



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(8): 1037-1048
Received: 17-06-2026
Accepted: 20-07-2026

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Effect of integrated nutrient management on growth and yield of field pea (*Pisum Sativum* L.)

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i8m.6381>

Abstract

The present investigation entitled “Influence of Integrated Nutrient Management of Yield Potential of Field Pea (*Pisum Sativum*)” was done to understand the effect of Integrated Nutrient Management on growth and yield of pea. The investigation was carried out at Field of Agronomy Department, School of Agriculture Research and Technology, Sardar Patel University, Balaghat, (M.P.) during the *Kharif* season of 2023. The experiment was laid out in Randomized Block Design (RBD) with 22 treatments comprising three replications each. The treatment combination comprised T0;-Control, T1;-Vermicompost, T2;-FYM, T3;-RDF, T4;-Rhizobium+FYM (100%), T5;-Rhizobium+FYM (75%), T6;-Rhizobium+ Vermicompost (100%), T7;-Rhizobium+ Vermicompost (75%), T8;-Rhizobium+ Nitrogen (100%), T9;-Rhizobium+ Nitrogen (75%), T10;-PSB+FYM (100%), T11;-PSB+FYM (75%), T12;-PSB+ Vermicompost (100%), T13;-PSB+Vermicompost (75%), T14;-PSB+Nitrogen (100%), T15;-PSB+Nitrogen (75%), T16;-Rhizobium+PSB+FYM (100%), T17;-Rhizobium+PSB+FYM (75%), T18;- Rhizobium+PSB+ Vermicompost (100%), T19;-Rhizobium+PSB+ Vermicompost (75%), T20;-Rhizobium+PSB+ Nitrogen (100%), T21;-Rhizobium+PSB+ Nitrogen (75%), T22;-RDF. The results of this study clearly indicate that the T20;-Rhizobium+PSB+ Nitrogen (100%) significantly improves the growth and yield of pea. Among all treatments, the T20;-Rhizobium+PSB+ Nitrogen (100%) treatment (T₁) consistently out performed others, yielding the tallest plants, maximum number of branches, and superior seed and yields. Notably, T₁ achieved the highest seed yield per plant (69.93 grams), seed yield per plot (3.20 kg), and test weight (10.47 grams), demonstrating its superior nutrient provision that supported robust plant growth and optimal seed production. Organic treatments, particularly T₁₁ (33.33% FYM + 33.33% VC + 33.33% PM), also demonstrated impressive results, showing nearly comparable performance to the inorganic treatment in terms of growth parameters like plant height (100.98 cm at 60 DAS), number of branches per plant (27.56 at 60 DAS); (14.00) nodules per plant; seed yield per plant (69.70 grams); test weight (10.20 grams) and 20.69 q/ha of seed yield. The integrated nutrient supply from farmyard manure (FYM), vermicompost (VC), and poultry manure (PM) in T₁₁ enhanced soil fertility, microbial activity, and nutrient availability, leading to improved growth and productivity. T₁₁ also recorded the highest harvest index (29.51%), reflecting efficient utilization of biomass for seed production. From a cost-benefit perspective, T₁ and T₁₁ showed the highest net returns and benefit-cost ratios, making them the most economically viable options for pigeon pea cultivation. Thus, a balanced approach incorporating both inorganic and organic fertilizers can effectively enhance productivity and profitability in pigeon pea farming. Therefore, in addition to RDF, the incorporation of 33.33% FYM + 33.33% VC + 33.33% PM and 50% VC + 50% FYM is recommended to enhance crop productivity and improve the overall performance of pigeon pea in Balaghat (M.P.) conditions.

Keywords: Benefit cost ratio, harvest index, vermicompost, poultry manure Pigeon Pea

1. Introduction

1.1 Importance of Field Pea

Field pea (*Pisum sativum* L.) is an important leguminous crop cultivated for its food, nutritional and agricultural value. It is considered one of the important pulse crops and is consumed in different forms as a source of plant-based food. The crop is particularly valuable because its seeds contain substantial amounts of protein and other nutrients required for human nutrition. Field pea also forms an important component of cropping systems because, like other legumes, it has the ability to establish a symbiotic association with *Rhizobium* bacteria and contribute to biological nitrogen fixation. The productivity of field pea is influenced by several factors, including soil fertility, nutrient availability, water management, climatic conditions and crop management

practices. Among these factors, adequate and balanced nutrient supply is particularly important because nutrients directly influence vegetative growth, reproductive development and final seed production. Proper nutrient management promotes healthy plant development, increases branching and pod formation and supports better seed filling.

Field pea is also important from the perspective of sustainable agriculture. The inclusion of legumes in cropping systems can contribute to soil fertility and reduce dependence on external nitrogen inputs. However, the extent of these benefits depends on effective crop management and appropriate nutrient availability. Therefore, improving nutrient management practices in field pea can contribute to both higher crop productivity and more sustainable agricultural production.

1.2 Nutritional and Agricultural Importance

Field pea is nutritionally important because its seeds provide protein, carbohydrates, vitamins and minerals. It also contains important amino acids such as lysine and tryptophan, which contribute to its dietary value. The nutritional composition of field pea makes it an important component of diets where pulses are used as a major source of plant protein.

From an agricultural perspective, field pea has importance beyond seed production. As a leguminous crop, its association with nitrogen-fixing bacteria can improve the availability of nitrogen within the crop system. The biological nitrogen fixation process is particularly important because nitrogen is one of the major nutrients required for plant growth. Adequate nitrogen availability supports leaf development, photosynthetic activity, biomass accumulation and reproductive growth.

The yield of field pea is determined by several yield-contributing characters. Important parameters include plant height, number of branches per plant, number of pods per plant, number of seeds per pod, seed weight and final seed yield. In the present study, integrated nutrient management produced marked differences in these yield attributes. The maximum number of pods per plant and seeds per pod was recorded under the combination of *Rhizobium* + PSB + 100% nitrogen, indicating the importance of balanced nutrient availability for reproductive development.

Thus, appropriate nutrient management is essential for realizing the production potential of field pea. Improvement in nutrient availability during different stages of crop growth can support better vegetative development, flowering, pod formation and seed filling, ultimately resulting in improved productivity.

1.3 Problems Associated with Excessive Chemical Fertilizer Use

Inorganic fertilizers are widely used in modern agriculture because they provide nutrients in readily available forms and can produce rapid responses in crop growth. Nitrogen fertilizers, in particular, play an important role in promoting vegetative development and improving crop productivity. However, dependence on chemical fertilizers alone may not always be sufficient to maintain long-term soil productivity.

