya under Control and Induced Stress Condition**



**Fig 7. Top Performer Tomato Genotype in Terms of RGR, RGE, RGI and RVI**

Two cherry tomato landraces and eight tomato genotypes were evaluated for their yield performance during *rabi* season, 2015 at ICAR Research farm (October 2015 – January 2016), Mizoram center. Among all the tested genotypes/varieties, PKM -1 gave highest yield (26.2 t/ha) followed by Arka Vikas (23.9 t/ha) and Pusa Rohini (20.7 t/ha). PKM -1, Pusa



Rohini, Arka Vikas and Arka Sourav varieties are suitable for subtropical humid condition of Kolasib both under open and close system. These varieties may be recommended for farmers to increase farm resilience against climate variability.

## Theme-II Assessment of mitigation potential through Soil Water Management (SWM) practices for enhancing climatic resilience

Strong El Nino years tends to reduce *kharif* rice yield in Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura by 5, 9, 7, 18.9, 11.5, 12.5 and 7.7 %, respectively over non El Nino years. Climatic analysis of Mizoram revealed non uniform changing pattern across the districts of Mizoram for different climatic parameters. Mamit is the wettest district (annual rainfall: 2558.6 mm) and Champhai is the driest district (annual rainfall: 1906.8 mm) in Mizoram. Reduction in monsoon rainfall during 1991-2011 in comparison to 1971-1990 is the highest in Saiha and Lawngtlai (-15.3 % each) districts (Fig 8). As a whole, Mizoram has lost monsoon rainfall by 6.3 % during 1991-2011. During 1981-90 all the districts of Mizoram experienced above average monsoon rainfall, ranging from 2.3 % in Kolasib to 11.1 % in Lawngtlai and Saiha.

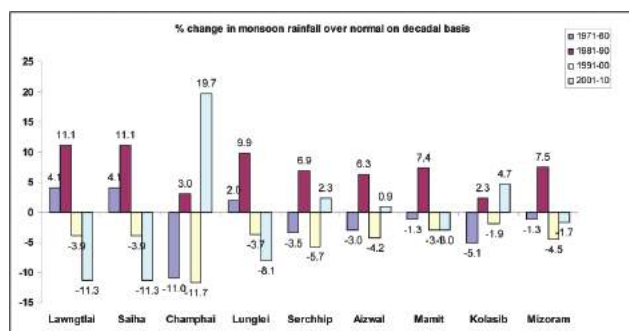


Fig 8. Percentage change in monsoon rainfall over normal on decadal

The extreme rainfall events have also showed variation over the two periods of comparison. RX 1-day (monthly maximum 1-day precipitation) and 5-days (monthly maximum consecutive 5-days precipitation) and R75 mm (annual nos. of days with rainfall  $\geq$  75 mm) have become negative in 1991-2011 in most of the districts of Mizoram. CDD (Consecutive dry days) has turned to positive side indicating more dry periods going to affect normal crop activities in

most parts of Mizoram.

A sustainable land use model was developed for hill slopes (30-40 %) under Meghalaya conditions to enhance water and nutrient use efficiency through *in-situ* moisture conservation practices. The land use model involves maintenance of natural forest (Pine forest) at hill top with catch pit (1.5 m x 0.5 m x 0.3 m), cultivation of fodder crops (*viz.* Broom, Congo, Hybrid Napier and Guinea grass) and cover crops (*viz.* groundnut, soybean, rice bean & cowpea) in terraces, intercropping (maize with groundnut, soybean, rice bean and cowpea) and conservation tillage. Among the different cropping systems studied, the fodder crop based system was found to be the most effective in reducing soil (loss 2.21-4.43 t/ha) loss as compared to other cropping system that tested loss of (11.28 to 22.30 t/ha) and farmers' practice (31.57-44.29 t/ha). Adoption of this land use model could reduce the loss of SOC under farmers' practice substantially (Fig 9).

