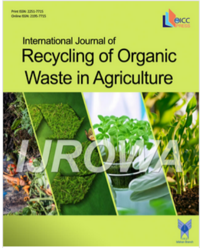

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Quantifying the impact of fermented liquid bio formulations, biofertilizers and organic amendments on horticultural and soil nutrient traits of garden pea (*Pisum sativum* L.)

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Original Research

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Abstract:

Purpose: Modern agriculture heavily relies on the use of synthetic fertilisers, which are expensive and associated with significant environmental risks. Hence, it is necessary to focus on developing integrated farming practices that encompass cost-effective synthetic fertilisers.
Method: The present experimentation was carried out to assess the effect of various treat-ments comprised of fermented liquid bio formulations, biofertilizers, & organic amendments on the horticultural, biochemical, & soil nutrient attributes of garden pea varieties. A Factorial Randomized Block Design was laid out for treatments in three replications.
Results: The results of the investigation exhibited a significantly positive influence of the treatments and their interaction with pea varieties for most of the studied traits. Among varie-ties, treatments, and their interactions, variety GS-10 and PB-89 treatment modules, *viz*., Jeevmurta 20% + Phosphorus solubilizing bacteria 100% + Farmyard manure, and their interaction were found to be best for improving the various horticultural and soil traits i.e. shelling percentage, protein content, effective nodules per plant, available nitrogen and phosphorus content. However, the application of Jeevamurta 20 % + Rhizobium 100 % + Farm yard manure on pea variety GS-10, resulted a positive increment in yielding traits namely, plant height, number of pods per plant, single pod weight, total pod yield, pod yield per plant and pod yield per plot.
Conclusion: The combination of variety "GS-10" with Jeevamurta 20%, Rhizobium 100%, and FYM, showed the positive increment in productivity of the garden pea, also found to be effective to control the incidence of rust and powdery mildew.

Keywords: Bio formulations; Biofertilizers; Disease incidence; Phosphorus solubilizing bacteria; Organic amendments

1. Introduction

Pea (*Pisum sativum* L.) is a legume crop, one of the most sustainable vegetable crops grown in India. The favourable environmental conditions in the hills of the North Western Himalayas in India facilitate year-round off-season cultiva-tion of peas. The popularity of this plant is attributed to its tender green pods, foliage and seeds, which are commonly consumed as fresh pods or preserved through canning, freezing, and dehydration (Sharma et al., 2022). Peas are widely grown and consumed globally, playing a crucial role in human nutrition (Wu et al., 2023). It offers a rich supply of protein, low fat, folic acid, lysine, bioactive compounds, high dietary fibres, carbohydrates, minerals (Zn, I, Mg, Ca, P), slow digestible starch, vitamins, polyphenolics and saponine, with potential human health benefits (Kumari and Deka, 2021; Han et al., 2023). It possesses various properties such as antioxidant, antifungal, antibacterial, anticancer, anti-diabetic, anti-hypercholesterolemia, anti-inflammatory, which make it a valuable addition to a nutritious diet (Pawar et al., 2017; Wu et al., 2023).

Plant growth is reliant on the presence of nutrients in the soil that can be provided through the appropriate application of fertilizers. The use of fertilisers is a key approach to enhance the accessibility of soil nutrients to plants. The application of fertiliser can have a positive impact on plant characteristics. However, infrequent application of fertilisers and chemicals can lead to a greater possibility of health hazards. The substantial vegetable cropping system has exhib-ited an imbalanced utilisation of major nutrients, leading to the expression of multiple nutrient deficiencies. This occurrence can be attributed to the significant depletion of nutrient reserves within the soil, as highlighted by Sharma et al. (2016). The utilisation of chemical fertilisers for the purpose of augmenting soil fertility and optimising crop productivity has frequently exhibited adverse implications on the intricate network of biogeochemical cycles (Chandel et al., 2022). The use of intensive cropping systems, characterised by continuous and imbalanced application of synthetic fertilisers to support fertilizer-responsive varieties, has resulted in the depletion of soil organic carbon and deterioration of soil health. This has frequently led to the unsustainability of crop production systems. The phenomenon of agricultural land decline can be attributed to the rapid expansion of urban areas and the intensification of industrial activities. Therefore, in order to satisfy the continuously expanding necessities of the growing population, it is imperative to enhance agricultural productivity per unit of land area (Noori et al., 2023). To address this, it is necessary to implement integrated nutrient management practises that are feasible, economically sustainable, socially acceptable, and environmentally friendly. Consequently, a wide range of alternative and traditional farming methods were devised to augment agricultural productivity by increasing microbial activity and introducing nitrogen and phosphorus. This objective can be accomplished by utilising organic manures, bio formulations and biofertilizers, as they have the ability to rapidly progress the composition of soil microorganisms, fauna, & overall fertility. According to Yogananda et al. (2020), the applica-tion of these inputs has been found to enhance the soil physical, chemical, & biological properties, such as increase in moisture holding capacity. This improvement in soil conditions ultimately contributes to higher crop productivity. Plant growth regulators are contemplated as new generation agro chemicals post fertilizers, to augment the yield and quality of seed as it enhances the source and sink relation by stimulating the translocation of photoassimilates this rendering better retention of flowers and fruits (Dhomne et al., 2021). Indigenous liquid organic manures likely jeevamurtha, beejamrit and panchgavya etc. play an important role in enhancing the growth and expansion of crop as their solutions are enriched with effective microorganisms and comprises of macro nutrients and essential micronutrients, vitamins, amino acid and other growth promoting substances alike Indole acetic acid and Gibberellic acid (Maity et al., 2020). The fermented liquid bio-formulations have embraced and enhanced the fertility of soil by preserving and boosting the micro flora population thus improving the nutrient availability (Jain et al., 2021). Farmyard manure is a primary source of organic matter as it alone or in combination with other biofertilizers supply nutrients to the plant as well as soil. FYM supplies all essential nutrients to the plants as it contains 0.64% nitrogen, 0.20% phosphorus (P_2O_5) and 0.5% potash (K_2O). It improves soil physico-chemical properties by improving the water holding capacity and encouraging the activities of soil microbes (Joshi et al., 2020).

