Content list available at https://icarneh.icar.gov.in/; ISSN: 0970-6429

Indian Journal of Hill Farming

June 2024, Volume 37, Issue 1, Pages 59-69

Performance of garden pea (*Pisum sativum*) cultivars under organic mulching in North Eastern India

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ARTICLE INFO

***Article history*:**
Received: 01 April, 2024
Revision: 10 April, 2024
Accepted: 30 April, 2024

Key words: *Bio mulches, pulses, residual soil moisture, rice fallow, water conservation, water productivity*

DOI: 10.56678/iahf-2024.37.01.9

ABSTRACT

In spite of having favourable soil and agro-climatic conditions in the North-Eastern Region (NER) for pulse cultivation, NER's average productivity (848 kg ha^{-1}) is lower than the national average (885 kg ha^{-1}). Due to non-adherence of suitable water conservation strategies, severe water scarcity during post-monsoon season is being felt which forces the farmers to leave their land fallow during winter months after rainy season rice cultivation. Under these scenarios, an agronomic trial was taken up during 2022-23 winter season in a split plot design with four main plot treatments (mulches), *viz.*, no-mulch, paddy straw mulch, maize stover mulch and weed mulch, applied @ 5 t ha^{-1} and four sub-plot treatments (cultivars), *viz.*, Arkel, Punjab 89, Pusa Pragati and Pusa Prabal. This trial was replicated thrice. Best results were registered for organic mulching with paddy straw mulch followed by weed mulch, maize stover mulch. Water productivity, soil moisture (%), green pod yield, and benefit cost ratio were recorded highest under paddy straw mulch as, 34.81 kg ha^{-1} mm^{-1}, 12.11%, 8.51 t ha^{-1} and 3.96, respectively. Similarly, the highest green pod yield, water productivity and benefit cost ratio were recorded under cultivar Punjab 89 with values of 7.38 t ha^{-1}, 30.23 kg ha^{-1} mm^{-1} and 3.46, respectively.

1. Introduction

Pulses hold a paramount importance in global food grain production system due to its high protein content (Marwein and Ray, 2019; Dhivya *et al*., 2020; Swetha, *et al*., 2022; Parida *et al*., 2023; Ray *et al*., 2023a). India, with more than 28 Mha pulses cultivation area, is the largest pulse producing country in the world. During 2020-21 national productivity was at 885 kg ha^{-1}, however, it has increased significantly (Anonymous-I, 2022; Shirisha *et al*., 2023). However, the North-Eastern region (NER) of India has a deficit of about 82% of its pulse requirement in spite of the favorable soil agro-climatic conditions for pulse production. The average productivity of pulses in NER (848 kg ha^{-1}) is lower than the national average and with an inherent potential to bridge this gap (Bhadana *et al*., 2013; Das *et al*., 2016; Dhivya and Ray, 2020; Marwein and Ray, 2021).

Garden Pea (*Pisum sativum* L.)- an important pulse crop occupies an important position in supplementing low-cost plant protein. It is one of the popular and important high value crops grown in north-eastern region. It can emerge as a profitable crop for the farmers of Meghalaya, especially in most parts of West Khasi hills, East Khasi hills and Ri-Bhoi district. The farmers may obtain good remuneration from this crop as this crop was included in high value sequences due to their heavy demands in local and regional markets (Saha, 2011). Though the average annual rainfall is higher in North East Region (NER) (>2,000 mm) is very much high as compared to the national average (1,194 mm), the crop production in the region is meagre due to terminal moisture stress in winter or post-monsoon season and more than 80% of the area in NER remained fallow after rainy season rice (Singh, 2017; Ray *et al*., 2019). Rabi/post-monsoon season is

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very much favorable for pulse cultivation, but due to lack of appropriate irrigation water management coupled with lack of suitable soil and water conservation measures lead to severe water scarcity, particularly during post-monsoon season forces farmers to leave their land fallow (Saha, 2011; Ray *et al*., 2019; Shirisha *et al*., 2023).