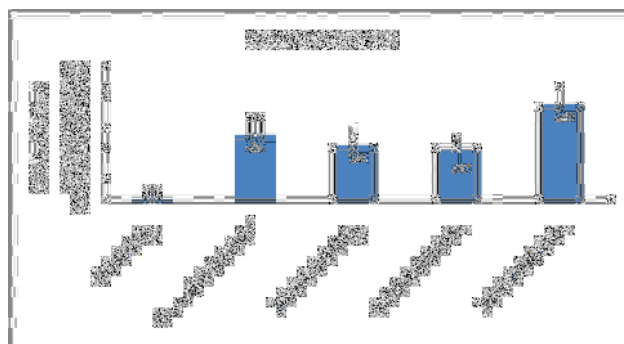
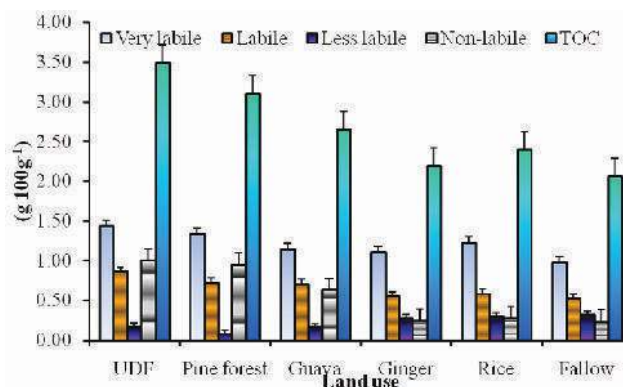


Fig 9. Soil organic carbon loss from different cropping system

Soil samples from different land use systems *viz.*, mixed forest, pine forest, guava, pineapple, ginger, paddy and fallow lands were collected and analyzed for total organic carbon (TOC), labile, less labile, very labile and non-labile fractions of soil organic carbon. For the highest mobility of soil organic carbon and high carbon sequestration, amongst the studied land uses, mixed forest (UDF) was found to be the best land use under the hilly ecosystems of North East India. Impact of land use pattern (16 nos.) and agro climatic conditions due to altitudinal variations on soil carbon dynamics and soil quality was studied under Manipur conditions. Study revealed that forest and tree bean land use pattern was found to be the most sustainable in terms of C- stock and microbial activities (Fig 10)

Three years of field studies on soil water management practices in upland rice under Sikkim conditions revealed that applications of FYM @ 50 % of recommended dose (RD, 10 t/ha) + Vermi





**Fig 10. Soil carbon dynamics and soil quality in Manipur**

compost (VC) @ 25 % of RD (2 t/ha) + Neem cake (NC) @ 25 % of RD (0.5 t/ha) + Biofertilizers (BF) @ of RD recorded the highest grain yield of rice in all the varieties tested (Bhalum 2- 35.97 q/ha, Bhalum 3- 38.53 q/ha, RCPL 412- 43.54 q/ha, Rajendra Bhagwati-27.37 q/ha). Application of FYM 100%, FYM 75 % + NC 25 % + BF, FYM 50% + VC 25 % + NC 25 % + BF and VC 75 % + NC 25 % + BF increased the SOC of surface soil (0-15 cm) by 6.98-29.07 % which was significantly different as compared to that of control plot. Bulk density also reduced in the similar fashion.

Long term effect (since 2012) of conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT) with and without residue (R) retention on moisture conservation and carbon sequestration in maize-mustard cropping system was studied under Basar conditions of Arunachal Pradesh. All the tillage treatments with residue retention significantly increased the SOC of soil. Residue retention significantly ( $p < 0.05$ ) lowered the bulk density in surface soil (0-15 cm) in both the cropping systems. Based on soil moisture content and other soil parameters, Centre has also developed contingency crop planning and advisories for 11 circles within the district of West Siang covering three climatically and topographically different locations.

Mineralization kinetics study revealed that favorable moisture regimes trigger the mineralization of biochar. Average cumulative carbon mineralization ( $\text{CO}_2$  flux) was 8 % higher in the samples maintained at field capacity (FC) as compared to that maintained at half of field capacity (1/2 FC) moisture regimes. Optimum moisture conditions trigger the  $\text{CO}_2$  flux and the rate of increase remains higher initially up to 2 weeks and decreases thereafter. Irrespective of the doses, higher  $\text{CO}_2$  flux was recorded from rice residues

as compared to maize residues. Carbon flux from biochar amended soil was almost similar to control (soil), and it was significantly lower than the residue treated soil. Conversion of crop residues into biochar and its application to soil can drastically reduce the  $\text{CO}_2$  flux from the soil as compared to the application of residues as such. Thus biochar amendment is one of the viable options to sequester carbon in soil and to reduce emission of greenhouse gases in changing climate scenario. However, the extent of benefit depends upon the nature and properties of biochar and the substrate from which it was prepared. Effect of biochar on productivity, nutrient use efficiency and C sequestration potential of maize based cropping system was studied under Meghalaya conditions. Study revealed that the use of biochar in combination with recommended dose of fertilizers improved the yield of maize and French bean (green pod) by 84.79 % and 87.84 % respectively over the treatment without biochar. Application of biochar improved the SOC, microbial biomass carbon, activity of dehydrogenase enzyme and soil pH and reduced the exchangeable aluminium and exchangeable acidity of the soil. Thus, biochar may offer a win-win technology for sustainable maize and french bean production system.