Being a legume crop, pea plants possess the ability to fix nitrogen and have been widely acknowledged for their role in improving soil fertility (Lalito et al., 2018). Leguminous pea residue contributes to the accumulation of soil organic matter, thereby activating microbial fractions (Kumar et al., 2018b). Its biomass, both above and below ground, directly contributes to the accumulation of soil organic carbon (Janusauskaite, 2023). Leguminous pea residue contributes to the accumulation of soil organic matter and activates microbial fractions (Kumar et al., 2018b). Pea plants have an aboveground biomass of 300 kg N per hectare, with 70% of this biomass being in the seed, indicating its potential for high yield (Zajac et al., 2013).

Rhizobium leguminosarum is a bacterium that forms a beneficial partnership with legume crops. It has the remarkable ability to convert atmospheric nitrogen into a usable form by creating nodules in the roots of the plants. The strains of rhizobia have the remarkable ability to enhance the nitrogen content of plants even in water-deficient conditions (Wang et al., 2018). These bacteria are Gram-negative, non-sporulating rods, and motile in nature. They have a symbiotic relationship with plants and are capable of fixing nitrogen at a rate of 50-100 kg ha^{-1}, but only in conjunction with legumes. The successful nodulation of leguminous crops by Rhizobium is heavily influenced by the presence of a compatible strain that is suitable for the specific legume being cultivated (Abdel Ghany et al., 2013). In agricultural settings, around 80 percent of the biologically fixed nitrogen comes from a symbiotic relationship between leguminous plants and certain bacteria. These bacteria belong to the αproteobacteria order Rhizobiales, specifically the family Rhizobiaceae, which includes species like *Rhizobium, Sinorhi-zobium, Bradyrhizobium, Mesorhizobium*, and *Azorhizobium* (Kuzmanovic et al., 2022). The presence of legume crops in the field affects the population of Rhizobium in the soil. Without legumes, the population tends to decrease. Every legume necessitates a particular species of Rhozobium to successfully develop nodules (Concha and Doerner, 2020). Various strains of Rhizobia have the ability to influence the growth of numerous legumes. However, it is important to note that the growth is only improved when effective strains of Rhizobia are able to produce nodules (Abdel Ghany et al., 2013).

Phosphorus, being a highly reactive element, does not naturally occur in elemental form within the soil. The soil solution contains both insoluble organic and inorganic phosphorus. This process in the ecosystem could be characterized as "sedimentary" as there is no exchange with the environment. Unlike nitrogen, there is no significant atmospheric source that may be rendered biologically accessible (Kalayu, 2019). The insufficiency of phosphorus significantly hampers the development and productivity of agricultural crops. The soil's phosphorus concentration is around 0.05 percent. Soil test readings often exhibit higher concentrations, with the majority, around 95 to 95 percent being mostly composed of insoluble phosphates. Low amounts of soluble P in soil solutions range from ppb in poor soils to 1 mg/L in intensively fertilized soils. Phosphorus fertilizers are the principal source of inorganic P in agricultural soil. Approximately 70-90 percent of soil phosphorus fertilizers are absorbed by cations and transformed to inorganic phosphorus (Walpola and Yoon, 2012).

Phosphorus (P) becomes immobilized in calcareous or normal soils due to the presence of cations like Ca^{2+}. This leads to the formation of a complex called calcium phosphate ($Ca_3(PO_4)_2$). In acidic soils, P gets embedded by cations that include Fe^{3+} and Al^{3+}, resulting in the formation of ferrous phosphate and aluminium phosphate (AlPO), correspondingly (Kumar et al., 2018a). These forms are insoluble in nature, thus rendering them unavailable for use. The phosphates that have built up in agricultural soils possess the capacity to sustain optimal crop yields globally for approximately 100 years, provided they can be mobilized and transformed into soluble forms of phosphorus through the utilization of phosphate-solubilizing microorganisms (Walpola and Yoon, 2012). Phosphate solubilizing microorganisms, also known as PSMs, are a group of advantageous microorganisms that possess the ability to break down organic and inorganic phosphorus compounds found in insoluble substances. Within the realm of Plant Growth-Promoting Microorganisms (PSMs), it is worth noting the presence of strains originating from various bacterial genera such as Bacillus, Pseudomonas, and Rhizobium (Tian et al., 2021). Additionally, fungal genera including Penicillium and Aspergillus, as well as actinomycetes and arbuscular mycorrhizal (AM) organisms. The soil serves as a natural substrate for the proliferation of microorganisms. Typically, a gram of fertile soil contains a range of 10^1 to 10^{10} bacteria, with their live weight potentially surpassing 2,000 kg per hectare. In the soil, we can observe a diverse microbial community. Specifically, there are certain bacteria known as P solubilizing bacteria, which make up approximately 1 to 50 percent of the total microbial population. Additionally, this phosphorus solubilizing fungi, which constitute around 0.1 to 0.5 percent of the overall microbial population (Kalayu, 2019). Plant stress markers (PSMs) are found in abundance throughout various agricultural environments, exhibiting distinct variations across different soil compositions. The majority of plant growth-promoting microorganisms (PSMs) were obtained from the rhizosphere, which is the region surrounding the roots of different plants. It is well-established that PSMs exhibit higher metabolic activity in this specific environment (Walpola and Yoon, 2012).

As, it exhibits positive responses to the utilisation of both manures and inorganic fertilisers. Each of the organic manures, biofertilizers and bio-formulations has their specific properties and contributes to improve the soil health and productivity. Keeping all the discussed facts in a view, the current experimentation was premeditated to estimate the influence of different integrated nutrient modules on pea varieties on various horticultural traits and nutrient status of the soil.

2. Material and methods

Experimental site

In order to fulfil the experimental objective, the trial was carried out during winter season in the year of 2020-2021 at Vegetable Research Farm of the Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidalaya, Palampur, Himachal Pradesh, India under protected conditions (naturally ventilated Poly-house). Agroclimatically, the agricultural site is positioned at coordinates 32°6′ North latitude and 76°3′ East longitudes, with an elevation of 1290.80 metres above the mean sea level. The soil is classified as typic Hapludalf, with a clay loam texture and a pH value of 5.6. The experimental site is located within the mid hill zone of Himachal Pradesh i.e. Zone-II, characterised by a subtemperate and semi-humid climate with high annual rainfall of 2500 mm, which is characterised by cold winters.