Continuous application of fertilizers without proper consideration of soil nutrient status can result in nutrient imbalance and inefficient nutrient utilization. Excessive or inappropriate fertilizer application may also adversely influence soil properties and the biological environment of the soil. In addition, increasing dependence on inorganic fertilizers can increase the cost of crop production and may not provide a complete solution for maintaining soil health.

The problem is therefore not the use of inorganic fertilizers itself, but their excessive or imbalanced use. An efficient nutrient-

management strategy should provide nutrients according to crop requirements while maintaining the productive capacity of the soil. This has created increasing interest in approaches that combine inorganic fertilizers with organic manures and beneficial microorganisms.

For field pea, such an approach is particularly relevant because the crop has a natural association with nitrogen-fixing microorganisms. Efficient integration of chemical fertilizers with biofertilizers can potentially improve nutrient-use efficiency and reduce the requirement for unnecessarily high fertilizer inputs. The present investigation therefore included different levels and combinations of nitrogen with *Rhizobium*, PSB, FYM and vermicompost to evaluate their relative effects on crop performance.

1.4 Role of Organic and Biofertilizers

Organic manures and biofertilizers are important components of sustainable nutrient management. Farmyard manure (FYM) and vermicompost supply nutrients while contributing organic matter to the soil. The addition of organic materials can improve the soil environment and support better nutrient availability. Their beneficial effects can become more pronounced when they are integrated with inorganic nutrient sources.

Biofertilizers are living microbial preparations that can improve nutrient availability and support plant growth through biological processes. Among the important biofertilizers used in legume production, *Rhizobium* has a major role because of its ability to form nodules on legume roots and fix atmospheric nitrogen. Effective nodulation can increase nitrogen availability to the plant and contribute to improved plant growth.

Phosphate-solubilizing bacteria (PSB) represent another important group of beneficial microorganisms. A considerable proportion of soil phosphorus may occur in forms that are not readily available to plants. PSB can help in converting relatively unavailable phosphorus into more accessible forms, thereby improving phosphorus nutrition. The thesis discussion suggests that PSB may improve phosphorus availability and nutrient uptake and consequently contribute to better growth and yield.

The combined application of *Rhizobium* and PSB can therefore provide complementary benefits. *Rhizobium* contributes to nitrogen nutrition through biological fixation, whereas PSB improves phosphorus availability. When these biofertilizers are combined with an appropriate level of nitrogen fertilizer, their effects may be reflected in improved plant growth, flowering, pod formation and seed development.

The experimental results support this concept. Treatments involving *Rhizobium* and PSB together with nitrogen generally performed better than several individual nutrient treatments. The combination of *Rhizobium* + PSB + 100% nitrogen recorded the highest number of pods per plant and seeds per pod, while the 75% nitrogen combination also performed strongly.

1.5 Concept of Integrated Nutrient Management

Integrated Nutrient Management (INM) refers to the combined and balanced use of inorganic fertilizers, organic nutrient sources and biofertilizers for maintaining adequate nutrient availability and improving crop productivity. Rather than depending exclusively on a single nutrient source, INM attempts to utilize the complementary benefits of different nutrient inputs.

The basic principle of INM is to supply nutrients in a balanced manner according to crop requirements while maintaining the fertility and biological productivity of the soil. Inorganic fertilizers can provide readily available nutrients, whereas organic manures contribute organic matter and nutrients and may improve

the soil environment. Biofertilizers can further enhance nutrient availability through biological processes. In field pea, the integration of these nutrient sources is particularly relevant because of the crop's association with nitrogen-fixing bacteria. The combination of *Rhizobium* with nitrogen fertilizer may provide both biological and readily available sources of nitrogen. Similarly, PSB can improve phosphorus availability and may enhance the overall efficiency of nutrient utilization. The thesis findings indicate that integrated nutrient management had a positive influence on important growth and yield characteristics. The treatment containing *Rhizobium* + PSB + 100% nitrogen recorded superior performance, while *Rhizobium* + PSB + 75% nitrogen was also among the best-performing treatments. The highest number of pods per plant was 33.31 under T20, followed by 32.35 under T21, compared with only 9.02 pods per plant in the control. The improvement may be associated with the complementary functions of the different nutrient sources. The thesis discussion suggests that nitrogen supplied through fertilizer, biological nitrogen fixation by *Rhizobium*, and improved phosphorus availability through PSB may have collectively supported better crop growth. Organic and inorganic nutrient sources may also interact positively by improving the soil environment and nutrient absorption. Therefore, INM can be considered a promising approach for achieving higher productivity while improving the efficiency of nutrient use. It also provides an opportunity to examine whether reduced levels of inorganic fertilizer, when combined with suitable biofertilizers, can maintain satisfactory crop performance.

1.6 Research Gap

Several studies have examined the effects of inorganic fertilizers, organic manures and biofertilizers on the growth and productivity of pea and other leguminous crops. Previous studies cited in the present thesis have reported positive effects of integrated nutrient management and biofertilizer application on growth, yield attributes and productivity of field pea. For example, Qureshi *et al.* reported the effect of integrated nutrient management on growth, yield attributes and yield of field pea, while Rani *et al.* evaluated biofertilizers in combination with chemical fertilizers in field pea. However, the response of field pea to nutrient management can vary depending on soil characteristics, climatic conditions, cultivar, fertilizer dose and the type and combination of organic and microbial inputs used. Therefore, results obtained

under one set of conditions cannot necessarily be directly applied to another production environment. Another important consideration is the identification of nutrient combinations that can provide high productivity without unnecessary dependence on higher levels of inorganic fertilizer. The comparison of 100% and 75% nitrogen levels in combination with *Rhizobium* and PSB is particularly relevant from this perspective. In the present study, *Rhizobium* + PSB + 75% nitrogen performed close to the 100% nitrogen combination for several parameters, suggesting the possibility of maintaining good crop performance with reduced inorganic nitrogen input. Therefore, there is a need for systematic evaluation of different combinations of organic, inorganic and biofertilizer sources under defined agro-climatic conditions. Such evaluation can help identify suitable nutrient-management practices for improving growth and yield while promoting more efficient and sustainable use of fertilizers. The present study was consequently undertaken to evaluate the influence of different integrated nutrient management treatments on growth, yield attributes and seed yield of field pea (*Pisum sativum* L.). The study particularly focused on the comparative performance of *Rhizobium*, PSB, nitrogen, FYM and vermicompost combinations and their potential to improve the overall productivity of field pea.

2. Materials and methods

The present investigation entitled “Influence Of Integrated Nutrient Management of Yield Potential of Field Pea (*Pisum sativum*)” was conducted from 2023-24 at the research farm and laboratories of Department of Agronomy, School of Agriculture Science Technology and Research, Sardar Patel University, Balaghat, (M.P.). Materials used and experimental techniques adopted during the course of investigation are described here.

