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Effect of Organic Mulches on Yield, Water Productivity and Economy of Garden Pea Cultivars

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Authors' contributions

This work was carried out in collaboration among all authors. Authors PKP, LIPR and KS contributed equally to this work. Author LIPR designed the experiments. Authors PKP and KS collected samples and performed the experiments. Author PKP drafted the manuscript and all authors revised it. All authors read and approved the final manuscript.

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ABSTRACT

Mulching techniques that are adaptive and extremely successful may be able to reduce the detrimental impacts of crop production and water stress on different varieties of peas in a climate change scenario. Field experiment was carried out in the Umroi region of Meghalaya during the *rabi* season (2020–2021) for this reason. This study used a split-plot design with three organic mulches as the main plot treatment and four pea types as the sub-plot treatments, which was replicated three times. The field trial showed that paddy straw mulch significantly outperformed both weed

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mulch and no mulch in terms of green pod yield, water productivity, and benefit cost ratio, with values of 89.33, 54.14 kg ha^{-1} mm^{-1}, and 3.16, respectively.VM 12 greatly topped other cultivars in terms of green pod yield, water productivity, and benefit-cost ratio (BCR), with values of 89.78 kg ha^{-1}, 54.41 kg ha^{-1} mm^{-1} and 3.33, respectively. The investigation showed that the best alternative agronomic strategy for achieving the maximum yield output of garden pea was paddy straw mulch, followed by weed mulch and un-mulch.

Keywords: Garden pea; mulch; water productivity; BCR; crop production.

1. INTRODUCTION

Pulses are one of the most important food crops grown globally due to higher protein content. India is the largest producer and consumer of pulses in the world, *viz*., 25% of global production and 27% of global consumption, respectively, which perfect evidence that pulses play an important role in Indian agriculture [1]. Among pulses, pea (*Pisum sativum* L.) is an important *rabi* season pulse crop. There are two different types of peas that were grown based on their moisture content: dry pea and green pea, which have 10-15% and 75-80% moisture content, respectively. Pea are rich sources proteins of 23.4 %, 60.1% carbohydrates, 1.2% fat, 21.2% dietary fibre, minerals, vitamins and phytochemicals [2]. In the world, dry pea is cultivated in an area of 7.16 m ha with a production of 14.2 m t and average yield is 1979 kg ha^{-1} while, green pea is cultivated in an area of 2.78 m ha with a production of 22 m t and average yield is 7824 kg ha^{-1}, while [3]. In India, dry pea is cultivated in an area of 0.60 m ha with a production of 0.81 m t and average yield is 1337 kg ha^{-1} while, green pea is cultivated in an area of 0.55 m ha with a production of 5.55 m t and average yield is 1000 kg ha^{-1}. However, in North Eastern Region (NER) the average production of pulses is 850 kg ha^{-1}. Despite making up 7.9% of the country's overall geographical area, it only contributes 1.5% of the nation's total production of food grains [4]. Per capita availability of pulses is very less *i.e*., 41.9 g day^{-1} whereas, before it was 60 g day^{-1} in 1950 [5]. It has been estimated that NER had a deficit of 78.79% in pulse requirement [6].

Though the average annual rainfall is higher in North East Hill (NEH) Region (2000 mm) compared to the national average (1194 mm), the production in the region is insufficient due to terminal moist stress in *rabi* season and more than 80% of the area in NER remained fallow after *kharif* rice [7]. Water stress is a serious problem for increasing the productivity and cropping intensity of the particular region during *rabi* season. Different agronomic practices like conservation farming, bio-intensive farming, organic mulching might be a perfect approach 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 [8]. To escape moisture stress, early maturing pea varieties with mulching can be practised under rice fallow residual soil moisture condition, due to early maturity of pea varieties and moisture conservation of mulches under pre monsoon rainfall can enhance the growth and development of the pea crop at maturity stage [9]. The production potential of different pea varieties needed to be ascertained under mid hill conditions of Meghalaya under suitable agronomic package of practices. In order to increase the production and productivity of the pulses in regions of NER, organic mulching may be a promising measure to be practiced under *rabi* season. Considering the scenarios mentioned above, a field experiment has been conducted to evaluate the growth, yield and economic performance of pea varieties under organic mulches.