Treatments and experimental details

During the present investigation, different organic sources were utilized for the preparation of treatments, which comprised three major components i.e. Jeevamurta, organic amendments (Farmyard manure), and biofertilizers (Rhizobium and Phosphorus solubilizing bacteria). Total nine diverse combinations (T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, and T_9) were prepared and applied at different concentrations, as mentioned in Table 1. Two pea varieties namely, GS-10 (V_1) and PB-89 (V_2) and other organic sources (bio formulations, Jeevamurta and organic amendments) were procured from CSK, Himachal Pradesh Agriculture University, Palampur, HP, India. The experiment was laid out in Factorial Randomized Block Design (FRBD) in three replications. The field was ploughed help of power tiller, and beds were prepared at least five days before seed sowing. FYM (20 t ha^{-1}) was incorporated and mix thoroughly in the soil during the bed preparation under Naturally Ventilated Polyhouse. Farmyard manure (FYM) is a decomposed mixture of livestock dung, stable bedding, and various remnants of crop residue and their stalks. In order to facilitate the process of inoculating pea seeds with bio-fertilizers such as Rhizobium and Azotobacter, slurry was meticulously prepared by utilizing a solution consisting of 10% jaggery. Subsequently, the seeds were immersed in the aforementioned so-lution in order to attain a homogeneous coating on their external layer. Rhizobium (R. *leguminosarum bv. viceae* (Rlv) and PSB were applied to the seeds at a rate of 20 g kg^{-1} and 10 g kg^{-1} of seeds and mixed meticulously. Then after the treated seed were dried in partial shade conditions, and sown in the field. Jeevamurta is prepared by incorporating ten kilogrammes each of locally sourced cow dung and cow urine. Additionally, two Kg each of local jaggery and pulse flour, and a small amount of garden soil are added to the mixture. The resulting volume is then adjusted to reach a total of two hundred liters. Then after, place the drum in a shaded area and cover it with a moist gunny bag. Proceed to stir the mixture in a clockwise direction at least thrice a day and initiate the incubation process. Jeevamurta was applied twice as a soil drenching after seed sowing at the rate of 250 ml per plant, while simultaneously after the emergence of seed the foliar application of Jeevamurta was also done at different concentrations at a fifteen-day interval. All the necessary intercultural operations were performed as per the recommended package and practices for pea, during the seed sowing (First week of November) row to row and plant to plant spacing was maintained at 45 × 10 cm. The freshly prepared Jeevamrut was acidic in nature with a pH of 5.88. and EC (Electrical Conductivity) of was 0.23 dS m^{-1}. Jeevamrut has N:1.48%, P: 0.28% and K:0.32%. Well rotten FYM consists of about N:0.44%, 0.25% P, 0.24% K. Chemical fertilizers comprise in-organic chemical substances that have a high concentration of nutrients. They provide nutrients to plants quickly, but they need to improve the soil quality significantly. On the other hand, organic fertilizers are derived from natural substances, possess a reduced nutritional density, gradually release nutrients, and enhance soil health and long-term fertility. The peas crop was harvested in the first week of January at the tender green pod stage.

Growth, phonological and yield traits

The data pertaining to growth, yield, & biochemical parameters were collected by recording observations on five randomly selected plants from each replication within every treatment combination. The observations were recorded for various horticultural traits viz., days to first flowering, days to first pod formation, plant height, number of pods per plant, single pod weight (g), pod length (cm), pod width (cm), pod yield per plant (g), pod yield per plot (kg), total pod yield (q ha^{-1}), shelling percentage (%), hundred seed weight (g). Days to first flowering was counted from the date seed sowing to the date of first flower appeared on the plant, a similar pattern was also followed to count the days for the first pod formation, where the day's count was started from date of first flowering to the date of the first pod formation. The pod yield per plant was determined by combining the weights of all the pods harvested from ten randomly chosen plants throughout multiple pickings in a specific plot or treatment, and then calculating the average for the same, accordingly. Pod yield per plot and total pod yield quintal per hectare was further calculated from average value of pod yield per plant multiplied with the number of plants occupied per area. To workout the average mean value for shelling percentage calculation following formulae was used as given below:

$$\text{Shelling percentage}(\%) = \frac{\text{Average grain weight}}{\text{Average pod weight}} \times 100$$

Quality traits

Total soluble solids content of pea seeds was analysed by using the standard procedure as given by AOAC (1970). Grain samples were crushed, and a small amount of juice was extracted by using muslin cloth. Few drops of extracted samples were placed on the glass of EMMA Hand Refractometer. Ascorbic acid content estimation was performed by using the volumetric method as per the procedure illustrated by Sadasivam and Manickam (1992). The freshly harvested pods were taken for the analysis, where oxalic acid was used for titration purposes of the samples. Meanwhile, protein content percentage was estimated by using Kjeldhal method, for calculating the percentage availability of protein nitrogen content of the pea seeds was multiplied by the factor value of 6.25.

Soil analysis

The soil samples were randomly collected from each treatment in three replicates, after final harvest and examined for various soil physicochemical properties. Available nitrogen content was estimated by using alkaline potassium permanganate method given by Subbiah and Asija (1956). However, the available phosphorus content was determined by means of spectrophotometrically, using 0.5 N $NaHCO_3$ solution with 8.5 pH value by following the standard procedure of Olsen et al. (1954). The available potassium content of the sample was extracted by means of normal neutral ammonium acetate, and estimated by using a flame photometer (Merwin and Peech, 1951). Moreover, on that effective nodules per plant were counted by using destructive sampling methods at the time of final harvesting of the crop.

Disease severity scale for powdery mildew and rust in pea

Total ten random samples were taken from the solo treatment of each replication. The disease severity indexing for rust and was done as suggested by Mayee and Datar (1968) on the scale range of 0-5, while the 0-9 scale for powdery mildew as mentioned by Saari and Prescott (1975), as presented in Tables 2, 3 and 4, respectively. The percent disease index (PDI) was calculated as per the formulae as mentioned below:

$$\text{Percent disease index PDI }(\%) = \sum \frac{\text{class rating} \times \text{class frequency}}{\text{total no of plant scored} \times \text{maximum rating}} \times 100$$

Statistical analysis

The mean data had statistical analysis through the analysis of variance technique, as described by Gomez and Gomez (1984), by means of MS-Excel & statistical software WASP2.0. The factor A (Varieties), factor B (Treatment) and their interaction (A × B) mean sum of square was tested against mean sum of square due to error by 'F-test' for (a-1), ab(r-1); (b-1), ab(r-1) and (a-1) (b-1), ab(r-1)

Table 1. Details of the varieties and treatments applied in pea.