Mustard responded well to residual soil moisture when planted immediately after harvesting of the main *kharif* crop under Meghalaya conditions. Straw mulched crop (@ 5 t/ha) could retain 8.8 to 30.7 % higher soil moisture and photosynthetically active radiation (PAR) interception increased by 7.2 to 114.1 % at the flowering stage over no mulch. Increased PAR interception influenced the seed yield, which ranged between 5.7 (cv. NPJ 112) and 11.0 (cv. NPJ 113) q/ha under mulch treatment compared to 3.8 and 4.7 q/ha in no mulched crops. Modification of soil/crop microclimate is positively related to increase harnessing of solar energy, improved plant growth and development and ultimate economic yield.

Experiment was conducted on resource conservation and crop diversification of rice based cropping system for enhancing climate resilience under Sikkim conditions. Among the tillage practice (conventional-CT, reduced-RT and zero tillage-NT) maximum grain yield of rice recorded was with NT (3.31 t/ha) followed by RT (3.28 t/ha) and lowest in CT (3.03 t/ha). Among the organic sources of nutrients [Control, 100% FYM + Biofertilizer (BF), 100% Vermi compost (VC) + BF and 50% FYM + 50% VC + BF] recorded significantly higher grain yield (3.83 t/ha) over other organic sources. Double zero till technology



reduces the turn around time of about 12-15 days for sowing of vegetable pea after rice. Further, study revealed that about 18-20% higher soil moisture was noticed in soil under double zero tillage practice as compared to that under conventional tillage. The highest pod yield was recorded under zero tillage (5.49 t/ha) followed by RT (4.96 t/ha) and lowest with CT (4.10 t/ha). Maximum system productivity (10.8 t/ha) was recorded with zero tillage. Application of 50% FYM + 50% VC + BF recorded higher system productivity (10.34 t/ha) over farmer's practices. In a similar study under Tripura conditions revealed that yield of rice and mustard under zero tillage was at par with that under conventional tillage.

Study on the effect of conservation tillage (CT) and live mulch on *kharif* productivity and soil moisture under Tripura conditions revealed that maize grown under reduced tillage (RT) with live mulch (LM) of cowpea produced significantly higher yield as compared to zero tillage (ZT), ZT + LM, RT and CT. However, in case of summer maize, zero tillage with live mulch of cowpea gave significantly higher yield as compared to ZT, RT + LM, RT and CT. The soil moisture study showed that the ZT + LM increased the residual soil moisture by 20-30 % over CT plots. The RT + LM also recorded higher soil moisture as compared to the plots under CT.

### **Theme 3: Understanding the unique traits of indigenous pig and poultry which make them resilient to climate change and development of data base**

The performance of various breeds of pig in different housing model was tested under Meghalaya conditions. The study revealed that the growth rate in deep litter housing was better and there were less incidence of diseases and occurrence of other abnormal behavior in deep litter housing system. Comparison of physiological parameters in different pig housing models revealed that, under concrete floor respiration rate, pulse rate and body temperature was higher by 11, 4.9, 0.39 % in summer and 28, 3.9, 0.47 % in winter respectively compared to deep litter housing system. Under Sikkim conditions, growth performances of Local/Lepcha and Hampshire pig breeds were found better under deep litter condition as compared to concrete floor pig pen. Morphometrically the small snout length of indigenous

pig makes it more suitable for deep litter housing system as they dig less when compared with other breed.

Experiment on formulation of fortified feed from kitchen waste for pig revealed that the group which is fed with 7 % molasses have better growth rate (280 g/d) as compared to control group (230 g/d) and molasses may help in protecting the animals from climatic stress.

Experiment was conducted to evaluate the effect of different seasons on ovarian activity, folliculogenesis, CL development and oocyte retrieval in relation to metrological data in pigs. Result showed that the number of follicles (11.56), CL (8.63) and culturable oocytes (6.24) is more in winter compared to monsoon (6.68, 5.58 and 3.56) and summer season (8.02, 6.15 and 3.7).

The Toll-like receptors (TLRs) are key regulators of the innate and adaptive immune response to bacterial, viral, and fungal pathogens. TLRs have been extensively studied, and their immense importance in innate immunity is now being unveiled. Peripheral blood mononuclear cells (PBMCs) represent a useful TLR-responsive model cell line for examining TLR1-10 signaling events. There is significant differences in the expression of TLRs from PBMCs between indigenous pigs, crossbred and Hampshire pigs probably reflecting the domestication process and differences in selective pressure in TLR genes expression.