2. MATERIALS AND METHODS

The field experiment was conducted during *rabi* season (2020-21) at experimental farm of College of Postgraduate Studies in Agricultural Sciences, Ri Bhoi district, Meghalaya. A schematic location of the experimental site is shown in Fig. 1. The soil type is sandy clay loam, acidic reaction (pH - 4.86) and high soil organic carbon content (1.13%). The experiment was carried out in split plot design with three main-plot treatments (mulches), *viz.,* i) M_0- un-mulch, ii) M_1- paddy straw mulch, iii) M_2- weed mulch are applied @ 5 t ha^{-1} and four sub-plot treatments (varieties), *viz*., i) V_1- VM 10, ii) V_2- VL sabji matar 15, iii) V_3- VM 12 and iv) V_4- VL sabji matar 13 and the experiment was replicated three times. Mulching was done on the next day of sowing in the respective experimental plots based on the requirement @ 5 t ha^{-1}.

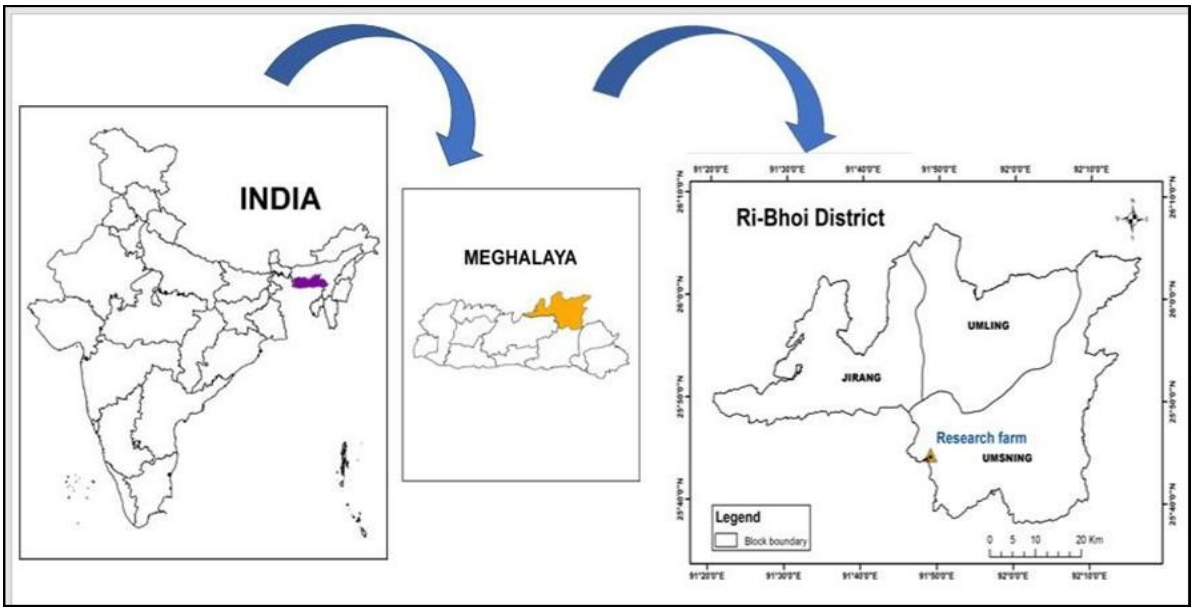

Fig. 1. Map showing Location of experimental site

The climate of Ri-Bhoi is classified as subtropical humid type with high rainfall and cold winters. The Monsoon rainfall is 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 decreasing 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 [10]. The maximum temperature rises up to 30°C in the months of July-August and minimum falls down to 5 to 6°C during the first week of January. The graphical representation of weekly rainfall (mm), average maximum and minimum temperature (°C) and relative humidity (%) is shown in Fig. 2.

