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Effect of Organic Manures and Biofertilizers on Growth, Yield and Quality of Pea (*Pisum sativum* L.)

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ABSTRACT

The present study was carried out at the Experimental Farm of College of Horticulture and Forestry, Neri, Hamirpur (HP) during November, 2020 to March, 2021. Experiment was laid out in Randomized Complete Block Design with three replications at spacing of 60×10 cm in a plot size of 1.8×1.0 m accommodating 30 plants in each plot. The experiment comprised of seventeen treatment combinations of organic manures and biofertilizers.The results revealed that treatment combination of Rhizobium+PSB+FYM was best for most of the characters like days to marketable maturity (95.00 days), plant height (77.66 cm), number of root nodules plant^{-1} (27.66), number of primary branches plant^{-1} (13.40), number of pods plant^{-1} (23.13), pod length (8.43 cm), pod weight (7.78 g), number of seeds pod^{-1} (8.13), pod yield plant^{-1} (97.06 g), pod yield plot^{-1} (2.90 kg), harvest duration (27.66 days), shelling percentage (50.16%) and protein content (11.62%) followed by RDF and combination of Rhizobium+PSB+Vermicompost. The highest gross income (₹ 2,57,760 ha^{-1}), net income (₹ 1,76,720 ha^{-1}) and benefit: cost ratio (2.18) were recorded by the treatment combination of Rhizobium+PSB+FYM. Hence, biofertilizers *viz*., Rhizobium and PSB when applied along with FYM in pea cultivation, they enhance the growth, yield and quality of the produce.

KEYWORDS: Pea, biofertilizers, rhizobium, PSB, yield, quality

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1. INTRODUCTION

Pea (*Pisum sativum* L.) is an important vegetable crop grown throughout the world. It is thought to be originated in the Ethiopia, part of Europe and Asia. In India, it is cultivated mainly as cool season crop in the plains of North India and as summer vegetable in the hills (Bhardwaj et al., 2021). It is mainly utilized as vegetable, consumed as pulse, canned, processed or dehydrated (Osman et al., 2010). Fresh pods contain 7.2% proteins, 19.8% carbohydrates, 0.8% mineral matter, while dried pea grain contains 19.7% proteins, 56.6% carbohydrates, 2.1% mineral matter and 4.4% iron (Singh et al., 2015; Prats et al., 2017). Pods are smooth, dark green, 5–9 cm long containing 8 to10 seeds in single pod (Sepehya et al., 2015). The seeds may be round, angular or wrinkled depending upon type and variety (Joshi et al., 2020). Pea occupies an area of 540 thousand hectares with an annual production of 5422 thousand tonnes in India (Anonymous, 2019). Pea occupies an area of 24.37 thousand hectares with an annual production of 294.96 thousand tonnes in Himachal Pradesh (Anonymous, 2019).

The increased use of chemicals under intensive cultivation has not only contaminated the ground and surface water but has also disturbed the harmony existing among the soil, plant and microbial population. Use of inorganic fertilizer alone is injurious to soil health and soil productivity (Sokolava et al., 2011). Therefore, there is an urgent need to reduce the usage of chemical fertilizers and in turn increase in the usage of organics. Biofertilization eradicates environment pollution (Chemining wa and Vessey, 2006). A judicious use of organic manures and biofertilizers may be effective not only sustaining crop productivity and in soil health, but also in supplementing chemical fertilizers of crop (Jaipal et al., 2011). There are several reports, which show that the combined and sole application of organic manures and biofertilizers increase the yield and quality attributes in vegetables (Rather et al., 2010).