The challenge for the agricultural sector is to produce more food with less water, and this can be achieved by increasing the crop water productivity (Ramadan *et al*., 2021; Jyothi *et al*., 2022; Ray *et al*., 2023b). Therefore, agronomic measures like conservation farming, bio-intensive farming, mulching might be suitable approaches to solve these problems by conserving soil moisture, building up soil organic carbon improving in both soil structure and microbial population in soil and finally by increasing resource use efficiency. Mulching is a protective layer of organic or inorganic material spread on the surface of the soil in order to reduce evaporation losses, prevent weed growth and reduce soil compaction due to heavy rains (Ali and Talukder, 2008). The use of different organic mulches can be beneficial in increasing yield, water-use efficiency, and profitability while also reducing weed pressure, improving physical, chemical and biological properties of soil and facilitating nutrient availability in the soil, is one way to combat *in-situ* soil moisture stress (Marwein and Ray, 2017, 2019; Garhwal *et al.,* 2020; Jadav *et al*., 2020; Parida *et al*., 2023).Considering the aforesaid scenario, an agronomic trail was conducted to assess the growth, yield, water productivity and economic performance of pea varieties under different bio mulches.

2. Materials and Methods

Description of experimental site with meteorological parameters

An agronomic field trial was carried out during *rabi* season, (November to March) of 2022-23 at the experimental farm of College of Postgraduate Studies in Agricultural Sciences, Umiam, Ri-Bhoi district, Meghalaya. The experimental site is situated at 91º 91’ East longitude and 25º 68’ North latitude and at an altitude of 950 m above Mean Sea Level (MSL). The location of the experimental site is shown in Fig. 1.

The climate of Ri-Bhoi is classified as subtropical humid type with high rainfall and cold winters. The monsoon rainfall normally sets in at the first fortnight of June and extends up to end of September. Withdrawal of monsoon takes place in October first week with a deceasing rainfall trend from September onwards. The experimental site experiences an average annual rainfall of 2617.10 mm with some pre-monsoon showers during March to May (Ray *et al*., 2012). A total of 19.3 mm of rainfall was received throughout the experimentation period and the maximum rainfall of 9.1 mm was received during 47^{th} standard meteorological week (SMW). Mean weekly maximum temperature was highest during 46^{th} SMW (28°C) and lowest in 3^{rd} SMW (21.29°C). Mean weekly minimum temperature was highest during 52^{nd} SMW (13.20°C) and lowest in 47 SMW (9.93°C). The average recorded weekly relative humidity was 72%. The weekly meteorological data along with amount of irrigation water applied are presented in Table 1.