For recording the growth characters and yield attributes, five (05) plants in net plot of each treatment were selected randomly and labelled with tags. Observations were recorded throughout the crop period. Destructive sample collected from border rows in sequence manner. The growth parameters were recorded at 30 days interval and data on yield parameters were recorded at harvest.

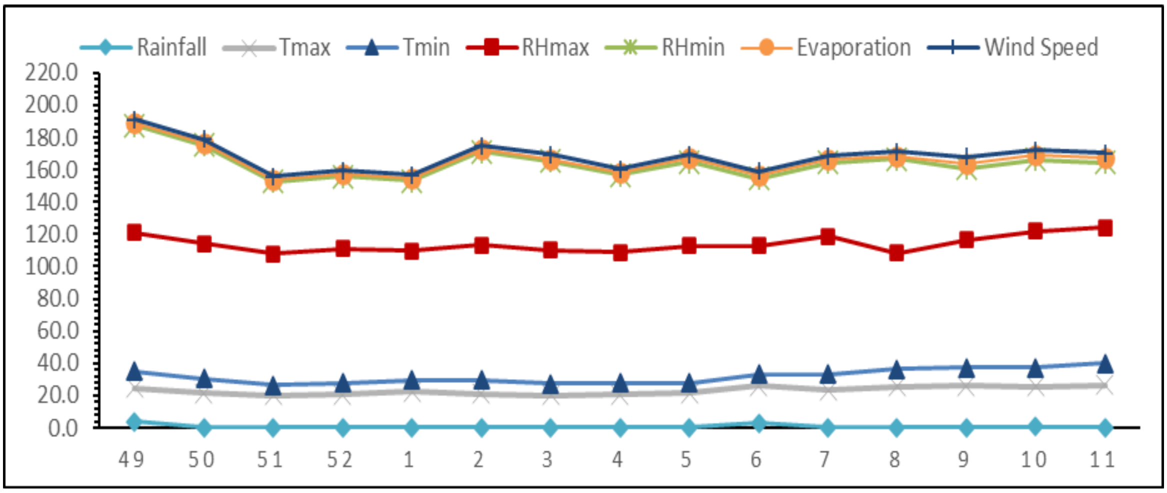

Fig. 2. Observed meteorological data during the experimental period (2020-21)

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

Water productivity of crop was calculated as the ratio of economic yield to amount of water applied as presented in Eq. (1) below.

Crop water productivity = (Economic yield / Total amount of water used by crop) --- (1)

2.2 Economical Parameters

2.2.1 Cost of cultivation

The cost of cultivation per hectare was calculated for the individual treatment on the basis of inputs used and prevailing market price of the farm produce.

2.2.2 Gross returns (Rs. ha^{-1})

Gross monetary returns were estimated by deducting cost of cultivation from gross monetary returns for each treatment as given in Eq. (2) below.

Gross returns = Seed yield (kg ha^{-1}) × Price of seeds (kg) --- (2)

2.2.3 Net returns (Rs. ha^{-1})

Net monetary returns were estimated by deducting cost of cultivation from gross monetary returns for each treatment as given in Eq. (3) below.

Net returns = Gross returns - Cost of Cultivation Seed yield (kg ha^{-1}) --- (3)

2.2.4 Benefit-Cost ratio

Benefit-cost ratio is an indicator showing the relationship between the relative cost and benefit of crop production. Benefit cost (B: C) ratio was calculated by dividing gross returns with cost of cultivation Gross returns as presented in Eq. (4) below:

B: C Ratio = Gross Return / Cost of Cultivation --- (4)

The observed field experimental data were statistically analysed as per the method described by Gomez and Gomez, [11]; Rangaswamy, [12].

3. RESULTS AND DISCUSSION

Various growth parameters, yield, yield attributes and economics were estimated for garden pea crop during *rabi* season and presented under different sub-sections in a structured way.