S. No.	varieties/treatment details
varieties (factor A)	
V_1	GS-10
V_2	PB-89
treatments (factor B)	
T_1	Jeevamurta 5% + Rhizobium 25% + FYM
T_2	Jeevamurta 10% + Rhizobium 50% + FYM
T_3	Jeevamurta 15% + Rhizobium 75% + FYM
T_4	Jeevamurta 20% + Rhizobium 100% + FYM
T_5	Jeevamurta 5% + PSB 25% + FYM
T_6	Jeevamurta 10% + PSB 50% + FYM
T_7	Jeevamurta 15% + PSB 75% + FYM
T_8	Jeevamurta 20% + PSB 100% + FYM
T_9	control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM)

Table 2. Details of the varieties and treatments applied in pea.

scale value	remarks
0 (0%)	absolutely free from pustules
1 (0.1-5%)	1 or 2 pustules on few leaves
2 (5.1-10%)	few pustules on some leaves
3 (10.1-17%)	few isolated pustules on most of the leaves
4 (17.1-25%)	many pustules on most of the leaves
5(25.1-50%)	many pustules coalescing to each other
6 (50.1-75%)	coalescing pustules on almost whole plant
7 (75.1-90%)	almost uniform powdery growth covering leaves and pods
8 (90.1-95%)	uniform powdery growth without any conspicuous pustules on the leaves, pod and stem
9 (95.1-100%)	whole plant covered with powdery mass giving light greyish white appearance leading to premature drying of plants

Table 3. Disease severity scale for rust in pea.

scale value	remarks
0	leaf and fruit free from infection
1	1-5 leaves are infected
2	6-20% leaves are infected
3	21-40% leaves and fruits are infected
4	41-70% leaves and fruits are infected
5	above 70% leaves and fruits are infected

Table 4. Disease severity scale for rust in pea.

PDI (%)	disease reaction
0	immune (I)
1-30	resistant (R)
31-50	moderately resistant / tolerant (MR/T)
>51	susceptible (S)

degree of freedom at 0.05 level of significance. The calculated F-values were compared with the tabulated F-value. When the F-test was found significant, critical difference was calculated to find out the superiority of one factor over the others. Co-efficients of variance were used to quantify the extent to which data points in a given series deviate from the mean, indicating the relative dispersion of the data.

3. Results and discussion

The positively significant influence of different concentrations of Jeevamurta along with different doses of biofertilizers and organic amendments was observed on various horticultural traits of pea varieties.

Growth attributes

In the current investigation, an examination of the data presented in Table 5 reveals the significant variations was observed in days to first flowering, days to first pod formation and plant height. The presented mean data depicted that the pea variety "GS-10 took the least days to first flowering, days to first pod formation and plant height, while amongst the nine treatment combinations, application of Jeevamurta 15% + Rhizobium 75% + FYM, showed the minimum day's value for both the studied trait. Additionally, the maximum plant height was recorded in an applied treatment module viz., Jeevamurta 10% + PSB 50% + FYM, while the minimum was recorded with Control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM). In between the interaction combination of varieties with treatments, lowest days to first flowering and days to first pod formation was recorded in PB-89 + Jeevamurta 15% + Rhizobium 75% + FYM. However, interaction of GS-10 with Jeevamurta 20% + Rhizobium 100% + FYM had maximum value measured for plant height, and the minimum was found in lowest PB-89 + Control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM). Earliness in flowering and pod formation could be attributed due to the proper establishment of source sink relation and supports the effective translocation of photosynthates in between of the applied organic nutrient resources and pea varieties, which supports (Sharma et al., 2022; Dhomne et al., 2022). However, Organic manures, along with bio-fertilizers, play a crucial role in maintaining soil fertility over an extended period of time, thereby maximising the crop's overall potential (Pawar et al., 2017). The growth of plant height was observed to have a significant increase as a result of improved nutrient supply through the integrated application of organic manures and biofertilizers, as reported by Rabade et al. (2022).

Yielding attributes

The highest number of pods per plant, single pod weight, pod length, pod width, pod yield per plant, pod yield per plot and pod yield per hectare was recorded in GS-10, while lowest was with PB-89 (Tables 5, 6 and 7). In case of number of seed per pod, hundred seed weight and shelling percentage variety PB-89 had the maximum, and GS-10 was noted with lowest value (Tables 6 and 8). In between the treatment combinations, the application of Jeevamurta 20% + Rhizobium 100% + FYM had the highest value for no. of pods per plant, pod length and shelling percentage, while single pod weight was found with Jeevamurta 20% + PSB 100% + FYM. The lowest value for no. of pods per plant, pod length & shelling percentage and single pod weight was found with Jeevamurta 20% + PSB 100% + FYM, Jeevamurta 15% + PSB75% + FYM and Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM, respectively. However, the treatment of Jeevamurta 5% + PSB 25% + FYM had the highest pod width, number of seeds per pod, while the lowest observed in Control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM), Jeevamurta 10% + Rhizobium 50% + FYM, respectively. In contrast of this, maximum hundred seed weight was exhibited by application of Jeevamurta 10% + Rhizobium 50% + FYM, and minimum was showed in lowest Control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM). Similarly, amongst the interaction combination, variety GS-10 treated with Jeevamurta 20% + Rhizobium 100% + FYM showed the maximum number of pods per plant and single pod weight, and the minimum was recorded with variety PB-89 treated with Jeevamurta 5% + PSB 25% + FYM and GS-10 + Control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM), respectively. In addition to this, the maximum pod length was measured in interaction of GS-10 with Jeevamurta 10% + Rhi-zobium 50% + FYM, and the minimum was recorded with PB-89 treated with Jeevamurta 15% + PSB 75% + FYM. Accordingly, maximum pod width, number of seeds per pod was achieved when + Jeevamurta 5% + PSB 25% + FYM applied on PB-89, although another interaction combination of PB-89 + Jeevamurta 10% + PSB 50% + FYM also shared the similar value for number of seeds per pod and the minimum was with PB-89 combined with Jeevamurta 10% + Rhizobium 50% + FYM, GS-10 +Jeevamurta 10% + Rhizobium 50% + FYM respectively.