Pea being a leguminous crop, maintains soil fertility through biological nitrogen fixation in association with symbiotic *Rhizobium* prevalent in its root nodules and thus play a important role in fostering sustainable agriculture (Negi et al., 2006; Joshi and Varma, 2018). Nitrogen deficiency leads to chlorosis, reduced growth and yield (Caliskan et al., 2008). Seed inoculation with Rhizobium is known to increase nodulation, N uptake, growth and yield parameters of legume crops (Erman et al., 2011; Namvar et al., 2011). Rhizobium maintains the soil fertility along with higher crop yields (Arora et al., 2017; Kumar et al., 2015). Along with the organic method, microorganisms like PSB also use the proton-extrusion mechanism to solubilize the phosphate (Patel et al., 2020). Biofertilizer applications have shown exclusive results in pea (Rao et al., 2014). *Rhizobium* application is a very cost effective way of nitrogen management in leguminous crops. Phosphate-mobilizing microbes can mobilize the immobile forms of phosphorous (Suthar et al., 2017). Phosphate Solubilizing Bacteria enhances phosphorus in soil and further its use by plants. Seeds when inoculated with *Rhizobium* and Phosphate Solubilising Bacteria produce more pod yield as compared to the un-inoculated (Gabr et al., 2007). However the fixed phosphorus in the soil can be solubilized by Phosphate Solubilizing Bacteria which has the capacity to convert inorganic unavailable phosphorus form to available soluble forms in soil and make them available to plants (Varsha et al., 2015).

Besides this, organic manure and biofertilizers enhance crop production and sustain soil heath (Qureshi et al., 2015. Jeevamrit contains macro nutrients, micronutrients, vitamins, essential amino acids, growth promoting factors like IAA, GA and beneficial microorganisms (Palekar, 2006). Organic farming is becoming prominent among the farmers and consumers in India, bearing in mind the safety of food and being ecofriendly.

2. MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm of the Department of Vegetable Science, College of Horticulture & Forestry, Neri, Hamirpur, Himachal Pradesh, India during November, 2020 to March, 2021. Geographically, Neri is located at an altitude of 650 meters above mean sea level lying between latitude of 31°41’47.6”N and 72°28’6.3”E.The site fall sunder low hill zone of Himachal Pradesh and is 11 km away from Hamirpur city. The climate of the region is characterized as subtropical, with hot summers and mild to cool winters. Generally May and June are the hottest months whereas, December and January are coldest months. Precipitation is mostly received during monsoon period i.e. from June to September. The experiment comprised of seventeen treatments viz., FYM (20 t ha^{-1}), Vermicompost (10 t ha^{-1}), Jeevamrut (drenching @ 10%), Rhizobium, Rhizobium+FYM (20 t ha^{-1}), Rhizobium+Vermicompost (10 t ha^{-1}), Rhizobium+Jeevamrut (drenching @ 10%), PSB, PSB+FYM (20 t/ha), PSB+Vermicompost (10 t ha^{-1}), PSB+Jeevamrut (drenching @ 10%), Rhizobium+PSB,Rhizobium+PSB+FYM (20 t ha^{-1}), Rhizobium+PSB+Vermicompost (10 t ha^{-1}), Rhizobium+PSB+Jeevamrut (drenching @ 10%), RDF (25N:60P:60K kg ha^{-1}) and control. Cultivar ‘Azad Pea-1’ was employed for the present study. The experiment was laid out in Randomized Complete Block Design in three replications ina plot size of 1.80×1.0 m at a spacing of 60×10 cm accommodating 30 plants in each plot. The planting was done on 5.11.2020. The experimental field was ploughed thoroughly with the help of tractor followed by planking. Stones, pebbles and crop residues of previous crop were removed manually. The soil was brought to the fine tilth and leveled. After leveling, plots were prepared according to the layout plan. The organic manures *viz*., farmyard manure, vermicompost and recommended dose of fertilizers were applied at the time of field preparation as per the treatments in the respective plots. Recommended dose of Nitrogen, Phosphorus and Potassium @ 25:60:60 kg ha^{-1} were applied in the form of Urea (54.35 kg ha^{-1}), SSP (375 kg ha^{-1}) and MOP (100 kg ha^{-1}) as per treatments before planting of crop. Half dose of N along with full doses of P and K was applied as basal dose. Remaining dose of N was divided in two equal splits and applied at monthly interval. While, FYM @ 20 t ha^{-1} and vermicompost @ 10 t ha^{-1} were broadcasted uniformly before planting of crop as per the treatments. Seeds were inoculated with *Rhizobium* culture, Phosphate Solubilizing Bacteria culture and *Rhizobium*+Phosphate Solubilizing Bacteria culture as per treatments. 100 g of Jaggery was dissolved in 100 ml of warm water. Seeds were soaked in Jaggery solution for 15–20 minutes and seeds were dried under shade. Thereafter, these seeds were coated with *Rhizobium* culture @ 25 g kg^{-1} and Phosphate Solubilzing Bacteria @ 25 g kg^{-1} and with mixed culture of *Rhizobium* and Phosphate Solubilizing Bacteria as per the treatments. Treated seeds were dried in shade before planting. Jeevamrut @ 10% was drenched at 20 days interval and first drenching was given after 15 days after sowing. Observations were recorded on days to marketable maturity, plant height (cm), number of root nodules plant^{-1}, number of primary branches plant^{-1}, number of pods plant^{-1}, pod length (cm), pod diameter (cm), pod weight (g), number of seeds pod^{-1}, pod yield plant^{-1} (g), pod yield plot^{-1} (Kg), harvest duration (days), total soluble solids (°B) and protein content (%). Mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1984) for Randomized Complete Block Design.