3.1 Growth Parameters

Data regarding different growth parameters, *viz.,* plant height, number of branches per plant and dry matter production are presented below in Table 1. The results of the analysis of variance revealed that the crop's growth characteristics were gradually enhanced as the crop developed.

Plant height of the garden pea increased gradually from germination to maturity and it was highly affected by both organic mulches and garden pea cultivars. Under different level of mulches, it was observed that the mean values of plant height values were significantly higher in paddy straw mulch over un-mulch during 30, 60 and 90 DAS, *i.e*., 16.35, 42.17 and 51.55 cm, respectively, while shorter plant height were recorded in no mulch condition. The mean values of the plant height influenced significantly in different cultivars of garden pea throughout the growing season, under different varietal condition, VM 12 recorded significantly higher plant height over other varieties during 30, 60 and 90 DAS, *i.e.,* 17.22, 41.11 and 53.34 cm, respectively. Higher value for plant height in variety VM 12 was due to its genetic potential and very high resource use efficiency. Mulch materials favoured the growing environment for crop by preserving the soil moisture content and decreasing the number of weeds that would otherwise consume and transpire an adequate amount of water in the field. The result was in agreement with Iqbal, et al., [13]; Iqbal et al., [14]; Iqbal and Andersen, [15]; Davari, [16]; Ahmad et al., [17], Mutetwa and Mtaita, [18]; Nwokwu and Aniekwe, [19]; Sajid et al., [20]; Zhao et al*.,* [21]; Nasrullah and Khan, [22], who observed that plant height was significantly affected by different organic mulching material.

Number of branches per plant significantly increased with increase in age of the plant. Under different levels of mulches, paddy straw obtained significantly higher mean number of branches per plant during 30, 60 and 90 DAS, *i.e*., 6.34, 10.93 and 16.73, respectively over others. However, VM 12 reported highest and VM 10 reported lowest mean number of branches per plant, *i.e*., 6.49, 11.28 and 17.20 and 5.12, 9.19 and 13.56 at 30, 60 and 90 DAS, respectively. This result is found similar with Hirich et al., [23], who reported that application of any mulch helps to increase the number of branches than no mulch condition. The number of branches per plant is increased by straw mulch more than other types of mulch. This may be because straw mulching an area increases nodulation and nitrogen fixation, which leads to more branches and pods per plant, this result is in conformity with Masete et al., [24]; Singh et al., [25]; Kumar, [26]. According to Lu et al., [27]; Awal et al., [28]; Ashrafuzzaman et al., [29], mulches alter the soil's temperature and moisture content, which may encourage rapid development and result in plants that are taller than those that were grown in the absence of mulch. The plants covered in black and transparent plastic had somewhat more primary branches than the plants covered in straw, while the lowest number had no mulched plants at all.

Similarly dry matter production also increased by multi fold as increases in plant growth, a tremendous change in dry matter accumulation during 30 to 90 DAS. There was a significant difference in dry matter production between mulch and no mulch condition. Under different level of organic mulches, paddy straw reported significantly higher mean dry matter production throughout the growing period, *i.e.*, 2.63, 6.69 and 9.58 g over no mulch, *i.e.*, 2.02, 5.64 and 8.70 g and reported at par with weed mulch during 30, 60 and 90 DAS, respectively. However, variety VM 12 shown significantly higher dry matter production, *i.e.,* 2.56, 6.53 g and 9.72 g during 30, 60 and 90 DAS, respectively, over VM 10 and VL sabji matar 15 and VM 10 reported lower dry matter production, *i.e.*, 2.21, 5.84 and 8.60 g during 30, 60 and 90 DAS, respectively. Mulches reduce evaporation and enhance nutrient availability, microbial activity of soil result in vigorous plant growth, dry matter production and yield, this result was in conformity with Qureshi et al., [30]. High soil moisture availability lead to reduced closure of stomata, which prompts the opening of the pathways for the exchange of water, carbon dioxide, and oxygen, increasing the rate of photosynthetic activity and more dry matter production, reported by Habermann et al., [31]; Dass and Bhattacharyya, [32]; Moshelion et al., [33].