Identification of the unique traits in indigenous pigs which make them resilient to climate change was done in Basar centre, ICAR RC for NEH Region, Arunachal Pradesh. The unique traits identified in the local breed of pig of Arunachal Pradesh are long bristle length (4-9 cm) and having pot belly. Long hair bristle acts as insulator during cold season and sheds it during summer season. Similarly, pot bellied condition may be one of the distinguish features for dissipation of heat during high temperature.

The performance of Vanaraja poultry under backyard farming system in farmers' field at different altitude under diversified agro-climatic condition of Mizoram was evaluated. Average body weights of Vanaraja male birds recorded to be 0.95, 1.50, 2.75 and 3.55 kg at 8, 10, 20 and 40 weeks of age, respectively whereas in case of female bird it was recorded to be 0.82, 1.25, 2.25 and 2.63 kg. Fertility and hatchability per cent was found to be 71 % and 75-80 % respectively. Mortality rate was found to be 6-8 %. The long shank legs help these birds in faster



movement to escape from predators. Vanaraja birds have high tolerance to incidence of diseases and showed wide adaptability at different altitudes.

Hampshire x Yorkshire crossbred and Mizo local pigs (Zovawk) were evaluated in different altitude under farmers' field conditions in Mizoram. Studies revealed that crossbred pigs have the greatest potential for their use as improved breed for meat and litter size as compared to local pigs (Zovawk). The average body weight at birth and weaning was found to be 1.52 kg, 8.12 kg in crossbred whereas 0.512 kg and 4.21 kg were recorded in local pigs. The average litter size at birth (8-12) and litter size at weaning (8-9) was found to be higher in crossbred pigs than that of local pigs (4-6). The results of crossbred pigs in farmers' field showed substantial improvement in body weight at slaughter and feed conversion efficiency. The optimum level of exotic inheritance in crossbred ranges from 50-87.5 % and has been found to be suitable for subtropical humid condition of tribal hill regions of Mizoram. The farmers experienced a positive impact on the pork productivity and income. The overall livestock cropping intensity was enhanced to the extent of 80-85 %.

Nursing of carp fry in the farmers operated water harvesting poly ponds (Jalkund) for promotion of climate resilient aquaculture among tribal farmers of Meghalaya revealed that among all the four different fish species tested (Amur common carp, local common carp, Mrigal and Goniis), the Amur common carp (*Cyprinus carpio* var. Amur) fry performed the best in a *Jalkund* covering an area of 38.5 square meters. A study on evaluation of *Notopterus notopterus* (Pallas,

1769) for thermal tolerance and stress under Tripura conditions was conducted. The fishes evaluated at different temperature regimes, viz., 18°C, 24.5°C and 35°C for biochemical responses. *Notopterus notopterus* recruits well at normal water temperature of 28.5 to 32.8°C in pond conditions. Biochemical, enzymatic, immunological and hematological responses of the fish were better at 24.5-35°C. The fishes lose equilibrium at 10°C. Normal range and seasonal variation of hematological and innate immune system in *Labeo bata* was also studied under Tripura conditions. Myeloperoxidase activity was significantly higher in summer season (0.89) compared to rainy and winter season (0.75 and 0.65). However, significantly lower respiratory burst activity (0.15) was observed in winter seasons compared to summer and rainy season (0.28 and 0.25).

#### **Theme 4: Technology demonstration**

Demonstration on rain water harvesting and its utilization, conservation agriculture, land configuration for crop intensification and water use efficiency, improved shelter and feeding management in pig and poultry, efficient irrigation methods, etc. were conducted in the NICRA adopted village (Nongthymmai, Ri-Bhoi dist.). Under capacity building programme, 6 nos. of farmers training and 44 nos. of trainers training on climate resilient agriculture were organized in head quarter (Umiam) and six regional centres during the 2015-16 with a direct beneficiary of 180 and 1234 respectively.



## TRIBAL SUPPORT PLAN (TSP)

More than 17130 numbers of tribal farmers of north eastern states were benefitted during 2015-16 by various livelihood improvement programmes conducted under Tribal Sub Plan (TSP). Four hundred ninety one (491) numbers of different physical assets viz., low cost polyhouse (3), low cost pig shed (102), low cost poultry shed (39), low cost cow shed (2), *Jalkund* /water harvesting structures (81), pig breeding unit (4), fruit farming model (1), integrated farming system model (15), mushroom spawn production unit (2), mushroom demonstration unit (21), vermi-compos production unit (156), wooden check dam (1), carp fish production unit (1), honey production unit (16), briquette mould (2), solar drier (2), electric motor (2), water lifting device viz. pump set/Tulu pump (31), demonstration unit for pig and poultry farming (2), demonstration unit for duck and fish farming (1), fruit processing unit (5), turmeric & ginger processing unit (2) etc. were created/provided in different tribal villages of the north east.

