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Effect of integrated nutrient management on yield, quality and economic aspects of pea (*Pisum sativum* L.) in rainfed condition of Himachal Pradesh

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Abstract

A field experiment was conducted during *Rabi* season of 2023-24 at Chamelti Agriculture Farm, Shoolini University of Biotechnology and Management Sciences Solan (H.P.). Ten treatments of integrated nutrient management comprising T₁ Control, T₂ 50% RDF, T₃ 75% RDF, T₄ 100% RDF (20:60:20 kg ha⁻¹ N:P:K), T₅ 50% RDF + PSB, T₆ 75% RDF + PSB, T₇ 100% RDF + PSB, T₈ 50% RDF + FYM 1.0 tha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄, T₉ 75% RDF + FYM 1.0 tha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄, T₁₀ 100% RDF + FYM 1.0 tha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ and Peas Maximum 3636 Variety of Pea was tested in Randomized Block Design (RBD) with three replications. On the basis of experimental findings, it can be concluded that applying of (T₁₀) 100% RDF + FYM 1.0 tha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ resulted in the highest growth parameters (plant height, number of leaves per plant, number of branches per plant, accumulation of dry matter), yield attributes (number of pods per plant, number of grains per pod, and seed index), yield (grains, stover and biological yield), nutrient uptake, and quality parameters compared to the other treatments. Furthermore, it increases the B:C ratio, net returns, and gross returns.

Keywords: *Rhizobium*, PSB, yield, quality and economics

Introduction

The pea (*Pisum sativum* L.) is a cool-season crop and member of the *leguminosae* family. It is quite nutrient-dense, with a 7.2 g amount of protein, 0.1 g fat, 15.9 g carbohydrates, 93 Kcal energy, 20 mg calcium, 139 mg phosphorus, 1.5 mg iron, 83 microgram carotene, zero point 25 mg thiamine, 0.01 mg riboflavin, 9 mg vitamin C and 0.8 mg niacin whereas dry pea contains 16.0% moisture, 19.7 g protein, 1.1 g fat 4.5 g fibre, 56.5 g carbohydrates, 315 Kcal energy, 75 mg calcium, 298 mg phosphorus, 7.05 mg 39 microgram carotene, 0.47 mg thiamine, 0.19 mg riboflavin and 3.4 mg niacin respectively (Chaudhary *et al.*, 2009) [3]. Pea maintains soil fertility through biological nitrogen fixation in association with symbiotic *Rhizobium* prevalent in its root nodules and thus plays a vital role in fostering sustainable agriculture (Negi *et al.*, 2006) [14]. Pea is grown on 71.90 million hectares, produced 146.42 million tons and yield 2036 kg ha⁻¹ worldwide, respectively. The Canada, Russia, China, USA and India are the leading countries that generate the most peas. Pea is grown on 6.17 million hectares, produces 7.97 mt and yield 1292 kg ha⁻¹, respectively in India (FAO, 2020) [5]. Himachal Pradesh is fifth leading pea producing state of India with total production of 294.96 thousand metric ton. In the Solan District of Himachal Pradesh total area and production of vegetable pea is about 510 ha, 5275 mt, respectively (APMC, 2018-19). Integrated Nutrient Management is a comprehensive strategy for preserving soil fertility and plant nutrient supply at their optimal levels in order to maintain crop productivity at the targeted level Mahajan and Gupta (2009) [5]. In order to maintain soil health, improve the environment, and increase crop productivity over the long term, this system seeks to strike a balance between the judicious use of chemical fertilizers and organic manures, compost, well-decomposed crop residues, bio fertilizers, legumes in cropping systems, and other locally available nutrient sources (Mahajan and Sharma, 2005) [7].

A crucial nutrient for boosting pulse productivity, phosphorus is the primary cause of low productivity (Sarawgi *et al.*, 2005) [17]. However, in addition to promoting the biological fixation of atmospheric nitrogen and enhancing nitrogen and phosphorus availability, biofertilizers also play a significant role (Bhat *et al.*, 2013) [1]. Organic manures like FYM is the rich source of organic matter, humus and nutrients, which offer several benefits for the association of microorganisms (Singh *et al.*, 2017) [21]. The present hypothesis on pea is constituted due to declining the fertility status of the soil and continuous application of chemical fertilizers affect soil health and pollute ground water. Therefore, keeping the above facts in view of the above considerations the present investigation was carried out.