3.2 Yield Parameters

Data regarding different yield parameters are presented in Table 2. Analysis of variance showed that presented yield parameters were affected due to different varieties and mulches.

The mean values of different yield attributes were significantly influenced by both various mulches and varieties. Under different level of mulches, paddy straw recorded significantly higher mean values of yield attributes over weed and no mulch. Highest number of green pod weight per plant, number of pods per plant, number of seeds per pod and fresh seed weight per plant were observed under paddy straw mulch, *i.e.*, 33.50 g, 16.98, 6.84, and 14.98 g, respectively and lowest under control treatment, *i.e.*, 27.83 g, 12.88, 6.05, 12.42 g, respectively. These were might be due to increased soil moisture made cells more turgid, and when cells are more turgid, they transport and translocate nutrients more effectively than when they are stressed. As

Table 1. Effect of organic mulches on the growth parameters of different garden pea cultivars

Treatment	Plant height (cm)			No. of branches			Dry matter (g)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Main plot treatments (mulch)									
M_0	13.27	32.67	41.96	5.00	9.08	13.66	2.02	5.64	8.70
M_1	16.35	42.17	51.55	6.34	10.93	16.73	2.63	6.69	9.58
M_2	14.09	41.00	51.50	5.23	10.61	14.58	2.43	6.19	9.00
S.E.(m) ±	0.50	0.79	2.15	0.25	0.38	0.59	0.10	0.19	0.21
C.D.(p=0.05)	1.98	3.09	8.45	1.00	1.48	2.33	0.39	0.74	0.81
Sub plot treatments (variety)									
V_1	12.54	36.0	45.97	5.12	9.19	13.56	2.21	5.84	8.60
V_2	14.03	37.44	47.18	5.32	10.66	15.20	2.38	6.09	9.13
V_3	17.22	41.11	53.34	6.49	11.28	17.20	2.56	6.53	9.72
V_4	14.49	39.89	46.87	5.15	9.71	14.01	2.29	6.24	8.92
S.E.(m) ±	0.56	1.09	1.87	0.17	0.44	0.55	0.11	0.16	0.15
C.D.(p=0.05)	1.67	3.24	5.55	0.52	1.29	1.64	0.33	0.46	0.44

turgor pressure rises, physiological photo-synthetic rate rises as well, improving assimilate production and transportation from source to sink while simultaneously increasing pod length and other yield attributes. This was in conformity with Marwein and Ray, [4]; Raza and Saleem, [34]. Organic mulches increase soil's physical qualities by adding organic matter and boosting soil water-holding capacity. This leads to greater aeration and drainage, which promote better root development and nutrient absorption, which was in conformity with Abd El-Wahed et al., [35]; El-Samnoudi et al., [36]. This outcome may be attributable to the rice straw mulching, which helps to sequester carbon and adds nutrients to the soil when it decomposes through microbial action, which was in agreement with Rahman, et al., [37]; Dossou-Yovo et al., [38]; Rahman et al., [39]; Wang et al., [40].

Yield of garden pea were significantly affected by both cultivars and organic mulches. The mean value of yield parameters was recorded significantly higher in paddy straw mulch over weed and no mulch. However, VM 12 produced significantly higher yield over other varieties. The graphical representation of green pod yield is shown in Fig. 3.