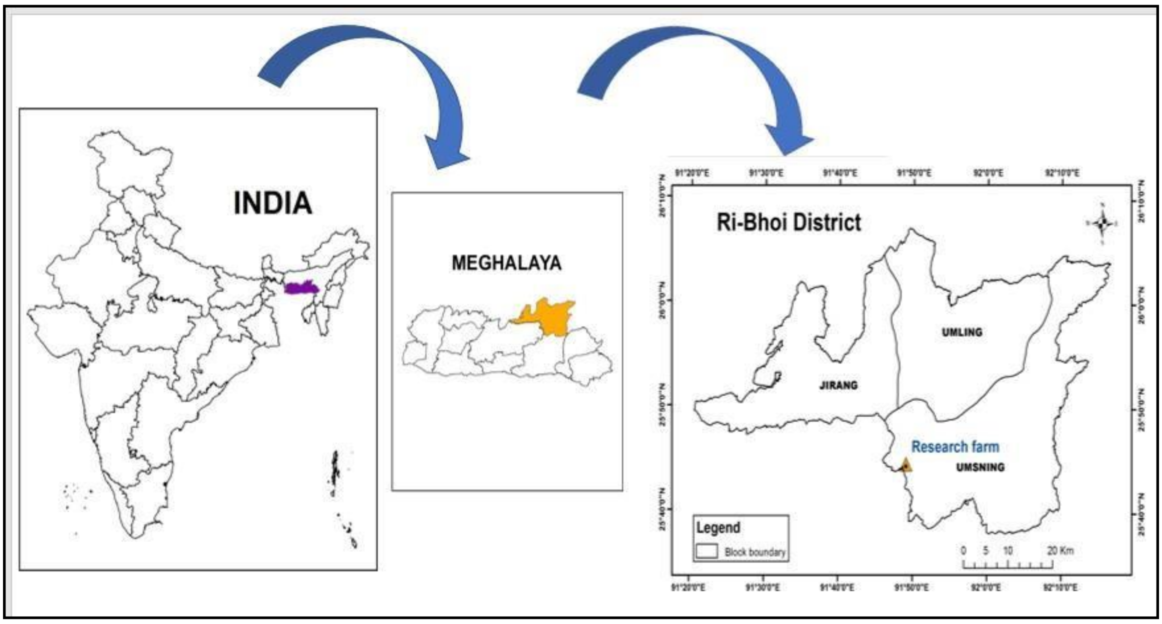

Figure 1. Location map of the study area

Prior to the experiment, initial soil samples were collected to determine the basic soil physical and chemical properties. The representative soil samples were taken at a depth of 0-30 cm with the help of a soil auger to find the textural class and inherent fertility status of the experimental plots. At first, these soil samples were thoroughly mixed and then composite samples were prepared. Further, those samples were air dried, grounded and sieved through 2 mm mesh. The processed samples were utilized for the analysis of the soil physical and chemical properties. The standard methods used for estimation, the values obtained, and the derived inferences are enlisted in Table 2.

The soil at the experimental site was found to be sandy clay loam. The soil has initial organic carbon and pH of 1.3%, 5.16, respectively. The average values of available nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) at 0-30 cm were 230.05, 20.50, and 210.33 kg ha^{-1}, respectively. The soil of the experimental field is acidic in reaction.

Table 1. Standard meteorological week (SMW) data prevailed during crop growing season and the amount of irrigation water applied during the experiment

SMW	Total Rainfall (mm)	Avg. Max. temperature (˚C)	Avg. Min. temperature (˚C)	Relative Humidity (%)
46	0	28	9.93	76.92
47	9.1	26.57	9.17	72.79
48	6	25.36	14.64	71.68
49	1.4	26.88	17.5	70.47
50	1.4	26.67	25.36	68.06
51	1.4	24.71	26.63	77.13
52	0	25.13	26.67	69.54
1	0	24.07	24.14	71.26
2	0	23.5	23.69	69.89
3	0	21.29	23	70.71
4	0	22.57	22.43	79.40
5	0	21.86	20.29	77.04
6	0	21.57	18.14	74.27
7	0	22.43	15.86	74.94
8	0	23.29	18.79	74.29
9	0	25.07	19.14	57.11

Table 2. Physical and chemical properties of the soil at the experimental site

Soil parameters	Value	Inference	Methods of estimation
1. Soil physical properties			
Soil texture		Sandy clay loam	Buoyoucos Hydrometer method (Chopra and Kanwar, 1976)
Sand (%)	55.50		
Silt (%)	10.89		
Clay (%)	30.16		
2. Soil chemical properties			
Soil pH	5.16	Acidic	pH Meter (Jackson, 1973)
Available N (kg ha^{-1})	230.05	Low	Alkaline Potassium Permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	20.50	Medium	Bray and Kurtz No. 1 method (Bray and Kurtz, 1945)
Available K (kg ha^{-1})	210.33	Medium	Neutral normal ammonium acetate extraction method followed by flame photometer (Jackson, 1973)
Organic carbon (%)	1.3	High	Walkley and Black's method (Walkley and Black, 1934)