Materials and Methods

A field experiment was conducted during Rabi season of 2023-24 at Chamelti Agriculture Farm, Shoolini University of Biotechnology and Management Sciences Solan (H.P.) to study the. Geographically, Agriculture Farm Chamelti is lies in the heart of Solan District of Himachal Pradesh and situated at 30 km away from Solan city at an elevation of 1,270 meters above mean sea level lying between latitude 30° 85'67.38 N and longitude 77° 13'20.38 E. The soil of experimental field was well drained and medium in organic carbon and available nitrogen while, high in phosphorus and potassium. The recommended dose (100% NPK 20:60:20 kg ha⁻¹) as per the treatments was applied as a basal dose (at the time field preparation) during last ploughing. The crop was sown on dated 11th October 2024 at a spacing of 40 cm row to row and 10 cm from plant to plant. For taking observations point of view, the five plants were randomly selected and tagged in each net plot area. The growth parameters were recorded from the five tagged plant in each treatment and then average value was computed for consideration for final data. The plant height was measured from the tagged plants by using the meter scale from ground level to tip of the plant and then average value was computed for final data. Total number of branches and leaves per plant (five tagged plants) was counted manually and then average value was taken for final data. For dry matter accumulation five plants was harvested from the ground levels thereafter sun dried for few days and then oven dry at 65±5 °C till constant weight was achieved and finally average value was used for representation of data in the Table. The yield attributing characteristics were recorded from the tagged plants and then average value was computed for consideration of final data. At the time of harvesting, firstly border row was removed from each plot and then net plot area was left over in the field for sun dry for 5 days. After sun drying, the biological yield of pea was measured in each plot (net plot area) by using the weighing balance and then grains are removed by manual threshing. Finally yield converted into q ha⁻¹ by multiplying with appropriate conversion factor. The total soluble solids (TSS) were estimated with the help of Hand-Held Refractometer under room temperature conditions by using the method given by A.O.A.C. 1970. The protein content percent was estimated by using the data of nitrogen content percent in grains (Kjeldhal method). Thus, the protein yield was calculated by using the formula given below:

$$\text{Protein yield (kg ha}^{-1}\text{)} = \text{Protein content (\%)} \times \text{Grain yield (q ha}^{-1}\text{)}$$

The analysis of cost of cultivation is an important aspect which decides the option for the growers to choose the treatment combination according to their investment capacity and production of crops. The total cost was calculated by adding the

expenditure incurred in all kind of operation as per treatment on per hectare basis in terms of Rs. ha⁻¹. The gross returns, net returns and B:C ratio was computed by using the formula given below:

$$\text{Gross returns (Rs. ha}^{-1}\text{)} = \{\text{Grain yield} \times \text{Price}\} + \{\text{Stover yield} \times \text{Price}\}$$

$$\text{Net returns (Rs. ha}^{-1}\text{)} = \text{Gross returns} - \text{Cost of cultivation}$$

$$\text{B:C ratio} = \text{Net returns} / \text{Cost of cultivation}$$

Results and Discussion

Growth

Among the Integrated Nutrient Management treatments, significantly higher plant height (52.30 cm), number of branches per plant (40.43), number of branches per plant (10.60) and dry matter production (12.87 g m⁻²) was recorded under (T₁₀) 100% RDF + FYM 1.0 tha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ which is being exhibited statistically at par with treatments getting (T₉) 75% RDF + FYM 1.0 t ha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄, (T₇) 100% RDF + PSB and (T₈) 50% RDF + FYM 1.0 tha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄. The lowest value of crop growth parameters were recorded under the treatment (T₁) that was absolute control. This might be due to applying the full prescribed dosage of nutrients, which promotes cell division, elongation, and chlorophyll production. The use of FYM aids in mineralization, which enhances the soil's physical condition and gradually releases nutrients over an extended period of time. *Rhizobium* and PSB inoculation of seeds aids in the fixation of nitrogen and further solubilization of fixed phosphate into soluble form, both of which support crop development and growth. Additional zinc can be added by zinc sulphate. Zinc is a necessary component of enzymes and controls hormone function, which supports plant growth and development. Additionally, it is crucial for the manufacture of IAA, controlling the concentration of auxin in plants as well as other physiological and biochemical processes, and initiating primordia these results are in line with Rather *et al.* (2010) [15], Mishra *et al.* (2010) [10] and Metha *et al.* (2016) [9].