Agricultural inputs viz., seeds, planting materials, fertilizers, biofertilizers, manures, nutrient solutions, pesticide and bio-pesticides (*cereal, pulses and oilseed*: rice-11645 kg, Maize- 11615 kg, green gram -1532 kg, black gram- 1880 kg, groundnut- 14946 kg, soybean - 300 kg, pea-7325 kg, oat-150, lentil -3600 kg, toria/ mustards- 2000 kg and sesbania-420 kg, *seeds of vegetable crops*: spinach and fenugreek- 45 kg, broccoli - 2.06 kg, cabbage -302 g, capsicum - 1.3 kg, coriander-61.5 kg, onion -1 kg, tomato-2.1 kg, spainach-30 kg, carrot-14.2 kg, beet root -2.25 kg, radish -2.6 kg and methi-15 kg, *planting materials* : mango seedling 4495 nos, litchi seedling 1700 nos, *Khasi* mandarin 7979 nos., mousambi seedling 300 nos., mandarin budded plants 2100 nos., sweet orange seedling 400 nos, guava seedling 340 nos., peach seedlings 140 nos., lemon seedling 2206 nos., papaya seedlings 1120 nos., pineapple sucker 25050 nos., Assam lemon 50 nos., banana seedling 8200 nos., lemon grass slips 13000 nos., kiwi fruit seedling 18000 nos., tree sapling 3600 nos., hybrid Napier cuttings 5000 nos., Dalley chilly 500 nos., runners of strawberry 9000 nos., black pepper cutting 600 nos., broccoli-2000 nos, cauliflower-12100 nos, tomato-15500 nos, knolkhol-600 nos, king chilli -1150 nos, chilli seedling-25000 nos, capsicum seedlings 600 nos., brinjal

seedlings 10000 nos., onion seedlings 8000 nos., cabbage seedlings 20000 nos., tree bean seedling 4500 nos., potato seed tuber 11800 kg, turmeric seed rhizome -2400 kg, ginger seed rhizome 20450 kg, yam tuber 65 kg, colocasia seed corm 5150 kg, casava cutting 5000 nos., *fertilizer/manure/biofertilizers/nutrient solutions/pesticides etc.* : 31600 kg fertilizers, 65660 kg manures/vermi-compost, 5765 kg biofertilizers, 116 kg *Trichoderma*, 100 kg neem cake, 10851 kg agricultural lime, 11 kg sulphex , 10 liters organic formulation of foliar spray, 45 liters of inorganic formulation of foliar spray, >100 kg pesticide, 198 kg biopesticide, 209 liters biopesticide, 65.5 litre liquid formulation of pesticides and 24 kg copper oxychloride) were distributed among the tribal farmers for livelihood improvements. Apart from these input, 1280 kg of spawn, 2 nos. of inoculation hood and 2 nos. of pressure cooker, 40 rolls of non-absorbent cotton, 10 nos. of spirit bottle, 5 nos. of inoculation needles, 4 nos. of spirit lamp were distributed among the farmers for popularizing mushroom cultivation as a source of livelihood.

A total of 892 nos. of improved breed of piglets, 85041 nos. poultry chicks, 296 nos. of duck, 12 nos. of rabbits, 5 nos. of milching cow, 34 nos. of goat, 10000 nos. of vermi-worms, 25000 nos. of fish seeds and 220217 nos. of fish fingerlings, 18198 kg of livestock and poultry feed, 4180 kg of feed supplements, 3000 kg of fish feed were also distributed among the tribal farmers for livelihood improvement. Vaccinated 200 poultry chicks and distributed medicines for management of various animal diseases.

Minor agricultural tools and implements such as backpack sprayer (40 nos), briquette moulder (5 nos), briquette stove (3 nos), honey bee box (50 nos), water/ Rose can (90 nos), conoweeder (15 nos), maize sheller (1015 nos), adjustable row marker (36 nos), U-blade weeder (55 nos), zero-till furrow opener (20 nos), garden rake (1 nos), paddle operated thresher (5 nos), winnower (5 nos) and solar drier (2 nos) were distributed among the farmers. Apart from these tools and implements, insect trap (290 nos), water delivery pipe (48 coils), hammer mill grinder (1 nos.), pulverizer machine (1 nos), weighing balance (4 nos), sealing machine (5 nos), screw type juicer (3 nos), hand operated juicer (3 nos), refractometer (4 nos), grinder (2 nos), electric motor (2 nos.), auto electronic starter (2 nos), auto sealing machine (1 nos), weighing scale (8 nos), stainless steel tray (20 nos), wooden oven (1 no), bottles for fruit processing unit (6000 nos),



silpaulin sheet (101 nos for *Jalkund*), cast net (3 nos, for fishing), dragnets (3 nos., for fishing), trellising wire (1500 kg, for kiwi fruit) and pH paper (29 boxes, to test pH of water for fish) were also distributed among the tribal farmers.