The maximum mean value of green pod yield and green seed yield were recorded in Paddy straw, *i.e.,* 89.33 and 39.96 q ha^{-1}, respectively, followed by weed and no mulch, under different levels of mulches. Under different varietal treatments, VM 12, recorded highest green pod yield and green seed yield, *i.e*., 89.78 and 41.66 q ha^{-1}, respectively. However, lowest green pod yield and green seed yield recorded in V_1, *i.e*., 89.78 and 41.66 q ha^{-1}, respectively. This might be due to the genetic capacity of the variety which had bolder seeds, higher pod weight, higher number of pods per plant, higher number of seeds per pod and higher fruit bearing capacity per plant. Similar results were also reported by Marwein and Ray, [4]; Tao et al., [41]; Das et al., [42]; Zamir et al., [43]. This may be because more moisture in the soil encourages early emergence, healthy plant growth, higher chlorophyll content, root proliferation, and an increase in net photosynthetic rate, all of which improve leaf area, leaf area index, dry matter accumulation, root nodulation, yield attributes, and crop yield. Crop output has been demonstrated to increase when water regimens are increased and soil temperatures are decreased, which is in agreement with Kannan, [44]; Ahmad et al., [45]; Karunakaran, [46].

3.3 Water Productivity

Water productivity in garden pea is significantly affected by mulch treatments. Rainfall, evaporation irrigation provided during the crop season is presented in Table 3. Water productivity (kg green pod yield per ha-mm) was reported significantly highest under paddy straw mulch (54.14 kg $ha^{-1}mm^{-1}$) over weed mulch (46.73 kg ha^{-1} mm^{-1}) and un-mulch (44.98 kg $ha^{-1}mm^{-1}$), presented in Table 2 and Fig. 3. Anup et al., [47]; Sanbagavalli et al., [48] reported that, rainfall use efficiency was significantly higher under bajra straw mulch (3.30 kg ha^{-1} mm^{-1}) compared to control treatment (2.72 kg $ha^{-1}mm^{-1}$). El-Beltagi et al., [49]; Choudhary et al., [50]; Bhardwaj, [51], found that at night, the underside of the mulch absorbs long wave radiation emitted by the soil, thereby, slowly cooling of the soil. In addition to modifying the soil and air temperatures, there were also benefits of protection from wind and in some instances rain, insects, diseases and vertebrate pests.

3.4 Economical Parameters

Data regarding economical parameters, *viz*., gross return, net return and benefit cost ratio are presented in Table 4.

Paddy straw mulch and VM 12 recorded significantly maximum economics over other mulches and varieties under different level of mulches and varieties, respectively. Paddy straw mulch shown highest gross return, net return and benefit cost ratio, *i.e*., Rs. 159822.06, 121413.96 and 3.16, followed by weed mulch and control. However, among different varieties VM 12, recorded highest gross return, net return and benefit cost ratio, *i.e*., Rs. 166636.87, 128143.77 and 3.33 and lowest under V_1, *i.e*., Rs. 12549.50, 89056.40 and 2.32, respectively. The justification behind expanded benefit: cost ratio is due to an increase in marketable pod yield and furthermore because of the cheapest cost of paddy straw mulch. Similar statements were obtained by Das, et al. [52]; Jaipaul, et al., [53] and Murungu et al., [54], who obtained a higher B:C ratio as compared to control [55].

Table 2. Effect of organic mulches on the yield attributes, yield and water productivity of different garden pea cultivars

Treatments	Yield attributes				Yield		Water productivity
	Green pod wt. plant^{-1} (g)	No. of pods plant^{-1}	No. of seeds pod^{-1}	Fresh seed wt. plant^{-1} (g)	Green pod yield (q ha^{-1})	Green seed yield (q ha^{-1})	kg green pod yield per ha-mm
Main plot treatments (mulch)							
M_0	27.83	12.88	6.05	12.42	74.22	33.11	44.98
M_1	33.50	16.98	6.84	14.98	89.33	39.96	54.14
M_2	28.92	13.72	6.68	12.89	77.11	34.36	46.73
S.E.(m) ±	0.94	0.67	0.14	0.52	2.52	1.38	1.53
C.D.(p=0.05)	3.71	2.61	0.55	2.03	9.89	5.42	5.99
Sub-plot treatments (variety)							
V_1	27.89	13.23	5.66	11.96	74.37	31.89	45.07
V_2	30.00	15.01	7.53	13.47	80.00	35.91	48.48
V_3	33.67	15.78	6.64	15.62	89.78	41.66	54.41
V_4	28.78	14.07	6.26	12.67	76.74	33.78	46.51
S.E.(m) ±	1.31	0.61	0.23	0.71	3.48	1.91	2.11
C.D.(p=0.05)	3.88	1.80	0.68	2.12	10.35	5.66	6.28