Experimental Site

The current investigation was carried out in Kharif-2024 at Student Research Farm, Department of Agronomy, School of Agriculture Science Technology and Research, Sardar Patel University, Balaghat, (M.P.). Balaghat District is located the south-eastern portion of the Satpura Range and the upper valley of the Wainganga River. The district extends from 21°19' to 22°24' north latitude and 79°31' to 81°3' east longitude. The meteorological data for the cropping seasons are presented in Table 3.1. and Figure 3.1.

Table 1: Meteorological data during experimental period (Kharif-2023)

Months	Week	Temperature (°C)		Relative Humidity (%)		Total rainfall (mm)
		Max.	Min.	Max.	Min.	
June-2023	I	45.69	33.34	97.68	72.31	3.00
	II	43.28	34.65	98.98	64.30	12.36
	III	43.76	35.00	100.00	61.00	20.00
	IV	44.98	34.98	91.68	72.32	0.00
July-2023	I	40.25	30.23	98.22	65.66	10.25
	II	39.50	31.52	95.68	63.20	8.05
	III	36.81	28.34	80.00	58.86	0
	IV	36.04	28.40	82.56	61.67	35.40
August-2023	I	34.58	27.58	88.00	62.63	45.60
	II	34.94	27.80	81.86	61.71	0
	III	35.97	27.60	85.29	62.14	3.40
	IV	33.69	27.44	85.22	66.33	98.00
September-2023	I	36.14	27.66	86.57	62.86	8.40
	II	32.55	27.00	91.63	79.25	38.80
	III	34.33	26.88	87.38	68.75	40.20
	IV	34.49	25.77	85.71	60.57	0
October-2023	I	33.34	25.77	90.43	67.00	30.40
	II	32.03	24.83	94.00	69.57	49.60
	III	32.14	20.80	92.86	57.43	0
	IV	31.83	18.11	92.86	57.57	0
November-2023	I	31.91	17.46	94.00	56.71	0
	II	30.71	16.60	88.71	57.86	0
	III	30.03	14.71	83.71	53.57	2.0
	IV	27.63	11.83	90.29	58.29	0.5
Grand total rainfall (mm) = 405.96						

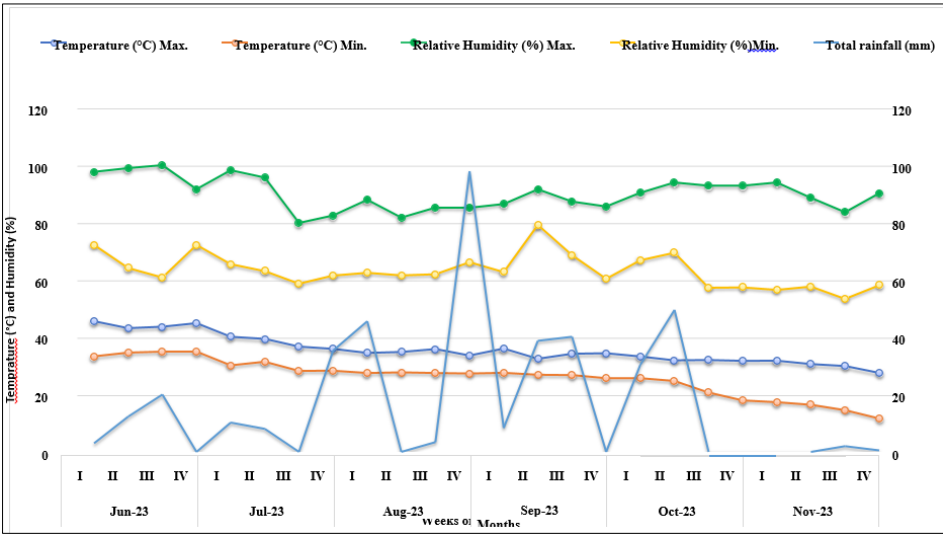


Fig 1: Graphical Representation of Weather during cropping months

Soil Characteristics of the Experimental Site

The experimental site is levelled land with sandy loam soil of uniform fertility status with low clay and high sand percentage. Soil samples were collected randomly from depth of 0-30 cm and

the soil was analysed for pH, electrical conductivity (EC), organic carbon, available nitrogen, available phosphorus, and available potassium which are presented in table 3.2

Table 2: Physical and chemical properties of soil at Field of Agronomy Department, School of Agriculture Research and Technology, Sardar Patel University, Balaghat, (M.P.)

S. No.	Particulars	Mechanical Properties	Methods used
Physical composition of the soil			
1	Fine Sand (%)	42.0	Hydrometer method (Bouyoucos, 1962)
2	Silt (%)	38.2	
3	Clay (%)	20.1	
4	Textural class	Sandy loam	
Chemical composition of the soil			
5	Soil pH	7.1	Digital pH meter (Jackson, 1958)
6	Organic carbon (%)	0.52	Wet method (Walkely and Black, 1965)
7	Available Nitrogen (N)	142.33 kg/ha	Alkaline permanganate method (Subbiah& Asija 1956)
8	Available Phosphorus (P)	4.56 kg/ha	Calorimetric method (Olsen <i>et al.</i>, 1954)
9	Available Potash (K)	206.11 kg/ha	Flame Photometric method (Pauline, 1946)

Experimental Materials

To fulfil the requirement of objectives of the investigation, the

field experiment was laid out as detailed follow

Table 3: Treatment details

T0	Control
T1	Vermicompost
T2	FYM
T3	RDF
T4	Rhizobium+FYM (100%)
T5	Rhizobium+FYM (75%)
T6	Rhizobium+ Vermicompost (100%)
T7	Rhizobium+ Vermicompost (75%)
T8	Rhizobium+ Nitrogen (100%)
T9	Rhizobium+ Nitrogen (75%)
T10	PSB+FYM (100%)
T11	PSB+FYM (75%)
T12	PSB+ Vermicompost (100%)
T13	PSB+ Vermicompost (75%)
T14	PSB+Nitrogen (100%)
T15	PSB+Nitrogen (75%)
T16	Rhizobium+PSB+FYM (100%)
T17	Rhizobium+PSB+FYM (75%)
T18	Rhizobium+PSB+ Vermicompost (100%)
T19	Rhizobium+PSB+ Vermicompost (75%)
T20	Rhizobium+PSB+ Nitrogen (100%)
T21	Rhizobium+PSB+ Nitrogen (75%)

Layout of the Experiment

Design of experiment

Twelve treatments were applied in 4.50 m x 2.50 m plot size in Randomized Block Design (RBD) with three replications. The layout of the experimental plots is given in Fig. 3.1.