Scrutiny of data revealed that the integrated module of Jeevamurta 10% + Rhizobium 50% + FYM with variety PB-89 had highest hundred seed weight, and the lowest value was observed with PB-89 + Control (Jeevamurta 2.5%+ Rhizobium 10% + PSB 10% + FYM). Overall, a cursory glance of data exhibited that shelling percentage differed significantly due to various integrated treatment combinations (Table 8). The shelling percentage decrease with successive decrease in concentration of Jeevamurta, Rhizobium, PSB and FYM applied on variety GS-10 i.e. Control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM), the vice-versa was observed for the interaction combination of GS-10 + Jeevamurta 20% + PSB 100%+ FYM for studied trait.

The augmentation in pod size can be attained through enhanced accessibility of atmospheric nitrogen and phosphorous availability (Ganie et al., 2010). The observed phenomenon may be attributed to the enhanced development of roots, resulting in increased absorption of nutrients during the entire growth cycle of the crop (Reddy et al., 2014). Kumar et al. (2016), Singh and Bhatt (2016), and Yogananda et al. (2020) observed increased translocation and accumulation of photosynthates in pea pods, leading to improved plant growth. The increased number of pods per plant observed in this study can be attributed to the synergistic effect of a well-balanced combination of nutrients (Kurbah et al., 2023). The higher concentration of nutrients, along with the presence of beneficial microbes, played a crucial role in mobilising the previously unavailable nutrients in the soil. This mobilisation process ultimately led to the optimal supply of nutrients during critical stages of crop growth, ensuring the successful acquisition of crucial macro and micro-nutrients (Pandey et al., 2006). The greater accessibility of assimilates may have expedited the development of additional flower buds, increased the number of pods, and ultimately resulted in a higher yield of pods (Dhomne et al., 2022).

Quality attributes

The economic yield in pulses is commonly attributed to their protein content, making it a significant factor in grain legume production. Consequently, enhancing protein content through appropriate agronomic practises is a primary goal in increasing grain legume yield. The grain protein yield is the final outcome of a multifaceted sequence of biochemical and physiological processes. In this study the appraisal of data in Table 8, for pea varieties represented that the highest amount of protein and ascorbic acid content was recorded in GS-10.

However, amongst the nine different treatments combinations, the application of Jeevamurta 20% + PSB 100% + FYM was found to be most effective to level up the protein content in pea, while the lowest was recorded with Jeevamurta 20% + Rhizobium 100% + FYM. Similarly, the applied dose of Jeevamurta 15% + PSB 75% + FYM had higher value and showed the positive effect by increasing the ascorbic acid content, and lowest amount was observed with the application of Jeevamurta 5% + Rhizobium 25% + FYM. In between comparison of different interactions of two pea varieties with different doses of Jeevamurta, biofertilizers and organic amendments, the highest protein content percentage was found to be in PB-89 treated with Jeevamurta 20% + PSB 100% + FYM, but the lower value for the same was recorded when Jeevamurta 5% + PSB 25% + FYM was applied in PB-89. However, the ascorbic acid content was found at the higher level in GS-10 treated with integrated module compris-ing Jeevamurta 15% + Rhizobium 75% + FYM, but the applied concentration of Jeevamurta 5% + PSB 25% + FYM in PB-89 was found to be lower down the availability of ascorbic acid content. The efficient translocation of nitrogen from the vegetative parts to the developing seeds, along with the synthesis of protein from the reduced nitrogen compounds within the seeds, has been attributed to this phenomenon (Kumari et al., 2010). The findings align with the research conducted by Mishra et al. (2014) and Singh et al. (2014).

The estimation of total soluble solids content in pea seeds is a significant quality trait that serves as an indicator of seed sweetness and shows the overall quality of the pods (Pawar et al., 2017). In the current investigation, amongst the two studied varieties of pea, the maximum amount of total soluble solids was found in PB-89 (Table 8). The application of Jeevamurta 10% + Rhizobium 50% + FYM had shown their positive effect and increased the amount of TSS, meanwhile the integrated module of Jeevamurta 15% + PSB 75% + FYM showed the lowest value for studied trait. Additionally, on the basis of mean performance of various interaction combinations of varieties and integrated modules, highest TSS was recorded in those pea pods of PB-89 which were grown under the application of Jeevamurta 10% + Rhizobium 50% + FYM, while the application of + Jeevamurta 15% + PSB 75% + FYM in GS-10 lower down the level of TSS. Sharma et al. (2022) have previously reached a similar conclusion regarding TSS.

Soil nutrient status analysis

The assessment of soil nutrient status has been done in order to investigate the impact of organic sources and biofertilizers on soil nutrition. The statistical analysis of variance revealed that the utilisation of integrated sources of nutrients led to notable variations in pea plants with respect to all studied soil traits. Similarly, it is evident from the present study that the effect of individual "variety" was also found to be significant for most of the traits. However, "variety x treatment" effects were also observed on nutrient status of soil. The utilisation of diverse integrated combinations of nutrient resources with various pea varieties resulted in a notable enhancement in the nutrient content of the soil. This improvement can be attributed to the conversion of nutrients from an unavailable form to an available form (Vimera et al., 2012; Shilpa et al., 2022). The observed augmentation in the number of effective nodules per plant signifies a favourable correlation between the presence of nutrient sinks and sources for the microbial community. This correlation plays a role in governing the availability of various nutrients through microbial transformation. Pea variety GS-10 was found to have maximum effective nodules per plant. Additionally, from the investigated data represented in Fig. 1., depicted that amongst the various treatments, maximum count for effective nodule per plant was observed with application of Jeevamurta 15% + PSB 75% + FYM, meanwhile, the Control (Jeevamurta 2.5% +

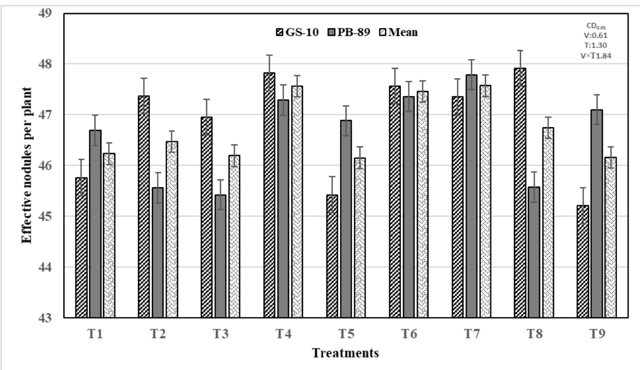

Figure 1. Influence of Jeevamurta, organic amendments and biofertilizers on effective nodules per plant of pea varieties.