3. RESULTS AND DISCUSSION

Earliness is an important parameter which indicates of early yield and ensures more profit. Data for days to marketable maturity is presented in Table 1, which varied from 95.00–103.33 days. Minimum days

Table 1: Effect of organic sources of nutrients on different characters of pea

Treatment Code	Treatment	Days to Marketable maturity	Plant height (cm)	No. of root nodules plant^{-1}	No. of primary branches plant^{-1}	No. of pods plant^{-1}	Pod length (cm)	Pod weight (g)
T_1	FYM (20 t ha^{-1})	99	65.06	17	11	16	7.8	6.44
T_2	Vermicompost (10 t ha^{-1})	102.00	64.13	17	10	16	7.9	6.21
T_3	Jeevamrut (drenching @ 10%)	100.66	66.0	18	10	14.80	7.5	6.56
T_4	Rhizobium	97	68.4	21.46	11.06	15.46	7.7	6.73
T_5	Rhizobium+FYM (20 t ha^{-1})	96.33	71.06	25.36	11.43	20.93	8.18	7.24
T_6	Rhizobium+Vermicompost(10 t ha^{-1})	98.33	66.2	23.66	10.36	19.43	7.85	6.87
T_7	Rhizobium+Jeevamrut (drenching @10%)	98.66	64.46	20.03	9.66	17.96	7.82	6.78
T_8	PSB	101.33	65.53	20.23	10.46	15.86	7.83	6.80
T_9	PSB+FYM (20 t ha^{-1})	97.00	69.80	21.20	11.26	20.56	8.11	7.18
T_{10}	PSB+Vermicompost(10 t ha^{-1})	97.66	65.03	19.06	10.73	19.30	7.79	6.50
T_{11}	PSB+Jeevamrut(drenching @ 10%)	100.00	65.60	18.73	10.40	18.53	7.61	6.22
T_{12}	Rhizobium+PSB	99.00	68.00	20.70	10.60	17.00	8.16	7.12
T_{13}	Rhizobium+PSB+FYM (20 t ha^{-1})	95.00	77.66	27.66	13.40	23.13	8.43	7.78
T_{14}	Rhizobium+PSB+Vermicompost (10 t ha^{-1})	96.33	74.63	25.03	12.33	21.83	8.13	7.69
T_{15}	Rhizobium+PSB+Jeevamrut(drenching @ 10%)	98.00	69.13	20.46	10.53	20.83	7.84	7.19
T_{16}	RDF (25 N:60P:60K kg ha^{-1})	95.66	77.03	23.30	12.83	22.63	8.36	7.74
T_{17}	Control	103.33	52.53	14.83	8.63	13.30	7.47	6.08
	Mean	98.66	67.70	20.78	10.84	18.42	7.91	6.89
	CD (p=0.05)	2.78	2.50	1.96	1.20	1.84	0.46	0.28

Table 1: Continue...