The experimental details are as follows:-

Replications: 3

Design: Randomized

Treatment: 22

Total Plots: 66

Plot Size: 4.00 m $\square$ 3.0 m = 7.20 m²

Net: 828m²

Spacing : 30x10cm

Preparation of experimental field

The experiment field was given a pre-sowing irrigation and at proper tilt two plugging by tractor was done followed by planking each time. Then field was finally laid out into plots leaving irrigation channels and bunds in between treatments.

Application of fertilizer

The different levels of P₂O₅ 60 kg ha⁻¹, 20 kg N and 20 kg K₂O ha⁻¹ were applied at the time of sowing as basal dressing through Single Super phosphate (SSP), Urea and MOP, respectively.

Seeds and sowing

The quality seed of all four varieties of field pea was sown @ 80 kg ha⁻¹ at the distance of 30 cm apart. Sowing was done in furrows prepared by a narrow spade (kudali) which were covered with fine soil after sowing.

Harvesting and threshing

Prior to harvesting of experimental crop border rows were harvested and removed first from experimental plot. Thereafter, the net plot was harvested manually. The total dry weight of bundles of net plot was recorded plot-wise just before threshing and finally threshing was done by manual labour and seed weight per plot was recorded.

Cultural operations all the cultural operations performed during crop period are given in Table 3.4.

Table 4: Cultural operations

S.No.	Operations	Date	Remark
A.	Pre-sowing operations		
1.	Pre-sowing irrigation	10-11-2023	By Canal manually
2.	Ploughing	17-11-2023	By tractor drawn disc harrow
3.	Leveling	17-11-2023	By tractor drawn planker
4.	Layout Execution	18-11-2023	By manual labour
B.	Sowing Operations		
1.	Seed sowing and fertilizer application	19-11-2023	By manual labour.
C.	Post sowing operations		
1.	Sticking & Tagging	02-12-2023	By self
2.	Weeding –I	17-02-2023	
3.	Weeding –II	14-03-2023	By manual labour
4.	Irrigation-I	21-01-2023	Canal water by manual labour
5.	Irrigation-II	22-02-2023	
D.	Harvesting		
1.	Collection of tagged plant	27-03-2023	By self
2.	Harvesting	29-03-2023	By manual labour
3.	Threshing	22-04-2023	By manual labour

Studies made

Growth and development studies: - The details of the various growth observations recorded at successive stage of crop growth and development characters taken into consideration are given below

i.) Germination Count (15 DAS):- One metre row length of 2 rows per net plot randomly selected and used for this purpose.

ii.) Plant height:- The plant height (cm) of pea was recorded at 30, 60 and 90 days after seeding and at harvest from the four plants which tagged randomly in each net plot. The plant height was measured from the soil surface to the base of last pair of leaves and their average was expressed as plant height.

iii.) Number of branches:- The total number of primary and secondary branches of pea was counted at each observation of the tagged plants in each net plot. The number of branches so counted averaged and reported as number of branches per plant.

iv.) Days to 50% Flowering:- To take the "days to 50% flowering" parameter for pea, count the number of days from sowing until approximately half of the plants in a field or plot have at least one open flower. Perform regular visual assessments, preferably twice a week, with a clear view of the entire field.

v.) Days to maturity:- To determine maturity by observing the

Pods; for shell peas, this is when the pods are plump and well-filled but not waxy, while for snap or snow peas, it's when the pods are glossy and before the seeds inside are fully mature.

Yield Studies

Yield attributes (Per plant studies)

No. of Pods per plant:- All the pods of four plants of pea already tagged plot-wise separated out, counted and finally averaged.

Number of grains per pod:- The grains from each pod of tagged plants were counted and recorded for the purpose.

Yield (per hectare studies)

Grain yield (q ha⁻¹):- The grain yield was obtained from each net plot after threshing and it was converted into (q ha⁻¹).

Laboratory studies

Test weight (g):- One thousand seeds in each treatment were counted, weighed and expressed in grams.

Seed density (g/cc):- One hundred seeds from each treatment were taken and weighed on precision balance. These seeds were dipped in water; density of water is 1.0g/cc at 20°C. Volume of water displaced by the seeds was recorded and seed density of

each treatment was calculated by using the following formula:

Weight of 100 seeds (g)

Seed density = _____

Vol. of water displaced by seeds (cm³)

Standard germination (%):- One hundred seeds of each treatment plot in three replicates were placed in between sufficient moistened rolled towel papers (BP) and kept at 25°C in seed germinator. The first count was taken on 5th day and final count on 8th day and only normal seedlings and hard seeds were considered for percent germination according to the rules of International Seed Testing Association (ISTA 2011).

Seedling length (cm):- Ten randomly selected normal seedlings taken from three replications of standard germination test and average length of seedlings was worked out and recorded in centimeter for final calculation.

Seedling dry weight (g):- Seedling dry weight was assessed after the final count in the standard germination test (8 days). The ten fresh seedlings of each treatment were taken and dried in a hot air oven for 24 h at 80±10°C. The dried seedlings of each replication were weighed and average seedling dry weight was expressed in milligram.

Statistical analysis

In order to test the significance of result, standard statistical method based on the analysis of variance technique as suggested by Panse and Sukhatme (1967) were employed. The treatments differences were compared with the critical difference (CD) at 5% level of probability to ascertain their significance. All the results have been summarized in the suitable tables presented under “Experimental Findings” given the means of treatments.

$\sqrt{\frac{V_E}{r}}$ The critical difference (CD) was calculated with the help of following formula: Standard Error of mean (SEM ±) =

$\sqrt{\frac{2V_E}{r}}$ Critical difference (CD) = ' error df. Where,

CD = Critical Difference

„t“ value at 5% level of significance for VE = MSS of Error (Error variance)

r = Number of observations averaged

„t“ = „t“ value from Fisher's table for error degree of freedom at 5% level of probability.

General Mean Coefficient of variance (CV%) was also computed as: Coefficient of variance (CV%)

=

Structure of ANOVA Table

Source	DF	Sum of squares	Mean Square	F-Cal	F-Tab
Replication	2				2.81
Treatment	21				2.81
Error	42				2.81
Total	65				

Presentation of data

Results obtained from the field experimentation are consolidated in the suitable tabular form and summarized in the appendix tables for better classification. The graphic curves and bar diagrams are also sketched for better presentation

3. Experimental results

The present investigation entitled “Influence of Integrated

Nutrient Management of Yield Potential of Field Pea (*Pisum Sativum*)” was carried out during Kharif 2023 at Field of Agronomy Department, School of Agriculture Research and Technology, Sardar Patel University, Balaghat, (M.P.). The experiment was laid out in Randomized Block Design (RBD) with 22 treatments comprising three replications each. The result of the present investigation, regarding the production of pea has been presented in the tables, figures and illustrations wherever required. The results have been interpreted in the light of impact of different treatment combination during the experimentation. The results of the experiment have been presented separately under the following headings.