Rhizobium 10% + PSB 10% + FYM) had lowest count for the same. Amongst the interactions, GS-10 in combination with Jeevamurta 20% + PSB 100% + FYM seemed to have the highest count for effective nodules per plant, while the lowest was observed, when GS-10 combined with control treatment i.e. Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM.

In view of the various integrated nutritional modules and their combination with two diverse varieties of pea were evaluated in the present investigation, the information of mean performance value of availability of NPK are given in the Table 9, that shows substantial diversity of accessible NPK content. The maximum amount of available nitrogen found in pea variety PB-89, while the integrated module comprising Jeevamurta 20% + PSB 100%+ FYM showed their positive effect and recorded with higher level, but the least value for studied trait was observed with Jeevamurta 5% + Rhizobium 25% + FYM. The data pertaining to interaction mean performance, resulted that increase in nitrogen accessibility was found with maximum value, when PB-89 was treated with Jeevamurta 20% + PSB 100% + FYM, on over this the applied dose of Jeevamurta 5% + Rhizobium 25% + FYM in GS-10 reported with lowest value for studied trait. As far as the phosphorus content concerned, variety GS-10, treatment combination of Jeevamurta 20% + PSB 100% + FYM, and among the interactions, GS-10 + Jeevamurta 5% + PSB 25% + FYM had registered with significantly higher mean value of phosphorus content. Meanwhile the amongst the treatment and interactions, lowest value for phosphorus content was observed with Control (Jeevamurta 2.5%+ Rhizobium 10% + PSB 10% + FYM), Jeevamurta 5% + Rhizobium 25% + FYM shared similar value, and PB-89 + Jeevamurta 5% + Rhizobium 25% + FYM, respectively. As per the mean data performance, the results ensures that the available potassium content was also to be found maximum in GS-10, while amongst the various treatment, it was found with application of Jeevamurta 15% + PSB 75% + FYM solely, and also the interaction amongst these have shown the significantly positive response for the studied trait. In addition to this, Jeevamurta 10% + Rhizobium 50% + FYM, and interaction combination of PB-89 + Jeevamurta 20% + Rhizobium 100% + FYM were documented with least mean value for accessible potassium content, respectively.

The increase in available nitrogen has been attributed by Sharma et al. (2014) to two key factors: the direct application of nitrogen through the utilisation of farmyard manure and the proliferation of soil microorganisms. The microorganisms possess the capacity to transform nitrogen that is bound within organic compounds into an inorganic state, thereby facilitating the augmentation of the nitrogen accessible within the soil. Similarly, the use of organic manures has been linked to an increase in phosphorus availability (Sharma et al., 2022). The use of organic manures, which aid in the direct assimilation of phosphorus and encourage the release of different organic acids during their decomposition, is responsible for this phenomenon. Since organic acids may form complexes with iron and aluminium, they can aid in the solubilisation of indigenous phosphorus (Dass et al., 2008). According to studies conducted by Prativa and Bhattarai (2011), when organic matter is present in soil, a unique layer forms on sesquioxides, reducing the soil's capacity to hold and immobilise phosphate. The positive impact of farm yard manure on the availability of potassium can be attributed to the direct introduction of potassium into the soil's potassium pool, in addition to the decrease in potassium fixation (Sharma et al., 2022). The synergistic utilisation of manures in conjunction with plant growth-promoting rhizobacteria (PGPR) resulted in a notable enhancement of nitrogen (N), phosphorus (P), and potassium (K) levels within the soil, as opposed to the application of manures in isolation from PGPR. It has been reported that the utilisation of phosphorus solubilizes has the potential to augment the accessibility of phosphates within the soil. This, in turn, could potentially amplify the growth of leguminous plants by optimising the efficiency of biological nitrogen fixation (Brar et al., 2019). The sample exhibits a significant microbial load, which undergoes multiplication and serves as a beneficial soil tonic. The utilisation of this technology serves to optimise microbial activity within the soil, thereby facilitating the efficient acquisition and utilisation of essential nutrients by agricultural crops. Jeevamrut is known to stimulate significant levels of biological activity within the soil, thereby improving the accessibility of nutrients for crops. Jeevamrut is an economically viable and innovative formulation that effectively enhances the soil's microbial diversity by introducing indigenous microorganisms. This is of utmost importance as it facilitates the process of mineralization, as highlighted by Brar et al. in their research conducted in 2019.

Plant disease incidence percentage for powdery mildew, rust and their reactions

The disease incidence range for powdery mildew and rust was varied from 0-21.78% and 0-16%, respectively (Table 10).