Yield attributes and yield

Data related to yield attributing characteristics of pea showed that significantly higher number of pods per plant (12.20) and number of grains per pod (9.60) was recorded with application of (T₁₀) 100% RDF + FYM 1.0 tha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ followed by (T₉) 75% RDF + FYM 1.0 tha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄, (T₇) 100% RDF + PSB and (T₄) 100% RDF (20:60:20 kg ha⁻¹ N:P:K). Seed index of pea was did not differed significantly due to Integrated Nutrient Management practices and varied from 12.89 to 13.50 g. Whereas, the least number of pods per plant and number of grains per pod was recorded under (T₁) Control. Among the treatments, (T₁₀) 100% RDF + FYM 1.0 t ha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ produced the highest grain yield (14.50 q ha⁻¹), stover yield (18.09 q ha⁻¹), biological yield (32.59 q ha⁻¹) and harvest index (44.52%) followed by (T₉) 75% RDF + FYM 1.0 tha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄, (T₇) 100% RDF + PSB, and (T₈) 50% RDF + FYM 1.0 tha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄. The higher accumulation of photosynthesis from source to sink with full dosage NPK fertilizer may be the cause of this rise in the quantity of grains per pod and pods per plant. Growth-promoting chemicals such auxins, gibberellins, and cytokines were being promoted by double seed inoculation with *Rhizobium* and PSB and additional application of zinc. These compounds may enhance plant growth and encourage microbial proliferation. Increased phosphorus availability by seed inoculation with PSB promotes root

development. Increased root development extracts more water from the soil's deeper layers, which eventually affects the pea production and its contributing traits. The crop's supply of phosphorus and nitrogen as well as the enhanced solubilization of mineral phosphates and other nutrients may be the cause of the cumulative impact. These results are corroborated with the Negi *et al.* (2007) ^[13], Mishra *et al.* (2010) ^[10], Sharma and Chauhan (2011) ^[20], Dubey and Datt (2014) ^[4], Mishra and Mahapatra (2016) ^[11] and Bunker *et al.* (2018) ^[2].

Quality parameters

Amongst the treatments, significantly maximum TSS (15.42°Brix), protein content percentage in grains (24.38%) and protein yield of pea (353.42 kg ha⁻¹) was resulted in the grains of pea with fertilization of (T₁₀) 100% RDF + FYM 1.0 t ha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ which is closely followed by treatments received (T₉) 75% RDF + FYM 1.0 t ha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄, (T₇) 100% RDF + PSB and (T₈) 50% RDF + FYM 1.0 t ha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄. The increased Total Soluble Solid in grains of pea with application of manures, fertilizers and biofertilizers in combination significantly influenced the total soluble solids of pea which might be due to the higher availability of phosphorus which is an important constituent of ADP, ATP and other high energy compounds. Protein content percent and protein yield of pea was increased with application of (T₁₀) 100% RDF + FYM 1.0 t ha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ might be due to the improvement in protein content of pea with the addition of chemical fertilizers, organics manures and seed inoculation with *Rhizobium* may improve the availability of nitrogen. On the other hand, added organic manures play an important role in synthesis of protein by enhancing the availability of N and S through mineralization,

which help in formation of sulphur containing amino acids. Further addition of zinc through foliar application increased the amino acid synthesis and N-metabolism, which has drastically, increased the rate of protein synthesis and consequently, the grain protein content and protein yield. These results are corroborated by Negi *et al.* (2007) ^[13]; Sepehya *et al.* (2015) ^[18]; Sharma and Thakur (2016) ^[19]; Sangma *et al.* (2018) ^[16].