Experimental design and treatment combinations

The field trial was conducted to assess the performance of garden pea cultivars under different bio-mulch treatments. The experiment was taken up with spilt plot design (SPD) experimental design, with organic mulching under main plot and garden pea varieties under sub-plot. Three organic mulches (paddy straw mulch, maize stover mulch and weed mulch) and a control (no mulch) constitutes the main plot treatment while four different garden pea varieties (Arkel, Punjab-89, Pusa Pragati, Pusa Prabal) were taken under sub-plot treatment. Hence, there are a total of sixteen (16) numbers of treatment combinations. The experiment was replicated thrice. Garden pea cultivars were sown with spacing of 30 cm ×10 cm, seed rate of 75 kg ha^{-1} with recommended dose of fertilizers as 20:60:40 kg ha^{-1} (N: P_2O_5: K_2O). The organic mulch was applied @ 5 t ha^{-1}. The schematic layout of the plan of the experiment is shown in the Fig. 2. The details of the experimental combinations are presented in Table 3.

Sampling, soil moisture monitoring and data analysis

From each treatment plot, five (5) plants were selected randomly and were tagged to be the sample plants excluding the plant situated in the border rows and biometric observations, *viz*., plant height, number of branches per plant, dry matter accumulation per plant, seed yield and biological yield were recorded from these tagged plants. All the observations were recorded at regular 30 days interval starting from 30, 60, and 90 days after sowing (DAS) while yield attributes were taken at the time of harvesting. For estimating dry matter accumulation, three plants from each plot besides the tagged plant were selected and picked randomly. The excessive moisture was removed with the blotting paper after proper washing. Then the plant samples were kept in hot air oven for abbot 48 hour at 60ºC till a constant weight was achieved. The dried weight of destructive samples was recorded for estimating dry matter accumulation. The moisture sensitive stage based irrigation scheduling was followed to irrigate. Standard procedures were followed to monitor *in-situ* soil moisture up to 30 cm of soil depth. Gravimetric readings were taken at weekly interval.

Estimation of soil moisture content (%)

Soil samples of each experimental plot were taken with the help of a soil auger at depth (0-30 cm) and kept in aluminium boxes and weight was taken with the help of a digital balance. The soil samples were kept in oven at 105ºC for 24 hour and weighed again until constant weight was achieved. Soil moisture content was calculated by using the formula presented in Eq. 1.

$$\text{Soil moisture content (\%)} = \frac{\text{Weight of water (g)}}{\text{Weight of oven dry soil}} \times 100 \quad \text{.... (1)}$$

$M_o V_4$	$M_2 V_2$	$M_1 V_4$	$M_3 V_3$
$M_o V_1$	$M_2 V_3$	$M_1 V_2$	$M_3 V_4$
$M_o V_3$	$M_2 V_4$	$M_1 V_1$	$M_3 V_2$
$M_o V_2$	$M_2 V_1$	$M_1 V_3$	$M_3 V_1$

R_1

$M_3 V_2$	$M_1 V_3$	$M_2 V_1$	$M_o V_4$
$M_3 V_3$	$M_1 V_2$	$M_2 V_4$	$M_o V_2$
$M_3 V_4$	$M_1 V_1$	$M_2 V_2$	$M_o V_3$
$M_3 V_1$	$M_1 V_4$	$M_2 V_3$	$M_o V_1$

R_2

$M_2 V_3$	$M_3 V_1$	$M_o V_4$	$M_1 V_2$
$M_2 V_1$	$M_3 V_2$	$M_o V_3$	$M_1 V_4$
$M_2 V_2$	$M_3 V_4$	$M_o V_1$	$M_1 V_3$
$M_2 V_4$	$M_3 V_3$	$M_o V_2$	$M_1 V_1$

R_3

N

M = Mulching, V = Varieties, R = Replication

Fig 2. Schematic layout of experimental design

Table 3. Details of experimental treatments

Main plot treatment (Organic mulch)	**Sub-plot treatment (Garden pea cultivars)**
Control (No-mulch) (M_0)	V_1 – Arkel
Paddy straw mulch (M_1)	V_2 – Punjab 89
Maize stover mulch (M_2)	V_3 – Pusa Pragati
Weed mulch (M_3)	V_4 – Pusa Prabal