The data on yield and its attributes viz., Germination, days to 50% flowering, days of maturity, plant height (cm), number of branches/plant, number of pods/plant, seeds per pod and seed yield (q/ha) are presented below.

Germination%:- The data emanated from Table 4.1 revealed that all the INM treatment combinations have showed significant variations with respect to germination percentage. Significantly higher percentage ruination (98.00) was observed with Rhizobium+ PSB +100% nitrogen (T20) followed by Rhizobium+ PSB+ 75% nitrogen (T21: 97.67), Rhizobium+100% nitrogen (T8:97.33) and PSB + 100% nitrogen (T14: 96.67). The minimum percent germination (87.33) was recorded in control (T0), FYM (T2: 87.67) and Vermicompost (T1:88.33) as compared to rest of treatments

Table 5: Effect of integrated nutrient management on growth in Field Pea

	Treatments	Germination %	Plant Height	Number of Branches/plant
T0	Control	87.33	56.01	5.05
T1	Vermicompost	88.33	56.47	5.59
T2	FYM	87.67	56.20	5.34
T3	RDF	88.67	58.03	6.12
T4	Rhizobium+FYM (100%)	93.01	63.13	8.31
T5	Rhizobium+FYM (75%)	92.33	61.67	6.91
T6	Rhizobium+ Vermicompost (100%)	90.33	60.33	6.44
T7	Rhizobium+ Vermicompost (75%)	89.67	59.21	9.81
T8	Rhizobium+ Nitrogen (100%)	97.33	68.13	9.47
T9	Rhizobium+ Nitrogen (75%)	95.67	67.67	8.11
T10	PSB+FYM (100%)	92.67	62.63	8.03
T11	PSB+FYM (75%)	92.01	61.67	6.91
T12	PSB+ Vermicompost (100%)	90.01	59.47	6.19
T13	PSB+ Vermicompost (75%)	89.01	58.23	9.60
T14	PSB+Nitrogen (100%)	96.67	68.03	9.13
T15	PSB+Nitrogen (75%)	94.33	64.97	9.47
T16	Rhizobium+PSB+FYM (100%)	95.01	66.81	9.23
T17	Rhizobium+PSB+FYM (75%)	94.57	60.83	7.87
T18	Rhizobium+PSB+ Vermicompost (100%)	91.67	65.57	7.43
T19	Rhizobium+PSB+ Vermicompost (75%)	91.33	60.47	11.09
T20	Rhizobium+PSB+ Nitrogen (100%)	98.01	70.33	10.41
T21	Rhizobium+PSB+ Nitrogen (75%)	97.67	69.67	8.71
T22	RDF	93.33	64.01	8.69
	CD(0.05)	1.011	0.241	0.129
	SE(m)	0.331	0.071	0.052
	C.V.	0.711	0.229	1.001

Number of branches/plant:- A cursory glance over the data (Table 4.1) showed that the number of branches/plant differed significantly at all treatment combinations. Application of Rhizobium+ PSB + 100% nitrogen (T 20) has recorded maximum

number of branches (11.10) which was statistically at par with the treatments Rhizobium+ PSB + 75% nitrogen (T21: 10.40) and Rhizobium+ 100% nitrogen (T8: 9.80) while significantly lower number of branches were observed in control (T0: 5.05).

Plant height (cm):- The perusal of data in Table 4.1 revealed that mean performance of different treatments for plant height ranged from 56.00 to 70.33. The plant height differed significantly due to different INM treatments. Significantly highest plant height (70.33) was recorded in treatment Rhizobium+PSB + 100% nitrogen (T20) which was statistically at par with Rhizobium+ PSB + 75% nitrogen (T21: 69.67) followed by Rhizobium+ 100% nitrogen (T8: 68.63) and PSB+ 100% nitrogen (T14: 68.03)

whereas the lowest plant height (56.00) was recorded in control (T0).

Days to 50% flowering:- The analysed data for days to 50% flowering as influenced by organic and inorganic fertilizers along with biofertilizers are presented in Table 4.2. The number of days to 50% flowering were significantly influenced by different treatment combinations. The minimum number of days (71.00) taken for 50% flowering was recorded with the treatment Rhizobium+ PSB + 100% nitrogen (T20) which was statistically at par with the Rhizobium+ PSB + 75% nitrogen (T21: 71.33) while maximum number of days (87.67) were recorded in case of control (T0).

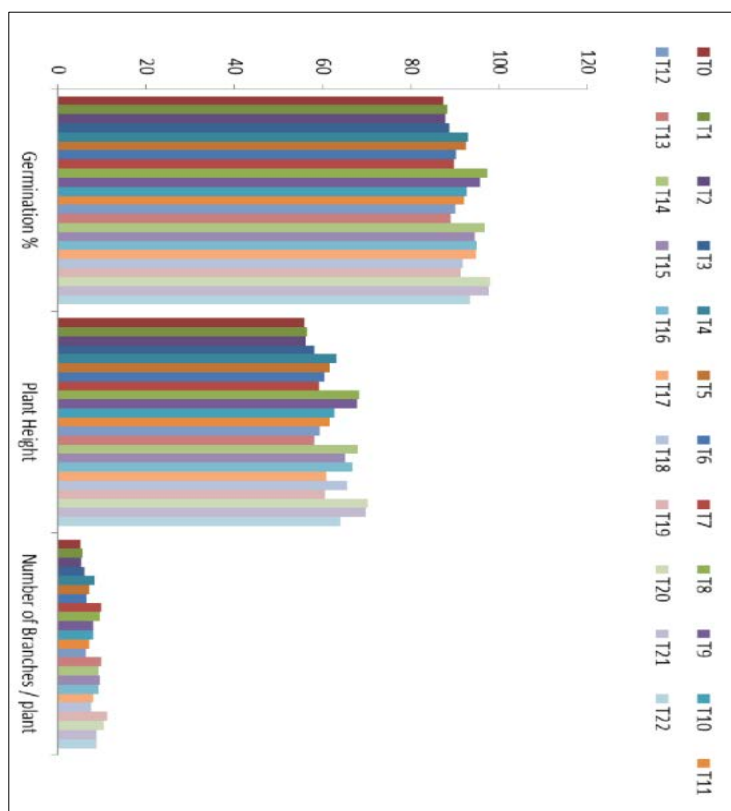


Fig 2: Effect of integrated nutrient management on growth in Field Pea

Table 6: Days to 50% flowering and Days to maturity as influenced by various treatments