Economics

Amongst the treatments, Maximum cost of cultivation (Rs. 54966 ha⁻¹), gross returns (Rs. 99699 ha⁻¹), net returns (Rs. 44732 ha⁻¹) and B:C ratio (0.81) of pea was recorded with application of (T₁₀) 100% RDF + FYM 1.0 t ha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ followed by (T₉) 75% RDF + FYM 1.0 t ha⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ and (T₇) 100% RDF + PSB. However, minimum cost of cultivation (Rs. 45217 ha⁻¹), gross returns (Rs. 43201 ha⁻¹), net returns (Rs. -2015 ha⁻¹) and B: C ratio (-0.04) was recorded under (T₁) Control. The net returns and B: C ratio was found to be negative, which might be attributed to naturally high moisture in the crop field during the early stages, which impeded crop growth and development. Naturally, excessive moisture seemed in experimental fields, maybe due to a lack of sunlight throughout the crop season caused by the shadowing effect of *Toona ciliata* and *Pyrus pashia* trees. Furthermore, the leaf shattering of these trees creates a layer on the soil surface similar to mulch, which was the primary reason of increased natural moisture in the crop fields. Increased excessive moisture may also induce wilt disease (*Fusarium oxysporum* f. sp. pisi), which may influence crop growth, development and production, which is why net returns and the B:C ratio was negative Mishra *et al.* (2010) ^[10], Mukherjee (2016) ^[12] and Kumari *et al.* (2022) ^[6].

Table 1: Growth parameters of pea as influenced by Effect of Integrated Nutrient Management practices

Treatments	Crop growth characters			
	Plant height (cm)	No. of leaves (plant ⁻¹)	No. of branches (plant ⁻¹)	Dry matter (g plant ⁻¹)
T ₁ Control	32.6	29.90	7.87	6.29
T ₂ 50% RDF	38.2	32.13	8.47	7.30
T ₃ 75% RDF	40.4	33.07	8.93	7.64
T ₄ 100% RDF (20:60:20 kg ha ⁻¹ N:P:K)	41.9	35.60	9.2	8.41
T ₅ 50% RDF + PSB	40.6	34.00	9.07	7.79
T ₆ 75% RDF + PSB	40.7	34.80	9.13	8.01
T ₇ 100% RDF + PSB	46.6	36.87	9.87	10.84
T ₈ 50% RDF + FYM 1.0 t ha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	43.0	36.73	9.80	10.62
T ₉ 75% RDF + FYM 1.0 t ha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	47.0	37.57	10.07	11.32
T ₁₀ 100% RDF + FYM 1.0 t ha ⁻¹ + <i>Rhizobium</i> 10 ml kg ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	52.3	40.43	10.60	12.87
SE(m)±	3.3	1.89	0.36	0.88
CD (p = 0.05)	9.5	5.46	1.05	2.54

Table 2: Effect of integrated nutrient management on yield attributes of Pea

Treatments	Yield attributes		
	No. of pods plant ⁻¹	No. of grains pod ⁻¹	Seed Index (g)
T ₁ Control	5.27	5.93	12.89
T ₂ 50% RDF	6.33	6.07	12.27
T ₃ 75% RDF	7.27	6.00	12.40
T ₄ 100% RDF (20:60:20 kg ha ⁻¹ N:P:K)	9.33	7.00	13.51
T ₅ 50% RDF + PSB	8.73	6.27	12.42
T ₆ 75% RDF + PSB	9.13	6.60	12.60
T ₇ 100% RDF + PSB	10.13	7.20	13.37
T ₈ 50% RDF + FYM 1.0 t ha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	9.87	7.07	13.25
T ₉ 75% RDF + FYM 1.0 t ha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	11.00	7.73	13.28
T ₁₀ 100% RDF + FYM 1.0 t ha ⁻¹ + <i>Rhizobium</i> 10 ml kg ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	12.20	9.60	13.50
SE(m)±	0.26	0.18	0.35
CD (p = 0.05)	0.75	0.51	NS

Table 3: Effect of Integrated Nutrient Management treatments on yield (grain, stover and biological) and harvest index of pea