Irrigation provided (mm)

To maintain equality, a given amount of irrigation water was applied four times throughout the experimentation period at sensitive stages of crop. Irrigation was provided by surface method using a 0.5 HP electric pump. The volume (m^3) of irrigation water was determined. Then standard conversion factor was multiplied for converting the unit from m^3 to litre (l) for easier calculation. The discharge rate of the electric pump was determined using the volumetric method as given in Eq. 2. The discharge rate was used to estimate the running time of the pump in order to apply the predetermined volume of irrigation water.

$$\text{Discharge rate (l sec}^{-1}) = \frac{\text{Amount of water collected in the bucket}}{\text{Time require to fill the bucket}} \quad \ldots (2)$$

Similarly, total amount of water used over the growing season including rainfall, was determined.

Water productivity *(kg ha^{-1} mm^{-1})*

Water productivity of crop was calculated as the ratio of green pod yield to total amount of water applied as presented in Eq. 3 and it is expressed in kg ha^{-1} mm^{-1}.

$$\text{Crop water productivity} = \frac{\text{Economic yield}}{\text{Total amount of water applied}} \quad \ldots. (3)$$

Benefit cost ratio

The benefit cost analysis (BCR) as per treatments was also estimated using standard protocols. The input costs were used based on the prevailing market price during 2022-23. BCR value was computed by taking the ratio of the benefits incurred relative to its costs and is expressed in monetary terms. It reveals the returns obtained with the rupee invested in the project as given in Eq.4.

$$\text{B: C ratio} = \frac{\text{Gross return}}{\text{Cost of cultivation}} \quad \ldots.(4)$$

The data obtained during this field trial were analyzed by using the technique of analysis of variance for split plot design over the computer. The difference between the treatment means was tested as for their statistical significance with appropriate critical difference (CD) value at 5% level of probability as explained by Gomez and Gomez (1984). All the field data were analyzed using Microsoft Excel of the MS office software.

3. Results and Discussions

Plant Growth parameters

The various plant growth parameters such as plant height, number of branches per plant and dry matter accumulation per plant are analyzed and presented in Table 4.

Plant height and Number of branches

Plant height is a crucial parameter for determining the growth of plant. Significant results were registered for the plant height for both the main plot and sub-plot treatments. Under the man plot treatment, M_1 recorded significantly the highest plant height (47.76 cm) over M_0 (34.02 cm) but it was at par with M_3 (46.19 cm) and M_2 (43.68 cm). Paddy straw mulch gave the highest plant height during the entire crop season. This might be due to the fact that, paddy straw has higher capacity to alter the soil temperature, soil moisture content, better suppression of weed growth and reduced nutrient loss from the soil which favoured vigorous growth and thus resulted in taller plants as compared to no mulch. These results were similar with the findings of Awal *et al*., 2016**;** Anand *et al*., 2020. Similarly, under sub-plot treatment, the highest plant was achieved by V_2 (47.49 cm) which was significantly higher over V_1 (44.64 cm), V_3 (38.83 cm) and V_4 (40.64). Significantly highest plant height was recorded in cultivar Punjab-89 (V_2) during the entire crop season. The reason in the variations of plant height may be due to genotype characteristics and also environmental adaptability of the individual cultivar. These findings are in agreement with Mukherjee *et al.*, 2013; Bairwa *et al.,* 2018; Sharma *et al*., 2020.

No. of branches

Among different mulching practices, significantly highest number of branches per plant was observed in M_1 (12.73) over M_3 (10.57) and M_2 (10.06) and M_0 (8.52). The number of branches per plant under different organic mulches was found to be significantly highest under paddy straw mulch which was at par with weed mulch in almost all the stages while the lowest was recorded under no-mulch plot. The reason for getting the highest number of branches may be due to better moisture conservation leading to greater uptake of moisture and thereby nutrient uptake by plant. This was in conformity with the earlier findings of Bunkar *et al.,* 2013 in mung bean crop. Similar result was also found by Singh *et al.,* 2019. Among the cultivars of garden pea, highest no. of branches was found in V_2 (12.53) which was significantly higher over V_1 (10.43), V_3 (9.87) and V_4 (9.04). Punjab-89 (V_2) recorded the highest number of branches over cultivar Arkel (V_1), Pusa Pragati (V_3) and Pusa Prabal (V_4). The variations in the number of branches per plant may be caused by environmental conditions or by the genetic variability of various genotypes as given by Raj *et al*., 2020; Sharma *et al*., 2020 in their studies.