	Treatments	Days to 50% flowering	Days of maturity
T0	Control	87.67	124.67
T1	Vermicompost	86.01	123.01
T2	FYM	86.33	123.33
T3	RDF	85.01	122.01
T4	Rhizobium+FYM (100%)	77.33	114.33
T5	Rhizobium+FYM (75%)	79.33	116.33
T6	Rhizobium+ Vermicompost (100%)	82.33	118.67
T7	Rhizobium+ Vermicompost (75%)	84.33	121.33
T8	Rhizobium+ Nitrogen (100%)	72.33	109.33
T9	Rhizobium+ Nitrogen (75%)	74.01	111.01
T10	PSB+FYM (100%)	78.67	115.67
T11	PSB+FYM (75%)	80.01	117.01
T12	PSB+ Vermicompost (100%)	83.67	120.67
T13	PSB+ Vermicompost (75%)	84.67	121.67
T14	PSB+Nitrogen (100%)	73.33	110.33
T15	PSB+Nitrogen (75%)	76.67	113.67
T16	Rhizobium+PSB+FYM (100%)	75.01	111.67
T17	Rhizobium+PSB+FYM (75%)	80.67	112.33

T18	Rhizobium+PSB+ Vermicompost (100%)	81.33	117.67
T19	Rhizobium+PSB+ Vermicompost (75%)	71.01	118.33
T20	Rhizobium+PSB+ Nitrogen (100%)	71.33	108.01
T21	Rhizobium+PSB+ Nitrogen (75%)	70.65	108.33
T22	RDF	77.01	114.00
	CD(0.05)	1.41	1.91
	SE(m)	0.711	0.529
	C.V.	1.229	0.934

Days of maturity:- A critical examination of the data for days of maturity as significantly affected by different treatment combinations are presented in Table 4.2. Among different treatments, minimum days of maturity (108) were observed with

Rhizobium+ PSB + 100% nitrogen(T20) which was statistically at par with Rhizobium+ PSB + 75% nitrogen (T21: 108.33) and Rhizobium+ 100% nitrogen (T8: 109.33) while maximum days (124.67) were recorded in control (T0).

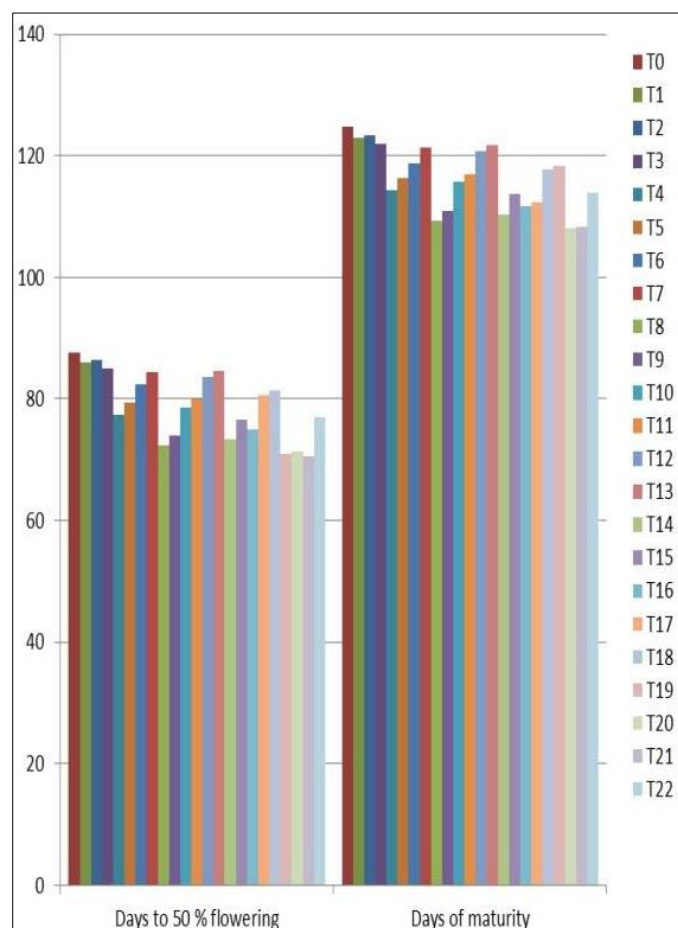


Fig 3: Days to 50% flowering and Days to maturity as influenced by various treatments

Yield attributes

Number of pods/plant

It is evident from the perusal of data (Table 4.3) that all the treatment combinations were statistically differed from each other in terms of number of pods/plant. Significantly maximum number

of pods/plant (33.31) were recorded with Rhizobium+ PSB + 100% nitrogen (T20) followed by Rhizobium+ PSB + 75% nitrogen (T21: 32.35) and Rhizobium+100% nitrogen (T8: 28.87) whereas control (T0) showed lowest number of pods/plant (9.02).

Table 7: Yield contributory characters of Field Pea as influenced various treatments

	Treatments	No. of pods / plant	Seed / Pod	Seed yield (q/ha.)
T0	Control	9.02	3.06	23.93
T1	Vermicompost	11.39	3.42	24.55
T2	FYM	10.38	3.22	24.37
T3	RDF	13.45	3.84	25.13
T4	Rhizobium+FYM (100%)	22.61	5.61	27.66
T5	Rhizobium+FYM (75%)	21.48	5.03	26.93
T6	Rhizobium+ Vermicompost (100%)	19.27	4.18	25.78
T7	Rhizobium+ Vermicompost (75%)	16.29	3.94	25.37

T8	Rhizobium+ Nitrogen (100%)	28.87	6.46	29.42
T9	Rhizobium+ Nitrogen (75%)	27.03	6.13	28.99
T10	PSB+FYM (100%)	22.3	5.26	27.56
T11	PSB+FYM (75%)	20.93	4.82	26.8
T12	PSB+ Vermicompost (100%)	17.47	3.97	25.66
T13	PSB+ Vermicompost (75%)	14.57	3.91	25.28
T14	PSB+Nitrogen (100%)	27.37	6.22	29.2
T15	PSB+Nitrogen (75%)	24.89	5.79	28.13
T16	Rhizobium+PSB+FYM (100%)	25.82	6.06	28.58
T17	Rhizobium+PSB+FYM (75%)	25.3	5.88	28.34
T18	Rhizobium+PSB+ Vermicompost (100%)	20.34	4.64	26.17
T19	Rhizobium+PSB+ Vermicompost (75%)	19.83	4.6	26.07
T20	Rhizobium+PSB+ Nitrogen (100%)	33.31	7.23	29.94
T21	Rhizobium+PSB+ Nitrogen (75%)	32.35	6.92	29.61
T22	RDF	23.29	5.65	28.01
	CD(0.05)	0.201	0.071	0.119
	SE(m)	0.029	0.021	0.033
	C.V.	0.281	1.01	0.261