Treatments	Yield (q ha ⁻¹)			Harvest index (%)
	Grain	Stover	Biological	
T ₁ Control	6.20	9.67	15.87	39.06
T ₂ 50% RDF	7.31	11.16	18.47	39.58
T ₃ 75% RDF	7.78	11.50	19.28	40.35
T ₄ 100% RDF (20:60:20 kg ha ⁻¹ N:P:K)	9.06	12.17	21.24	42.68
T ₅ 50% RDF + PSB	8.01	11.65	19.66	40.76
T ₆ 75% RDF + PSB	8.26	11.80	20.06	41.19
T ₇ 100% RDF + PSB	11.21	14.60	25.81	43.42
T ₈ 50% RDF + FYM 1.0 tha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	10.74	14.28	25.02	42.92
T ₉ 75% RDF + FYM 1.0 tha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	12.67	15.98	28.65	44.19
T ₁₀ 100% RDF + FYM 1.0 tha ⁻¹ + <i>Rhizobium</i> 10 ml kg ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	14.50	18.09	32.59	44.52
SE(m)±	0.45	0.61	1.05	0.36
CD (p = 0.05)	1.31	1.77	3.03	1.05

Table 4: Effect of Integrated Nutrient Management on quality parameters of pea

Treatments	Qualitative traits		
	TSS (°Brix)	Protein content (%)	Protein Yield (kg ha ⁻¹)
T ₁ Control	13.24	19.58	121.55
T ₂ 50% RDF	13.55	20.21	147.82
T ₃ 75% RDF	13.84	20.83	162.22
T ₄ 100% RDF (20:60:20 kg ha ⁻¹ N:P:K)	14.41	22.29	202.12
T ₅ 50% RDF + PSB	13.98	21.46	171.84
T ₆ 75% RDF + PSB	14.13	21.67	178.95
T ₇ 100% RDF + PSB	14.54	23.96	268.33
T ₈ 50% RDF + FYM 1.0 tha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	14.50	23.13	248.74
T ₉ 75% RDF + FYM 1.0 tha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	14.93	24.17	306.95
T ₁₀ 100% RDF + FYM 1.0 tha ⁻¹ + <i>Rhizobium</i> 10 ml kg ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	15.42	24.38	353.42
SE(m)±	0.11	0.35	12.51
CD (p = 0.05)	0.33	1.00	36.19

Table 5: Economics (Rs. ha⁻¹) of pea as influenced by integrated nutrient management

Treatments	Economics (Rs. ha ⁻¹)			B:C ratio
	Cost of Cultivation	Gross returns	Net returns	
T ₁ Control	45217	43201	-2015	-0.04
T ₂ 50%RDF	48827	50862	2034	0.04
T ₃ 75% RDF	50633	53999	3366	0.07
T ₄ 100% RDF (20:60:20 kg ha ⁻¹ N:P:K)	52437	62563	10126	0.19
T ₅ 50% RDF + PSB	48971	55582	6610	0.14
T ₆ 75% RDF + PSB	50777	57210	6432	0.13
T ₇ 100% RDF + PSB	52581	77225	24643	0.47
T ₈ 50% RDF + FYM 1.0 tha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	51212	74115	22903	0.45
T ₉ 75% RDF + FYM 1.0 tha ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	53017	87150	34133	0.64
T ₁₀ 100% RDF + FYM 1.0 tha ⁻¹ + <i>Rhizobium</i> 10 ml kg ⁻¹ + PSB 10 ml kg ⁻¹ + 0.5% ZnSO ₄	54966	99699	44732	0.81
SE(m)±	-	3116	3116	0.08
CD (p = 0.05)	-	9013	9013	0.23

Conclusion

On the basis of experimental findings, it can be concluded that applying of (T₁₀) 100% RDF + FYM 1.0 tha⁻¹ + *Rhizobium* 10 ml kg⁻¹ + PSB 10 ml kg⁻¹ + 0.5% ZnSO₄ resulted in the highest crop growth parameters (plant height, number of leaves per plant, number of branches per plant and dry matter accumulation), yield attributes (number of pods per plant, number of grains per pod, and seed index), yield (grains, stover and biological yield) and quality parameters as compared to the other treatments. Furthermore, it increases the B:C ratio, net returns and gross returns.

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