Dry matter accumulation

Under main plot treatment, significantly highest dry matter accumulation was obtained from M_1 (7.85 g) over M_0 (5.83 g), M_2 (6.13 g) and M_3 (6.53 g). Among all the organic mulches applied, paddy straw mulch was found to be significantly highest in dry matter production over the others. This may be due to increased soil moisture which promotes healthy plant growth, better chlorophyll levels, and higher net photosynthetic rates, all of which improves crop output and ultimately increase in dry matter production. This is supported by research findings of Akhtar *et al*., 2019; Dhivya and Ray, 2020; Shashikanth *et al*., 2022**.** Under sub plot treatment, V_2 (7.08 g) showed significantly highest dry matter accumulation over V_1 (6.78 g), V_3 (5.89 g) and V_4 (6.58 g). The highest dry matter accumulation was found to be in cultivar Punajb 89 (V_2) over the others. The differences in dry matter production among the cultivars maybe due to the fact that, it may have been influenced by both environmental stress and the underlying genetic diversity in the individual genotypes, which was supported by Nwadike and Vangel., 2015; Dhiva *et al*., 2020. Also, the gradual increase in dry matter production throughout the season maybe because of increase in dry weight of the stem and eventually leaf area and photosynthetic organs would be also increased thus resulting in increase in dry matter production. This result is also in agreement with the findings of Ahmed *et al*., 2020.

Table 4. Effect of mulching and cultivar treatments on growth performance of garden pea

Treatments	**Plant height (cm)**	**No. of branches per plant**	**Dry matter accumulation per plant (g)**
Main plot (Four level of mulching)			
No-mulch (M_0)	34.02	8.52	5.83
Paddy straw mulch (M_1)	47.76	12.73	7.85
Maize stover mulch (M_2)	43.68	10.06	6.13
Weed mulch (M_3)	46.19	10.57	6.53
S.E.(m) ±	2.34	0.53	0.13
C.D.(p = 0.05)	8.09	1.84	0.46
Sub-plot (Four different cultivars)			
Arkel (V_1)	44.64	10.43	6.78
Punjab- 89 (V_2)	47.49	12.53	7.08
Pusa Pragati (V_3)	38.83	9.87	5.89
Pusa Prabal (V_4)	40.68	9.04	6.58
S.E.(m) ±	2.15	0.58	0.08
C.D.(p = 0.05)	6.29	1.69	0.23

Table 5. Effect of mulching and cultivar treatments on yield attributes of garden pea cultivars

Treatments	**Green pod yield/ Economic yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**	**Water productivity (kg ha^{-1} mm^{-1})**
M_0	3.30	8.24	40.12	13.52
M_1	8.51	16.22	52.64	34.81
M_2	5.68	12.57	46.12	23.25
M_3	7.17	14.80	48.09	29.34
S.E.(m) ±	0.31	0.34	1.93	1.27
C.D.(p=0.05)	1.08	1.17	6.69	4.41
V_1	6.34	13.10	47.96	25.94
V_2	7.38	15.23	48.31	30.23
V_3	4.94	10.89	44.58	20.24
V_4	5.99	12.61	46.13	24.53
S.E.(m) ±	0.28	0.35	1.75	1.16
C.D.(p = 0.05)	0.83	1.01	NS	3.39