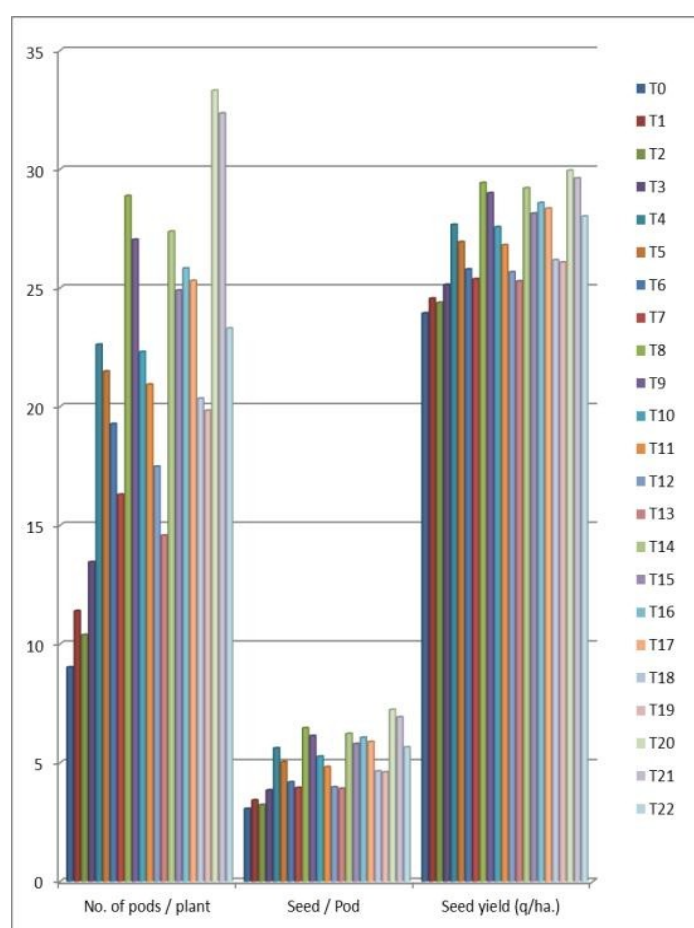


Fig 4: Yield contributory characters of Field Pea as influenced various treatments

Seeds per pod

The data presented in Table 4.3 showed the influence of integrated nutrient management on seeds/pod. Among different treatments, Rhizobium+PSB+100% nitrogen (T20) has recorded significantly maximum seeds/pod (7.23) which was at par with Rhizobium+ PSB + 75% nitrogen (T21: 6.92), Rhizobium+ 100% nitrogen (T8: 6.46) and PSB + 100% Nitrogen (T14: 6.22) while minimum seeds/pod were observed in control (T0: 3.06).

Seed yield (q/ha)

A glimpse of data (Table 4.3) revealed that seed yield might be varied significantly due to different treatment combinations.

Among all the treatment combinations, Rhizobium+PSB + 100% nitrogen has recorded maximum seed yield q/ha (T20: 29.94) followed by Rhizobium+ PSB + 75% nitrogen (T21: 29.61) and PSB + 100% nitrogen (T8: 29.42) and significantly minimum seed yield (23.93) was observed in control (T0) where no nutrients were applied.

To study the effect of integrated nutrient management on seed quality.

The seeds obtained from different treatment combinations were used for assessing the seed quality. The data recorded on seed quality parameters such as test weight (g), seed density(g/cc),

standard germination (%), seedling length (cm), seedling dry weight (g), vigour index-I and II, accelerated ageing test (%), electrical conductivity ($\mu\text{S cm}^{-1}\text{g}^{-1}$), catalase activity ($\text{mg protein}^{-1}\text{min}^{-1}$), peroxidase activity ($\text{mg protein}^{-1}\text{min}^{-1}$), dehydrogenase activity ($\text{OD g}^{-1}\text{ml}^{-1}$), and superoxide dismutase activity ($\text{mg protein}^{-1}\text{min}^{-1}$) are presented below.

Laboratory studies

Test weight (g)

The data on thousand seed weight (test weight) as affected by organic manures, inorganic fertilizers along with biofertilizers are presented in Table-4 application of Rhizobium+ PSB + 100% nitrogen (T20) showed significantly higher test weight (19.00) which was at par with Rhizobium+ PSB + 75% nitrogen (T21:18.87) and followed by Rhizobium+ 100% nitrogen (T8:18.77). Significantly lower test weight (15.03) was observed in control (T0).

Seed density (g/cc)

The results on seed density as influenced by organic, inorganic

fertilizers in combination with biofertilizers are presented in Table 4.4 It is evident from data that significantly higher seed density (1.60) was observed with the treatment combination of Rhizobium+ PSB + 100% nitrogen (T20) which was at par with Rhizobium+ PSB + 75% nitrogen (T21:1.59) and Rhizobium + 100% nitrogen (T8: 1.58). Significantly lower seed density (1.20) was recorded with control (T0) and that of treatments where only organic manures were applied viz., FYM (T2: 1.22) and Vermicompost (T1: 1.24)

Seedling length (cm)

The study of data presented in Table 4.4 revealed that seedling length was significantly influenced by organic manures, inorganic fertilizers and biofertilizers. Among the different treatments, Rhizobium + PSB + 100% nitrogen (T20) has showed maximum seedling length (32.50) which was at par with treatment Rhizobium+ PSB + 75% nitrogen (T21: 32.17) and Rhizobium+ 100% nitrogen (T8: 31.50) while the minimum seedling length (23.37) was recorded in control (T0)

Table 8: Effect of integrated nutrient management on seed quality of field pea (*Pisum sativum* L.) (Physiological parameters)