Training (173 nos.), awareness (64 nos.) and demonstration programmes (covering >330 ha) were

organized for capacity development in various fields (crop production, animal production and management, mushroom production, production and management of horticultural crops etc.) of agriculture. Two farmers fair were also organized for showcasing of agricultural technologies for the benefit of tribal farmers.



**Demonstration of Soil Health Test Kit to Farmers at Umiam, Meghalaya**



**Distribution of Soil Health Card by Hon' ble, Union Minister of Agriculture and Farmers Welfare, Shri Radha Mohan Singh on Soil Health Day at Gangtok**



**Capacity building and input distribution programme and integration of IFS components at Imphal, Manipur**



**Capacity building programme organized at Nagaland**



**Distribution of chicks by Shri Naresh Jmatia , Hon'ble Minister for Rural Development and Forestry, Government of Tripura**



**Trainees under TSP activities at Basar, Arunachal Pradesh**



**Demonstration on Zero tillage in mustard at Kolasib, Mizoram**



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#### Other Publications (HQ)\*

Books/Technical Bulletins/	: 20 nos
Training manuals	
Popular/Technical Articles/	: 73 nos
Book chapters/Lectures or	
Chapters in training manuals	
Leaflets/Extension Folders/	: 36 nos
Success stories	
Abstracts/lead papers/proceedings	: 108 nos
papers/extended summaries/	
technical articles/Oral presentations	
/Compendium papers/Presented	
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Abstracts in conferences	13 nos
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Books/Technical Bulletins	03 nos
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#### Other Publications:

Abstracts in conferences	76 nos
Extended/Symposium/Souvenir	03 nos
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Books	01 nos
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Technical Bulletin/Training Manuals	05 nos
Extension Folders	03 nos

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| Chapter in books, proceedings and Abstracts | 13 nos |
| Popular articles                            | 03 nos |
| Technical Bulletin/Training Manuals         | 01 nos |
- Nagaland Centre**
- Research papers**
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- Other Publications:**
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|---|--------|
| Poster Presentations/Abstracts in conferences             | 15 nos |
| Popular articles  | 05 nos |
| Books/Book Chapter/Training Manual/Technical Bulletin etc | 20 nos |
- Sikkim Centre**
- Research papers**
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#### Other Publications:

Abstracts/Extended Summary in	
conferences/Book Chapters	29 nos
Books	01 nos
Training Manual	01 nos
Popular Articles	04 nos
Extension Technical Folders	20 nos
Success stories	02 nos

#### Tripura Centre

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#### Other Publications:

Papers presented in conferences /Symposium/Seminars/Workshops	31 nos
Publications in Seminar/Symposia /Conferences Proceedings / Souvenirs etc	27 nos
Training Manual/Folder/ Technical bulletins	05 nos
Popular Articles	01 nos



## LIST OF CONTRIBUTORS

**Dr S. V. Ngachan, Director**

### **NATURAL RESOURCE MANAGEMENT**

Dr N. S. Azad Thakur, Principal Scientist (Agril. Entomology) & Head  
Dr D. J. Rajkhowa, Principal Scientist (Agronomy)  
Dr S. Hazarika, Principal Scientist (Soil Science)  
Dr U. S. Saikia, Senior Scientist (Agromet)  
Dr K. P. Mohapatra, Senior Scientist (Forestry)  
Dr B. U. Choudhury, Senior Scientist (Soil Science)  
Dr T. Ramesh, Scientist (Soil Science)  
Mr Puran Chandra, Scientist (Forestry)  
Dr Manoj Kumar, Scientist (Soil Science)  
Dr B. C. Verma, Scientist (Soil Science)  
Dr J. J. Rajappa, Scientist (Economic Botany)  
Mrs M. Prabha Devi, Scientist (Environmental Science)