Effect of mulching and cultivar treatments on yield attributes of garden pea

The yield attributes, *viz.*, green pod yield/economic yield, biological yield and Harvest index (%) are presented in Table 5. Economic yield or the green pod yield (t ha^{-1}) of garden pea cultivars was significantly highest in M_1 (8.51 t ha^{-1}) over M_3 (7.17 t ha^{-1}), M_2 (5.68 t ha^{-1}) and M_0 (3.30 t ha^{-1}) as presented in Table 5. The variations in the yield might be due to the fact that, paddy straw mulch resulted in higher soil moisture reserves which also increased the organic matter content of the soil, which may have improved the availability of macro and micronutrients in the soil pool for a longer time, possibly synchronising with plant need. These findings are in agreement with Uwah and Iwo 2011; Javeed *et al*., 2012; Marwein *et al*., 2017; Shashikanth and Thimmegowda., 2022; Devi *et al.,* 2023. Similarly, under sub-plot treatment, significantly highest green pod was recorded under cultivar V_2 (7.38 t ha^{-1}) over V_1 (6.34 t ha^{-1}), V_4 (5.99 t ha^{-1}) and V_3 (4.94 t ha^{-1}). This may be explained by the plant's capacity to absorb sufficient nutrients and moisture from the soil. Similar type of result was also reported by Marwein and Ray (2019) in rajma crop.

Paddy straw mulch, *i.e*., M_1 (16.22 t ha^{-1}) significantly recorded the highest biological yield over M_3 (14.80 t ha^{-1}), M_2 (12.57 t ha^{-1}) and M_0 (8.24 t ha^{-1}) which is presented in Table 5. It is possible that, the better soil water conservation and higher soil temperature, which result in more branches and pods per plant might be the cause of higher biological production from plants mulched with paddy straw. This is in line with the research findings of Awal *et al.,* 2016. In sub-plot treatment, significantly highest biological yield was recorded under V_2 (15.23 t ha^{-1}) over V_1 (13.10 t ha^{-1}), V_4 (12.61 t ha^{-1}) and V_3 (10.89 t ha^{-1}). The reason for this variation in the biological yield might be because of correlation between yield attributes, *viz*., pods per plant and pod weight per plant. The result was similar with the findings of Abdollahi *et al.,* 2009.

Significant result was obtained under organic mulch treatment; however, non-significant result was obtained under cultivar treatments. Significantly highest harvest index was obtained under paddy straw mulch (M_1) of 52.64%, whereas, lowest harvest index was recorded by un-mulch (M_0) of 40.12% as shown in Table 5. The reason for higher harvest index might be due to higher economic yield. This is in line with the findings of Asif *et al.,* 2020; Singh *et al.,* 2021.

Water Productivity (kg ha^{-1} mm^{-1})

The standard meteorological week data of rainfall and amount of irrigation water applied is presented in Table 1. Significantly highest water productivity was obtained in M_1 (34.81 kg ha^{-1} mm^{-1}) over M_3 (29.34 kg ha^{-1} mm^{-1}), M_2 (23.25 kg ha^{-1} mm^{-1}) and M_0 (13.52 kg ha^{-1} mm^{-1}) as presented in Table 5. Application of paddy straw mulch reduced soil moisture loss due to less evaporation, resulting in better moisture availability. This in turn enhanced the availability of plant nutrients in soil, and the uptake by plants of these nutrients led to an increase in crop output thus resulting in higher water productivity. This result is in accordance with the findings of Dutta, 2006; Choudhary, 2015; Nayak *et al*., 2015; Mawthaoh *et al*., 2023. Among the cultivars, significantly highest water productivity was obtained by cultivar V_2 (30.23 kg ha^{-1} mm^{-1}) over V_1 (25.94 kg ha^{-1} mm^{-1}), V_4 (24.53 kg ha^{-1} mm^{-1}) and V_3 (20.24 kg ha^{-1} mm^{-1}) as presented in Table 5. This variation might be due to the result of soil water being used for crop growth rather than in evaporation. This is in line with the findings of Shylla *et al*., 2016.