Table 3. Standard meteorological week data of rainfall, evaporation and irrigation provided during the crop season

Standard meteorological week	Rainfall (mm)	Evaporation (mm)	Irrigation provided (mm)
49	36.0	1.3	-
50	0.0	1.4	
51	0.0	1.5	32
52	0.0	1.5	-
1	0	1.7	-
2	0	1.4	-
3	0	1.4	38
4	0.0	1.8	-
5	0	2	-
6	29.0	2.0	-
7	0	2.0	-
8	0	1.8	30
9	0	2.8	-
10	4	3.1	-
11	0	3.3	-
	69		100

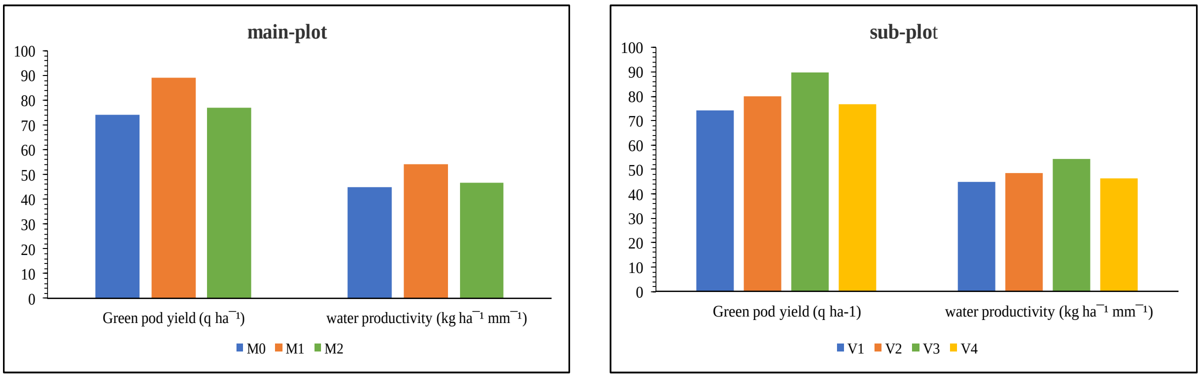

Fig. 3. Water productivity kg green pod yield per ha-mm cultivars

Table 4. Effect of organic mulches on the economical parameters of different garden pea cultivars

Treatments	Gross return (Rs.)	Net return (Rs.)	B:C Ratio
Main-plot treatments (mulch)			
M_0	132444.31	93271.21	2.38
M_1	159822.06	121413.96	3.16
M_2	137439.86	99541.75	2.63
S.E.(m) ±	5522.48	5522.48	0.14
C.D.(p=0.05)	21683.93	21683.93	0.56
Sub-plot treatments (variety)			
V_1	127549.50	89056.40	2.32
V_2	143644.30	105151.20	2.73
V_3	166636.87	128143.77	3.33
V_4	135110.98	96617.88	2.51
S.E.(m) ±	7621.80	7621.80	0.20
C.D.(p=0.05)	22645.52	22645.52	0.59

4. CONCLUSION

Paddy straw mulch reported higher values in growth and yield parameters of pea. Among the different varieties of pea, the significantly highest yield was reported by the variety VM 12. Soil moisture is most important constraint for crop production during the *rabi* season in NEH region. Therefore, the practice of paddy straw mulch along with the cultivation of pea variety VM 12 is proved to be best method to increase the crop yield and to improve the cropping intensity in NEH region during the moisture deficit winters.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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