Treatment code	Treatment	Pod diameter (cm)	No. of seeds pod^{-1}	Pod yield plant^{-1} (g)	Pod yield plot^{-1} (kg)	Harvest duration (days)	Shelling percentage (%)	TSS (°B)	Protein percentage (%)
T_1	FYM (20 t ha^{-1})	1.07	7.20	66.20	1.98	20.33	44.80	13.06	10.22
T_2	Vermicompost (10 t ha^{-1})	1.12	7.13	65.66	1.96	18.66	45.50	13.36	10.10
T_3	Jeevamrut (drenching @ 10%)	1.14	7.00	51.83	1.55	18.00	44.73	13.20	9.47
T_4	Rhizobium	1.12	7.20	52.80	1.58	19.33	47.33	13.96	10.60
T_5	Rhizobium+FYM (20 t ha^{-1})	1.15	7.80	74.33	2.22	24.33	47.56	14.03	11.26
T_6	Rhizobium+ Vermicompost (10 t ha^{-1})	1.12	7.33	72.60	2.17	19.66	46.76	13.53	10.74
T_7	Rhizobium+ Jeevamrut (drenching @10%)	1.13	7.26	70.46	2.11	20.00	46.90	13.60	10.56
T_8	PSB	1.10	7.13	52.06	1.56	18.66	46.80	13.63	10.93
T_9	PSB+FYM (20 t ha^{-1})	1.14	7.53	71.00	2.13	24.33	47.40	13.93	10.31
T_{10}	PSB+Vermicompost(10 t ha^{-1})	1.13	7.20	69.66	2.08	22.00	46.46	12.90	11.18
T_{11}	PSB+Jeevamrut (drenching @ 10%)	1.09	7.00	68.10	2.04	18.66	45.13	13.03	9.62
T_{12}	Rhizobium+PSB	1.14	7.73	53.53	1.60	21.33	46.10	14.10	10.49
T_{13}	Rhizobium+PSB+FYM (20 t ha^{-1})	1.18	8.13	97.06	2.90	27.66	50.16	14.13	11.62
T_{14}	Rhizobium+PSB+ Vermicompost (10 t ha^{-1})	1.23	7.93	92.70	2.77	25.00	48.53	15.33	11.24
T_{15}	Rhizobium+PSB+ Jeevamrut(drenching @ 10%)	1.11	7.20	74.06	2.22	22.00	46.93	13.66	10.53
T_{16}	RDF (25 N:60P:60 K kg ha^{-1})	1.17	8.06	95.86	2.87	26.33	49.56	14.43	11.06
T_{17}	Control	1.03	6.63	45.70	1.36	15.66	40.00	12.30	9.49
	Mean	1.31	7.38	69.03	2.06	21.29	46.60	13.66	10.55
	CD (p=0.05)	0.07	0.73	8.84	0.26	2.98	2.43	0.61	0.20

to marketable maturity (95.00 days) were recorded in treatment T_{13}(Rhizobium+PSB+FYM) which was statistically at par with treatments *viz*., T_{16} (RDF), T_{14} (Rhizobium+PSB+Vermicompost), T_5(Rhizobium+FYM), T_9 (PSB+FYM) and T_{10} (PSB+Vermicompost) noticing 95.66 days, 96.33 days, 96.33 days, 97.00 days and 97.66 days for marketable maturity, respectively. Overall mean for days to marketable maturity was 98.66 days. Minimum days to marketable maturity recorded in treatment T_{13} (Rhizobium+PSB+FYM) might be due to increased availability of nitrogen and phosphorus with biofertilizers application *viz*., Rhizobium and Phosphate Solubilizing Bacteria.