	Treatments	Test weight (g)	Seed density (g/cc)	Seedling length (cm)	Dry weight (g)	Germi nation%
T0	Control	15.03	1.21	23.37	0.30	73.00
T1	Vermicompost	15.21	1.23	24.50	0.31	74.00
T2	FYM	15.11	1.12	24.03	0.30	73.00
T3	RDF	15.37	1.27	25.11	0.31	74.33
T4	Rhizobium+FYM (100%)	16.83	1.45	28.93	0.41	84.33
T5	Rhizobium+FYM (75%)	16.43	1.43	27.87	0.38	82.67
T6	Rhizobium+ Vermicompost (100%)	15.8	1.35	26.17	0.34	77.67
T7	Rhizobium+ Vermicompost (75%)	15.53	1.31	25.81	0.32	75.67
T8	Rhizobium+ Nitrogen (100%)	18.77	1.58	31.50	0.49	89.67
T9	Rhizobium+ Nitrogen (75%)	18.37	1.55	30.69	0.47	88.33
T10	PSB+FYM (100%)	16.63	1.44	28.40	0.30	83.00
T11	PSB+FYM (75%)	16.21	1.41	27.33	0.39	81.67
T12	PSB+ Vermicompost (100%)	15.61	1.33	31.27	0.37	76.33
T13	PSB+ Vermicompost (75%)	15.43	1.29	29.91	0.33	75.33
T14	PSB+Nitrogen (100%)	18.57	1.56	30.43	0.32	89.00
T15	PSB+Nitrogen (75%)	17.41	1.50	30.03	0.48	86.00
T16	Rhizobium+PSB+FYM (100%)	18.11	1.53	27.01	0.45	87.67
T17	Rhizobium+PSB+FYM (75%)	17.83	1.52	26.61	0.46	86.33
T18	Rhizobium+PSB+ Vermicompost (100%)	16.03	1.39	32.51	0.46	80.33
T19	Rhizobium+PSB+ Vermicompost (75%)	15.91	1.38	32.17	0.36	79.00
T20	Rhizobium+PSB+ Nitrogen (100%)	19.01	1.61	29.33	0.34	90.67
T21	Rhizobium+PSB+ Nitrogen (75%)	18.87	1.59	28.21	0.50	90.00
T22	RDF	17.01	1.41	29.31	0.49	85.00
	CD(0.05)	0.171	0.03	0.50	0.05	2.29
	SE(m)	0.561	0.01	0.17	0.02	1.01
	C.V.	0.611	0.51	1.01	0.42	1.76

Seedling dry weight (g)

Data on seedling dry weight as influenced by different INM treatments are presented in the Table 4.4. There were significant differences in dry weight with the application of different

treatment combinations. Maximum dry weight (0.50) was recorded in Rhizobium+ PSB + 100% nitrogen (T20) followed by treatment combination of

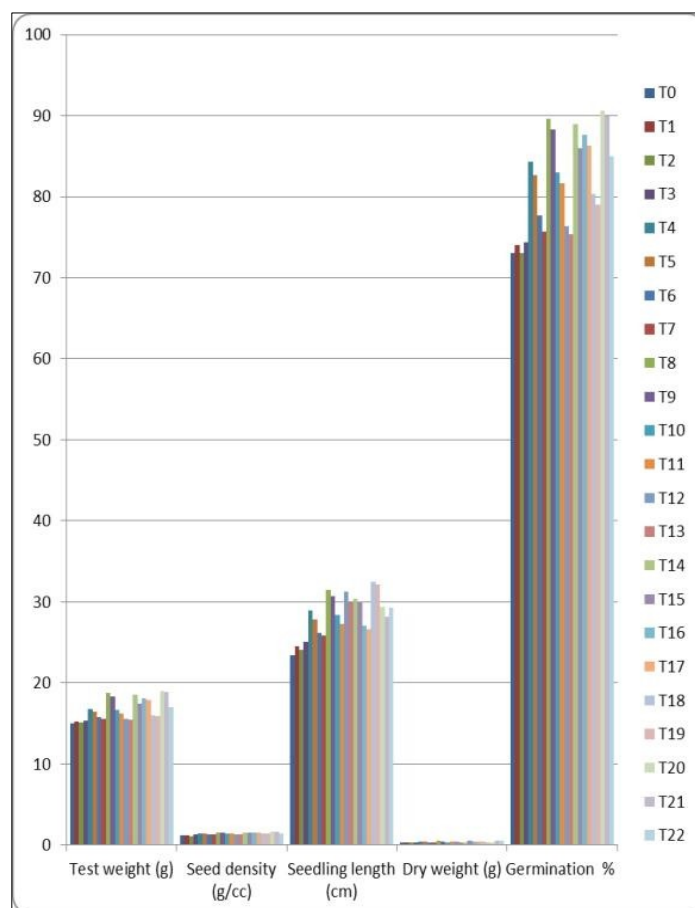


Fig 5: Effect of integrated nutrient management on seed quality of field pea (*Pisum sativum* L.) (Physiological parameters)

Rhizobium+PSB+75%nitrogen (T21:0.49), Rhizobium+ 100% nitrogen (T8:0.49) and PSB + 100% nitrogen (T14: 0.48). The minimum value (0.30) for dry weight was recorded in control (T0) and FYM (T2).

4. Discussion

The present investigation demonstrated that integrated nutrient management significantly influenced the growth, yield and seed quality of field pea. Among the treatments, Rhizobium + PSB + 100% nitrogen (T20) consistently showed superior performance, followed by Rhizobium + PSB + 75% nitrogen (T21) and Rhizobium + 100% nitrogen (T8). The combined application of biofertilizers and inorganic nitrogen appeared to provide better nutrient availability and utilization than individual nutrient sources. The earliest flowering (71.00 days), earliest maturity (108 days), maximum plant height (70.33 cm) and highest number of branches per plant (11.10) were recorded with T20. The control showed comparatively poor growth, indicating the importance of adequate nutrient availability for vegetative and reproductive development. Yield attributes also showed a positive response to integrated nutrient management. T20 recorded the maximum number of pods per plant (33.31) and seeds per pod (7.23). The highest seed yield was also obtained with T20 (29.94 q/ha), followed closely by T21 (29.61 q/ha). The improved performance may be associated with the complementary roles of *Rhizobium* in nitrogen fixation, PSB in phosphorus solubilization and inorganic nitrogen in providing readily available nutrients. Integrated nutrient management also improved seed quality. T20 recorded the highest test weight (19.00 g), seed density (1.60 g/cc), germination (98.00%), seedling length (32.50 cm) and seedling dry weight (0.50 g). These improvements may be related to better nutrient availability during seed development and greater

accumulation of seed reserves. During storage, seed quality gradually declined with increasing storage duration; however, T20 and T21 maintained comparatively better germination and seedling performance. After fifteen months of ambient storage, germination remained 89.00% in T20 and 88.33% in T21, compared with 68.00% in the control. The superior treatments also showed better physiological and biochemical performance during ageing, indicating improved seed storability.

5. Summary and conclusion

The study demonstrated that integrated nutrient management significantly improved the growth, yield attributes, seed yield and seed quality of field pea. Among the evaluated treatments, Rhizobium + PSB + 100% nitrogen (T20) produced the overall best performance, followed by Rhizobium + PSB + 75% nitrogen (T21) and Rhizobium + 100% nitrogen (T8). The combined application of *Rhizobium* and PSB with nitrogen improved plant growth, pod formation, seed development, germination and seedling performance. It also helped maintain better seed quality during natural and artificial ageing. Overall, the findings indicate that Rhizobium + PSB + 75% nitrogen (T21) may be a useful treatment for field pea seed production where reduction in inorganic fertilizer use is desired, while T20 provided the highest overall productivity and seed quality. The thesis concludes that integrated use of biofertilizers with nitrogen is a promising approach for improving field pea production and seed quality.

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