The maximum incidence of powdery mildew in pea was reported in GS-10 with applied dose of Jeevamurta 5% + Rhizobium 25% + FYM, and PB-89 during the incorporation of Jeevamurta 10% + Rhizobium 50% + FYM shared the similar value i.e. 21.78 showed the moderate resistance reaction. In addition to this, some of the integrated module showed resistant reaction toward powdery mildew i.e. Jeevamurta 10% + Rhizobium 50% + FYM, Jeevamurta 10% + PSB 50% + FYM, Jeevamurta 10% + PSB 50% + FYM when applied on GS-10 , while Jeevamurta 5% + Rhizobium 25% + FYM, Jeevamurta 10% + PSB 50% + FYM applied on PB-89, and Control 1 & 2 (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM), respectively, except from these resistant and moderate resistant reaction shown by treatments in different pea varieties, others were resulted immune reaction of powdery mildew incidence. Moreover on that, the moderate resistant reaction was observed with some of the interaction combinations namely, Jeevamurta 5% + Rhizobium 25% + FYM, Jeevamurta 15% + Rhizobium 75% + FYM, Jeevamurta 5% + PSB 25% + FYM when applied on GS-10, while the application of Jeevamurta 5% + Rhizobium 25% + FYM, Jeevamurta 10% + Rhizo-

Table 5. Disease severity scale for rust in pea.

characters	days to 1st flowering			days to 1st pod formation			plant height (cm)			single pod weight (g)		
varieties **treatment**	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean
Jeevamurta 5% + Rhizobium 25% + FYM	56.80	54.77	55.79	59.14	57.35	58.25	101.22	97.48	99.35	7.85	7.80	7.82
Jeevamurta 10% + Rhizobium 50% + FYM	57.48	56.47	56.98	60.41	59.48	59.95	100.74	95.17	97.96	7.99	7.80	7.90
Jeevamurta 15% + Rhizobium 75% + FYM	55.00	54.22	54.61	58.12	57.25	57.69	111.01	100.11	105.56	8.71	7.90	8.31
Jeevamurta 20% + Rhizobium 100% + FYM	55.28	55.75	55.51	57.12	59.22	58.17	113.50	103.07	108.28	9.11	7.60	8.36
Jeevamurta 5% + PSB 25% + FYM	59.75	59.75	59.75	62.11	65.77	63.94	105.01	88.90	96.95	8.78	8.10	8.44
Jeevamurta 10% + PSB50% + FYM	55.20	58.22	56.71	59.14	62.12	60.63	112.72	116.20	114.46	7.96	8.60	8.28
Jeevamurta 15% + PSB75% + FYM	56.91	58.10	57.51	60.00	62.48	61.24	115.38	102.30	108.84	8.06	8.40	8.23
Jeevamurta 20% + PSB 100% + FYM	56.99	57.92	57.46	60.75	63.22	61.99	110.53	97.40	103.97	8.32	8.80	8.56
control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM)	57.45	59.22	58.34	65.91	57.35	66.02	112.30	98.74	105.52	7.55	7.85	7.70
mean	56.76	57.16		60.30	61.45		109.16	99.93		8.26	8.09	
	CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%	
factor A (variety)	0.86	1.15		0.98	1.32		1.95	2.61		0.133	0.179	
factor B (treatment)	1.82	2.44		2.08	2.80		4.13	5.54		0.283	0.38	
A×B (variety * treatment)	2.57	3.45		2.94	3.95		5.84	7.84		0.40	0.537	
		CV:2.72			CV:2.92			CV: 3.37			CV:2.95	

Abbreviations: CV: coefficient of variation; CD: critical difference; FYM: Farm yard manure; PSB: Phosphorus solubilizing bacteria.

Table 6. Influence of Jeevamurta, organic amendments and biofertilizers on Pod length, pod width, number of seeds per pod and hundred seed weight of pea varieties.

characters	pod length (cm)			pod width (cm)			number of seeds per pod			hundred seed weight (g)		
varieties **treatment**	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean
Jeevamurta 5% + Rhizobium 25% + FYM	10.71	10.26	10.49	1.52	1.26	1.39	8.35	9.50	8.93	39.97	42.25	41.11
Jeevamurta 10% + Rhizobium 50% + FYM	10.92	9.58	10.25	1.48	1.04	1.26	7.89	9.30	8.60	41.88	45.00	43.44
Jeevamurta 15% + Rhizobium 75% + FYM	10.89	9.24	10.07	1.61	1.11	1.36	8.66	8.85	8.76	40.98	42.25	41.62
Jeevamurta 20% + Rhizobium 100% + FYM	10.94	10.64	10.79	1.66	1.14	1.40	8.81	8.75	8.78	40.91	41.75	41.33
Jeevamurta 5% + PSB 25% + FYM	10.86	10.47	10.67	1.44	1.96	1.70	8.29	9.60	8.95	42.18	43.42	42.80
Jeevamurta 10% + PSB50% + FYM	9.81	9.77	9.79	1.57	1.05	1.31	7.99	9.60	8.79	39.45	44.64	42.05
Jeevamurta 15% + PSB75% + FYM	10.33	8.16	9.25	1.52	1.13	1.33	8.45	9.40	8.92	42.38	41.75	42.07
Jeevamurta 20% + PSB 100% + FYM	10.16	10.17	10.17	1.49	1.10	1.30	8.69	8.40	8.55	41.46	40.25	40.86
control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM)	10.24	9.44	9.84	1.53	1.45	1.23	8.54	8.85	8.70	41.63	37.50	39.57
mean	10.54	9.75		1.53	1.20		8.41	9.14		41.21	42.09	
	CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%	
variety	0.14	0.18		0.02	0.02		0.12	0.16		0.559	0.751	
treatment	0.29	0.39		0.04	0.05		0.25	0.34		1.186	1.592	
variety * treatment	0.41	0.55		0.05	0.07		0.36	0.48		1.677	2.252	
		CV:2.44			CV:2.39			CV:2.45			CV:2.43	

Abbreviations: CV: coefficient of variation; CD: critical difference; FYM: Farm yard manure; PSB: Phosphorus solubilizing bacteria.