Plant height is an important parameter for growth and yield of crop. Plant height varied from 52.53−77.66 cm. Maximum plant height (77.66 cm) was recorded by treatment T_{13} (Rhizobium+PSB+FYM) which was statistically at par with treatment T_{16} (RDF) and T_{14} (Rhizobium+PSB+Vermicompost) recording plant height of 77.03 cm and 74.63 cm respectively. Inoculation of seeds with *Rhizobium* and Phosphate Solubilizing Bacteria along with application of FYM might have improved both nitrogen and phosphorus efficiency in rhizosphere, *Rhizobium* is symbiotic nitrogen fixer and PSB is Phosphorus Solubilizer and they secrete certain organic acids and some biochemicals and ultimately resulting in moreplantheight. Similar results were observed by Negi et al. (2006) in garden pea who noticed increased plant height with co-inoculation of bio fertlizers *viz*., *Rhizobium* and PSB. Similar finding were also recorded by Gopinath and Mina (2011), Jaipaul et al. (2011), Meena et al. (2014), Singh and Kumar (2016) and Singh et al. (2016).

Treatment T_{13} (Rhizobium+PSB+FYM) observed maximum number of root nodules plant^{-1} (27.66). Overall mean for the parameter was 20.78. Seed inoculation with *Rhizobium* increased the root nodulation through better root development and enhanced nutrient availability in soil, resulting in vigorous plant growth, better flowering, fruiting and pod formation. Whereas, Phosphate Solubilizing Bacteria increased the availability of phosphorus in root zone which in term resulted in better growth and development of roots and shoots and also helped in better nodulation. So, mixed inoculation with *Rhizobium*+PSB resulted in over all development of plant, enhanced photosynthesis and production of assimilates and number of root nodules. Similar results were noticed by Negi et al. (2006) in garden pea who reported that number of root nodules increased with the application of biofertilizers *viz*., *Rhizobium* and PSB.

Number of primary branches plant^{-1} is an important growth attribute which consequently affects the yield plant^{-1}. Primary branches plant^{-1} ranged from 8.63–13.40. Maximum number of primary branches plant^{-1} (13.40) were recorded in treatment T_{13} (Rhizobium+PSB+FYM) which was statistically at par with treatment T_{16}(RDF) and T_{14} (Rhizobium+PSB+Vermicompost) noticing 12.83 and 12.33 primary branches plant^{-1}, respectively. Application of biofertilizers in soil may have helped to enhance the biological nitrogen fixation and availability of phosphorus for strong vegetative growth. Increase in accessibility of nutrients in soil, enhanced the number of primary branches plant^{-1}.

The pod bearing capacity is one of the important crop yield component. Pods plant^{-1} ranged from 13.30–23.13. Maximum number of pods plant^{-1} (23.13) were recorded in treatment T_{13} (Rhizobium+PSB+FYM). However T_{13} (Rhizobium+PSB+FYM) was statistically at par with treatment T_{16} (RDF) and T_{14} (Rhizobium+PSB+Vermicompost) observing 22.63 and 21.83 pods plant^{-1}, respectively. Due to better availability of sufficient amount of nutrients from FYM application along with composite inoculation of seeds with *Rhizobium*+PSB have improved both nitrogen and phosphorus availability in rhizosphere that ultimately enhanced availability of nutrients in soil and helped the plants to bear more number of flowers and more number of pods plant^{-1}. Similar results were noticed by Negi et al. (2006) in pea who reported that pods plant^{-1} were significantly increased by co-inoculation of biofertilizers *viz*., *Rhizobium* and PSB. Similar findings were also reported by Gopinath and Mina (2011); Meena et al. (2014), Singh et al. (2016).