### **CROP PROTECTION**

Dr Satish Chandra, Principal Scientist (Plant Pathology) & Head  
Dr G. T. Behere, Senior Scientist (Agril. Entomology)  
Dr Pankaj Baiswar, Senior Scientist (Plant Pathology)  
Dr Sandip Patra, Scientist (Agril. Entomology)  
Dr D. M. Firake, Scientist (Agril. Entomology)  
Dr (Mrs) Rachna Pande, Scientist (Agril. Entomology)  
Dr (Mrs) Amrita Banerjee, Scientist (Plant Pathology)  
Dr Romila Akoijam, Scientist (Agril. Entomology)

### **CROP PRODUCTION**

Dr A. S. Panwar, Principal Scientist (Agronomy) & Head  
Dr Rajesh Kumar, Senior Scientist (Agronomy)  
Dr Anup Das, Senior Scientist (Agronomy)  
Dr J. P. Tyagi, Senior Scientist (Plant Breeding)  
Dr Avinash Pandey, Scientist (Plant Breeding)  
Dr Ramkrushna, G.I., Scientist (Agronomy)  
Mr Amit Kumar, Scientist (Plant Breeding) (on study leave)  
Dr Jayanta Layek, Scientist (Agronomy)  
Dr Krishnappa R., Scientist (Plant Physiology)

### **HORTICULTURE**

Dr Anjani Kumar Jha, Senior Scientist (Horticulture) & Head  
Dr V. K. Verma, Scientist (Horticulture)  
Dr N. A. Deshmukh, Scientist (Horticulture)  
Dr H. Rymbai, Scientist (Horticulture)  
Dr (Ms) S. Ruth Assumi, Scientist (Horticulture)  
Dr. (Ms) M. Bilashini Devi, Scientist (Horticulture)

### **AGRICULTURAL ENGINEERING**

Dr R. K. Singh, Principal Scientist (SWCE) & Head  
Dr B. K. Sethy, Senior Scientist (LWME)  
Er Arvind Kumar, Scientist (FMP)  
Mr Debasish Chakraborty, Scientist (Agromet)  
Er. Hijam Jiten Singh, Scientist (FMP)

### **ANIMAL PRODUCTION**

Dr Suresh Kumar D.S., Principal Scientist (Animal Reproduction) & Head  
Dr G. Kadirvel, Senior Scientist (Animal Reproduction)  
Dr Sunil Doley, Senior Scientist (Poultry Science)  
Dr P. K. Bharti, Scientist (Livestock Production and Management)  
Dr Ashok Kumar, Scientist (Animal Reproduction)

### **ANIMAL HEALTH**

Dr Arnab Sen, Principal Scientist (Veterinary Microbiology) & Head  
Dr R. Laha, Principal Scientist (Veterinary Parasitology)  
Dr (Mrs) I. Shakuntala, Principal Scientist (Veterinary Public Health)  
Dr S. Ghatak, Senior Scientist (Veterinary Public Health)  
Dr (Mrs) K. Puro, Scientist (Veterinary Microbiology)  
Dr (Mrs) Meena Das, Scientist (Veterinary Parasitology)  
Dr Samir Das, Scientist (Veterinary Public Health)  
Ms R. K. Sanjukta, Scientist (Veterinary Medicine)



**FISHERY SCIENCE**

Dr S. K. Das, Principal Scientist (Fisheries) & Head  
Dr. (Mrs) K Nath, Scientist (Aquaculture)  
Dr. Late Arup Nath (Fish Health)

**SOCIAL SCIENCES**

Dr A. K. Tripathi, Principal Scientist (Agril. Economics) & Head  
Dr A. K. Mohanty, Principal Scientist (Agril. Extension)  
Mr N. Uttam Singh, Scientist (Agril. Statistics)  
Dr Aniruddha Roy, Scientist (Agril. Economics)  
Dr D. K. Dangi, Scientist (Agril. Extension)  
Dr Piyashi Deb Roy, Scientist (Agril. Economics)

**CENTRE FOR BIOTECHNOLOGY**

Dr (Mrs) Premila Devi Thongbam, Principal Scientist (Plant Biochemistry) & Head  
Dr Bijoya Bhattacharyajee, Senior Scientist (Plant Biotechnology)  
Dr C. Aochen, Scientist (Biochemistry)

**ARUNACHAL PRADESH CENTRE**

Dr R. Bhagawati, Joint Director  
Dr Rajesh A. Alone, Scientist (Agroforestry)  
Dr Doni Jini, Scientist (Veterinary Extn. Edu.)  
Mr Raghuveer Singh, Scientist (Plant Pathology)  
Dr Anup Chandra, Scientist (Agril. Entomology)  
Mr Letngam Touthang, Scientist (Plant Genetics)  
Mr Badapmain Makdoh, Scientist (Agronomy)  
Mr Rahul Das, Scientist (Aquaculture)  
Mr Thejangulie Angami, Scientist (Fruit Science)  
Mr Nirmal, Scientist (Agroforestry)