Economics

The cost of cultivation under no-mulch, paddy straw mulch, maize stover mulch and weed mulch were ₹. 50,115, 48,615, 49,115, and 48,365, respectively. The details of the economic analysis of the treatments are presented in Table 6. The cost of cultivation is highest under no mulch due to extra labour requirement for weeding operation while it was minimum for the paddy straw mulch due to lower cost of mulching material in comparison to other mulch used. Significantly highest gross returns, net returns and benefit cost ratio (BCR) were recorded from paddy straw mulch as ₹ 2,04,291.67 ha^{-1}, ₹ 1,55,676.67 ha^{-1} and 3.96, respectively, over un-mulched. Similar results were also reported by Kamal *et al*., 2010; Deka *et al*., 2021; Parida *et al.,* 2023 and Shirisha *et al*., 2023. Among the cultivars, the gross returns, net returns and BCR were recorded significantly highest under cultivar V_2- Punjab 89 as ₹ 1,78,354.17 ha^{-1}, ₹ 1,29,306.67 ha^{-1}, and 3.46, respectively, over the other three cultivars, *viz*., V_1, V_3 and V_4. Similar finding was reported by Mukherjee *et al*., 2013.

Table 6. Gross returns (₹ ha^{-1}), Net returns (₹ ha^{-1}) and BCR of garden pea crop production

Treatments	Economic analysis		
Main plot (Level of mulching= 04)	**Gross return (₹ ha^{-1})**	**Net return (₹ ha^{-1})**	**BCR**
Un-mulch (M_0)	83,604.17	33,489.17	1.67
Paddy straw mulch (M_1)	2,04,291.67	1,55,676.67	3.96
Maize stover mulch (M_2)	1,41,993.06	92,878.06	2.89
Weed mulch (M_3)	1,70,680.56	1,22,815.56	3.57
S.E.(m) ±	7,561.54	7,561.54	0.15
C.D.(p = 0.05)	26,163.38	26,163.38	0.51
Sub-plot (Level of variety= 04)			
Arkel (V_1)	1,56,111.11	1,07,058.61	3.20
Punjab 89 (V_2)	1,78,354.17	1,29,301.67	3.46
Pusa Pragati (V_3)	1,21,520.83	72,468.33	2.49
Pusa Prabal (V_4)	1,44,583.33	95,530.83	2.93
S.E.(m) ±	6,757.10	6,757.10	0.14
C.D.(p = 0.05)	19,720.57	19,720.57	0.41

4. Conclusion

Bio mulches play key roles in saving soil and moisture conservation, and thereby help in good crop growth and yield. Paddy straw mulch gave better results as compared to weed mulch, maize stover mulch and un-mulch plots. The values of percent soil moisture increased over no-mulch were 22.07%, 12.00% and 4.64% in paddy straw mulch, weed mulch and maize stover mulch, respectively. Whereas, in terms of water productivity, it was also found to be highest under paddy straw mulch (34.81 kg ha^{-1} mm^{-1}) and lowest under un-mulch (13.52 kg ha^{-1} mm^{-1}). Among the cultivar treatments, garden pea cultivar Punjab-89 performed better as compared to the other cultivars producing significantly highest economic yield of 7.38 t ha^{-1}. The economic yield (7.38 t ha^{-1}), biological yield (15.23 t ha^{-1}), gross returns (₹ 1,78,354.17 ha^{-1}), net returns (₹1,29,426.67 ha^{-1}) and benefit cost ratio 3.46 were found to be highest for Punjab-89 cultivar. Therefore, under the hilly regions of NER where retaining soil moisture is of great concern, mostly during *rabi* season, practicing paddy straw mulch with garden pea cultivar Punjab-89 not only increases the cropping intensity but will also supplement pulse production of the region.

5. Acknowledgement

The authors would like to express their heartfelt gratitude to the Central Agricultural University-Imphal, for the financial support during the entire tenure of the research work. Special thanks go to the Dean, College of Post Graduate Studies in Agricultural Sciences for his support throughout the experiment.

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