Pod length is directly linked with the yield. Long pods have more number of seeds and give more yield. Pod length varied from 7.47–8.43 cm. Treatment T_{13} (Rhizobium+PSB+FYM) observed highest pod length (8.43 cm) which was statistically at par with T_{16}(RDF), T_5 (Rhizobium+FYM), T_{12} (Rhizobium+PSB), T_{14} (Rhizobium+PSB+Vermicompost) and T_9 (PSB+FYM) recording pod length of 8.36 cm, 8.18 cm, 8.16 cm, 8.13 cm and 8.11 cm, respectively. Overall mean for pod length was 7.91 cm. Composite inoculation of seed with *Rhizobium* and Phosphate Solubilizing Bacteria along with FYM enhanced both nitrogen and phosphorus in soil. *Rhizobium* is symbiotic nitrogen fixer and Phosphate solubilizing bacteria is Phosphorus Solubilizer, which ultimately increased the availability of nutrients and metabolic activity resulting in better vegetative growth. The increased vegetative growth, balanced C: N ratio and increased synthesis of carbohydrates, in turn increased the pod length. These results are in conformity with the findings of Negi et al. (2006) in garden pea who noticed increased pod length by co-inoculation of biofertilizers. Similar finding were noticed by Gopinath and Mina (2011) and Singh et al. (2016).

Values for pod diameter varied from 1.03–1.23 cm. Maximum pod diameter (1.23 cm) was recorded in treatment T_{14} (Rhizobium+PSB+Vermicompost) and was statistically at par with treatment T_{13} (Rhizobium+PSB+FYM) and T_{16} (RDF) exhibiting pod diameter of 1.18 cm and 1.17 cm respectively. Overall mean for the character was 1.31 cm. Pod weight varied from 6.08-7.78 g. Maximum pod weight (7.78 g) was recorded in treatment T_{13}(Rhizobium+PSB+FYM) which was statistically at par with treatment T_{16} (RDF), T_{14}(Rhizobium+PSB+Vermicompost), T_5 (Rhizobium+FYM), T_{15}(Rhizobium+PSB+Jeevamrut), T_9 (PSB+FYM) and T_{12} (Rhizobium+PSB)exhibiting pod weight of 7.74 g, 7.69 g, 7.24 g, 7.19 g, 7.18 g and 7.12 g respectively. Overall mean for the parameter was 6.89 g. Mixed inoculation of seeds with *Rhizobium* and Phosphate Solubilizing Bacteria along with FYM increased the availability of nutrients in soil, which that ultimately enhanced the vegetative growth of plant. Availability and uptake of more plant nutrients resulted in luxuriant vegetative growth with more photosynthetic area. The increased photosynthetic area and translocation of photosynthates in plants, accelerated the formation of more number of large-sized pods with more number of seeds per pod and resulting in increased pod weight. These finding were supported by finding of Singh et al. (2016)

Maximum number of seeds pod^{-1} (8.13) were observed in treatment T_{13} (Rhizobium+PSB+FYM) and was statistically at par with T_{16} (RDF), T_{14} (Rhizobium+PSB+Vermicompost), T_5 (Rhizobium+FYM), T_{12} (Rhizobium+PSB) and T_9 (PSB+FYM) exhibiting 8.06, 7.93, 7.80, 7.73 and 7.53 seeds pod^{-1}, respectively. While, minimum number of seeds pod^{-1} (6.63) were recorded in T_{17} (Control). Overall mean for seeds pod^{-1} was 7.38. Increase in number of seeds pod^{-1} might be due to application of *Rhizobium*, Phosphate Solubilizing Bacteria and FYM that enhanced the availability of nutrients in soil, which in turn encouraged more vegetative growth, metabolic activities and chlorophyll content and increased accumulation of more amounts of carbohydrates in the pods and thereby increasing the number of seeds pod^{-1}. Similar results were observed by Gopinath and Mina (2011), Meena et al. (2014) and Singh et al. (2016) inpea.