**MANIPUR CENTRE**

Dr Narendra Prakash, Joint Director  
Dr I. Meghachandra Singh, Principal Scientist (Seed Technology)  
Dr Ch. Basudha Devi, Senior Scientist (Fisheries)  
Dr Manas Ranjan Sahoo, Senior Scientist (Horticulture)  
Dr Lohit Kumar Baishya, Senior Scientist (Agronomy)  
Dr Subhra Saikat Roy, Scientist (Horticulture)  
Dr Kh. Rishikanta Singh, Scientist (Agril. Economics)  
Dr Sudhir Kumar, Scientist (Plant Breeding)  
Dr Meraj Alam Ansari, Scientist (Agronomy)  
Dr Blessa Sailo, Scientist (Veterinary Public Health)

Dr (Mrs) Arati Ningngombam, Scientist (Agril. Entomology)  
Dr Susheel Kumar Sharma, Scientist (Plant Pathology)  
Mrs Bhuvaneswari S., Scientist (Plant Breeding)  
Dr (Ms) Sonia Chongtham, Scientist (Poultry Science)  
Dr. T. Basanta Singh, Scientist (Soil Science)  
Dr. Chongtham Tania, Scientist (Horticulture)  
Mrs. Huirem Bharati Scientist (Fisheries)  
Dr. Chingakham Premabati Devi, Scientist (Horticulture)

**MIZORAM CENTRE**

Dr S. B. Singh, Joint Director  
Dr T. Boopathi, Scientist (Agril. Entomology)  
Dr Sudip Kumar Dutta, Scientist (Horticulture)  
Dr Akoijam Ratankumar Singh, Scientist (Plant Pathology)  
Dr Lungmuana, Scientist (Soil Sciences)  
Dr Saurav Saha, Scientist (Agril. Physics)  
Dr. Moirangthem Thoithoi Devi, Scientist (Agronomy)  
Mrs. Aruna Beemrote, Scientist (Agril. Entomology)  
Dr. Vishambhar Dayal, Scientist (Horticulture)  
Mr. Samik Chowdhury, Technical Officer, GKMS, IMD.

**NAGALAND CENTRE**

Dr Bidyut Chandan Deka, Joint Director  
Dr K. K. Barman, Principal Scientist (Soil Science)  
Dr Rakesh Kumar, Scientist (Agronomy)  
Mrs Tasvina R. Borah, Scientist (Plant Pathology)  
Dr Rajesha G, Scientist (Plant Pathology)  
Ms Christy B.K. Sangma Scientist (Soil Science)  
Dr H.D. Talang, Scientist (Horticulture)  
Dr Azeze Seyie, Scientist (Horticulture)  
Mr Jyotish Barman, Scientist (Fisheries Resource Management)  
Dr Ebibeni Ngullie, SMS (Animal Science), KVK Dimapur

**SIKKIM CENTRE**

Dr R. K. Avasthe, Joint Director  
Dr H. Kalita, Principal Scientist (Agril. Entomology)  
Dr Ashish Yadav, Senior Scientist (Horticulture)  
Dr R Islam, Senior Scientist (Animal Reproduction)  
Dr R. Singh, Senior Scientist (Agronomy)  
Dr Matber Singh, Scientist (Agro-forestry)



Dr R. Gopi, Scientist (Plant Pathology)  
Dr Subhas Babu, Scientist (Agronomy)  
Mr S. K. Das, Scientist (Soil Science)  
Dr B. Kumar, Scientist (Animal Reproduction)  
Dr Mahak Singh, Scientist (Animal Reproduction  
and Gynaecology)

**TRIPURA CENTRE**

Dr M. Datta, Joint Director  
Dr B. Das, Principal Scientist (Horticulture)  
Dr A. Halder, Principal Scientist (Animal  
Reproduction)

Dr S. P. Das, Principal Scientist (Plant Breeding)  
Dr S. N. Bhowmik, Senior Scientist (Agril.  
Microbiology)  
Mrs L. Sahoo, Scientist (Fishery Science)  
Ms H. Ranebennur, Scientist (Plant Pathology)  
Dr. C. Debnath, Scientist (Fishery Science)  
Dr G. S. Yadav, Scientist (Agronomy)  
Dr A. Gangarani Devi, Scientist, (Plant Physiology)  
Dr H. Lembisana Devi, Scientist (Horticulture)  
Dr Vinay Singh, Scientist (Poultry Science)  
Dr Rekha Das, Scientist (Fishery Science)