Data for pod yield plant^{-1} varied from 45.70–97.06 g. Highest pod yield plant^{-1} (97.06 g) was recorded by treatment T_{13}(Rhizobium+PSB+FYM) and was statistically at par with T_{16}(RDF) and T_{14} (Rhizobium+PSB+Vermicompost) observing 95.86 g and 92.70 g pod yield plant^{-1}, respectively. Overall mean for the parameter was 69.03 g. Treatment T_{13} recorded increase in pod yield and this might be due to better as similation of photosynthates through added biofertilizers which resulted in the improvement of soil physical, chemical and biological properties, which in turn helped in better nutrient absorption by the plant and better yield. These results are in line with the finding of Singh et al. (2019) inpea. Pod yield plot^{-1} varied from 1.36–2.90 kg. Treatment T_{13} (Rhizobium+PSB+FYM) recorded maximum pod yield plot^{-1} (2.90 kg) and was statistically at par with T_{16} (RDF) and T_{14} (Rhizobium+PSB+Vermicompost) observing pod yield of 2.87 kg and 2.77 kg plot^{-1}, respectively. Overall mean for pod yield plot^{-1} was 2.06 kg. Composite inoculation of *Rhizobium* and Phosphate Solubilizing Bacteria might have increased the growth, yield attributes and ultimately the yield, due to increased nitrogenase activity and available phosphorus status in soil as reported by Negi et al. (2006) in garden pea. Similar finding were also reported by Jaipaul et al. (2011), Gopinath and Mina (2011) and Sharma and Chauhan (2011).

Harvest duration ranged from 15.66–27.66 days. Maximum harvest duration (27.66 days) was recorded in treatment T_{13} (Rhizobium+PSB+FYM) and was statistically at par with treatment T_{16} (RDF), T_{14} (Rhizobium+PSB+Vermicompost), T_5 (Rhizobium+FYM) and T_9 (PSB+FYM) recording 26.33 days, 25.00 days, 24.33 days and 24.33 days, respectively. Overall mean for the character was 21.29 days. Shelling percentage is an important character in pea which determines the yield of pea. More the length of pods, more will be the number of seeds per pods and ultimately shelling percentage will be increased. Shelling percentage varied from 40.00–50.16%. Visualization of data in table 1, indicated that treatment T_{13} (Rhizobium+PSB+FYM) recorded higher (50.16%) shelling percentage. Treatment $T_{13}$was statistically at par with T_{16} (RDF) and T_{14} (Rhizobium+PSB+Vermicompost) noticing 49.56% and 48.53% shelling percentage, respectively. Overall mean for shelling percentage was 46.60%.

Total soluble solids measure the amount of total soluble solids present in the unit volume of solution. Total soluble solids range varied from 12.30–15.33 °Brix. Treatment T_{14} (Rhizobium+PSB+Vermicompost) recorded maximum total soluble solids (15.33 °Brix) and was statistically at par with T_{16} (RDF), T_{13} (Rhizobium+PSB+FYM), T_{12}(Rhizobium+FYM)and T_5(Rhizobium+FYM) noticing total soluble solids of 14.43 °Brix, 14.13 °Brix, 14.10 °Brix, and 14.03 °Brix respectively. Overall mean for the character was 13.66 °Brix.Composite inoculation of seeds with *Rhizobium* and Phosphate Solubilizing Bacteria was beneficial in enhancing total soluble solids due to higher nitrogen fixation in nodules and leading to increased availability of nitrogen and solubility of phosphorus resulted in enhanced totalsoluble solids in pods of pea.

Maximum protein content (11.62%) was recorded in treatment T_{13} (Rhizobium+PSB+FYM) and was statistically at par with T_5 (Rhizobium+FYM), T_{14}(Rhizobium+PSB+Vermicompost), T_{10} (PSB+Vermicompost) and T_{16}(RDF) recording11.26%, 11.24%, 11.18% and 11.06% of protein content, respectively. Overall mean for protein content was 10.55%. Protein content of grain is essentially a manifestation of nitrogen content.

Perusal of data given in Table 2, indicated that maximum gross income (₹ 2,57,760 ha^{-1}) was recorded in treatment T_{13} (Rhizobium+PSB+FYM) and minimum gross income (₹ 1,20,880 ha^{-1}) was observed in treatment T_{17} (Control) whereas, maximum total cost of cultivation (₹ 1,45,040 ha^{-1}) was recorded in treatment T_{14} (Rhizobium+PSB+Vermicompost) and minimum total cost of cultivation (₹ 44,140 ha^{-1}) was recorded in treatment T_{17} (Control). Net income (₹ 1,76,720 ha^{-1}) was recorded maximum in treatment T_{13}(Rhizobium+PSB+FYM) and minimum (₹ 30,080 ha^{-1}) was recorded in treatment T_2 (Vermicompost). Highest benefit: cost ratio (2.18) was recorded in treatment T_{13} (Rhizobium+PSB+FYM) and minimum (0.20) was recorded in treatment T_2 (Vermicompost). Similar results were recorded by Gopinath and Meena (2011) and Singh et al. (2016).

Table 2: Effect of organic sources of nutrients on economics of pea cultivation

Treatment code	Treatment	Total pod yield (t ha^{-1})	Total cost of cultivation (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio
T_1	FYM (20 t ha^{-1})	8.80	80,140	1,76,000	95,860	1.19
T_2	Vermicompost (10 t ha^{-1})	8.71	1,44,140	1,74,200	30,080	0.20
T_3	Jeevamrut (drenching @ 10%)	7.01	62,640	1,40,260	77,620	1.23
T_4	Rhizobium	7.02	44,640	1,40,440	95,800	2.14
T_5	Rhizobium+FYM (20 t ha^{-1})	9.86	80,640	1,97,320	1,16,680	1.44
T_6	Rhizobium+Vermicompost (10 t ha^{-1})	9.64	1,44,640	1,92,880	48,240	0.33
T_7	Rhizobium+Jeevamrut (drenching @ 10%)	9.37	63,640	1,87,540	1,24,400	1.97
T_8	PSB	6.93	44,540	1,38,660	94,120	2.11
T_9	PSB+FYM (20 t ha^{-1})	9.46	80,540	1,89,320	1,08,780	1.35
T_{10}	PSB+Vermicompost (10 t ha^{-1})	9.24	1,44,540	1,84,880	40,340	0.27
T_{11}	PSB+Jeevamrut(drenching @ 10%)	9.06	63,040	1,81,320	1,18,280	1.87
T_{12}	Rhizobium+PSB	7.11	45,040	1,42,220	97,180	2.15
T_{13}	Rhizobium+PSB+FYM (20 t ha^{-1})	12.88	81,040	2,57,760	1,76,720	2.18
T_{14}	Rhizobium+PSB+Vermicompost (10 t ha^{-1})	12.31	1,45,040	2,46,220	1,01,180	0.69
T_{15}	Rhizobium+PSB+Jeevamrut(drenching @ 10%)	9.86	63,540	1,97,320	1,33,780	2.10
T_{16}	RDF (25 N:60P:60K kg ha^{-1})	12.75	86,533	2,55,100	1,68,567	1.94
T_{17}	Control	6.04	38,640	1,20,880	76,740	1.00

Pea pods were sold @ ₹ 20 kg^{-1} (1 US$=₹ 73.2065 during harvesting month i.e. March, 2021)

4. CONCLUSION

Treatment combination of Rhizobium+PSB+FYM was found superior for most of growth and yield parameters and quality parameters followed by treatment RDF and Rhizobium+PSB+Vermicompost. Highest gross income, net returns and benefit: cost ratio were observed in treatment combination of Rhizobium+PSB+FYM. Therefore, combination of biofertilizersviz., *Rhizobium* and PSB with FYM not only reduces the cost of production and but also increases the profit of the farmer.

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