Table 7. Influence of Jeevamurta, organic amendments and biofertilizers on Total soluble solids, plant height, pod yield per plant and pod yield per plot of pea varieties.

characters	**number of pods per plant**			**total pod yield (q/ha)**			**pod yield per plant(g)**			**pod yield per plot (kg)**		
varieties **treatments**	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean
Jeevamurta 5% + Rhizobium 25% + FYM	13.6	11.92	12.76	189.80	165.29	177.54	106.76	92.98	99.87	3.20	2.79	3.00
Jeevamurta 10% + Rhizobium 50% + FYM	14.92	12.11	13.52	211.93	167.93	189.93	119.21	94.46	106.84	3.58	2.83	3.21
Jeevamurta 15% + Rhizobium 75% + FYM	15.55	10.66	13.10	240.78	149.71	195.25	135.44	84.21	109.83	4.06	2.53	3.30
Jeevamurta 20% + Rhizobium 100% + FYM	15.84	13.75	14.80	256.54	185.78	221.16	144.30	104.50	124.40	4.33	3.14	3.73
Jeevamurta 5% + PSB 25% + FYM	14.61	10.12	12.36	228.05	145.73	186.89	128.28	81.97	105.13	3.85	2.46	3.15
Jeevamurta 10% + PSB50% + FYM	13.21	14.78	14.00	186.94	225.97	206.45	105.15	127.11	116.13	3.16	3.81	3.48
Jeevamurta 15% + PSB75% + FYM	15.22	12.61	13.92	218.08	188.31	203.20	122.67	105.927	114.30	3.68	3.18	3.43
Jeevamurta 20% + PSB 100% + FYM	12.11	11.22	11.67	179.12	175.53	177.33	100.76	98.74	99.75	3.02	2.96	2.99
control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM)	14.23	11.92	12.47	191.00	149.46	170.23	107.44	84.07	95.76	3.22	2.52	2.87
mean	14.37	11.99		211.36	172.63		118.89	97.11		3.57	2.91	
	CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%	
variety	0.16	0.22		2.49	3.35		1.71	2.30		0.04	0.05	
treatment	0.34	0.46		5.29	7.10		3.64	4.88		0.08	0.10	
variety * treatment	0.48	0.65		7.47	10.03		5.14	6.90		0.11	0.15	
		CV:2.22			CV:2.35			CV;2.87			CV:2.03	

Abbreviations: CV: coefficient of variation; CD: critical difference; FYM: Farm yard manure; PSB: Phosphorus solubilizing bacteria.

Table 8. Influence of Jeevamurta, organic amendments and biofertilizers on total pod yield (q/ha), protein content, ascorbic acid, shelling percent-age of pea varieties.

characters	**total soluble solids**			**protein content (%)**			**ascorbic acid content (mg/100g)**			**shelling percentage (%)**		
varieties **treatment**	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean
Jeevamurta 5% + Rhizobium 25% + FYM	15.70	21.90	18.80	20.26	19.41	19.84	42.55	40.77	41.66	37.00	47.11	42.06
Jeevamurta 10% + Rhizobium 50% + FYM	14.76	28.20	21.48	20.15	20.59	20.37	43.11	41.22	42.17	37.26	42.00	39.63
Jeevamurta 15% + Rhizobium 75% + FYM	15.97	20.00	17.99	19.44	19.79	19.62	43.56	41.65	42.61	37.01	47.77	42.39
Jeevamurta 20% + Rhizobium 100% + FYM	14.87	20.30	17.59	19.41	19.15	19.28	41.56	42.65	42.11	36.77	49.12	42.95
Jeevamurta 5% + PSB 25% + FYM	14.38	26.40	20.39	19.55	19.06	19.30	42.05	42.11	42.08	37.78	41.78	39.78
Jeevamurta 10% + PSB50% + FYM	13.90	21.27	17.59	20.39	18.97	19.68	42.67	43.01	42.84	36.44	42.12	39.28
Jeevamurta 15% + PSB75% + FYM	12.50	19.40	15.95	20.12	20.42	20.27	42.55	43.24	42.90	35.74	40.12	37.93
Jeevamurta 20% + PSB 100% + FYM	14.45	18.22	16.34	19.56	21.77	20.66	43.15	42.43	42.79	36.12	45.22	40.67
control (Jeevamurta 2.5%+ Rhizobium 10% + PSB 10% + FYM)	14.24	19.20	16.72	20.68	19.79	20.23	42.87	42.77	42.82	44.22	41.58	42.90
mean	14.53	21.66		19.95	19.88		42.67	42.21		37.59	44.09	
	CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%	
variety	0.29	0.39		0.27	0.36		0.55	0.74		0.63	0.85	
treatment	0.62	0.83		0.56	0.75		1.17	1.57		1.34	1.80	
variety*treatment	0.87	1.17		0.79	1.07		1.65	2.22		1.90	2.54	
		CV:2.92			CV:2.40			CV:2.35			CV:2.79	

Abbreviations: CV: coefficient of variation; CD: critical difference; FYM: Farm yard manure; PSB: Phosphorus solubilizing bacteria.

Table 9. Influence of Jeevamurta, organic amendments and biofertilizers on effective nodules per plant, available nitrogen, phosphorus, and potassium of pea varieties.

characters	**AN (kg/ha)**			**AP (kg/ha)**			**AP (kg/ha)**		
varieties treatments	GS-10	PB-89	mean	GS-10	PB-89	mean	GS-10	PB-89	mean
Jeevamurta 5% + Rhizobium 25% + FYM	341.89	353.283	347.59	23.67	21.98	22.83	141.46	142.11	142.29
Jeevamurta 10% + Rhizobium 50% + FYM	354.77	349.19	351.98	24.14	23.37	23.76	141.12	143.12	141.57
Jeevamurta 15% + Rhizobium 75% + FYM	349.287	375.15	362.22	23.78	24.12	23.95	145.74	142.02	143.42
Jeevamurta 20% + Rhizobium 100% + FYM	372.36	372.46	372.41	23.857	23.983	23.92	145.13	141.11	144.99
Jeevamurta 5% + PSB 25% + FYM	353.33	342.79	348.06	24.687	23.91	24.30	141.63	144.84	142.45
Jeevamurta 10% + PSB50% + FYM	342.933	354.51	348.72	22.907	23.65	23.28	144.89	143.27	144.39
Jeevamurta 15% + PSB75% + FYM	354.81	372.57	363.69	23.97	23.81	23.89	145.87	143.88	145.23
Jeevamurta 20% + PSB 100% + FYM	377.73	377.83	377.78	24.44	24.557	24.50	145.01	144.60	144.64
control (Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM)	351.227	353.01	352.12	22.893	22.773	22.83	141.46	144.26	142.55
mean	355.37	361.20		23.82	23.57		143.66	143.34	
	CD 5%	CD 1%		CD 5%	CD 1%		CD 5%	CD 1%	
variety	4.96	6.66		0.29	0.40		2.51	3.37	
treatment	10.53	14.13		0.62	0.84		5.32	7.14	
variety * treatment	14.89	19.99		0.88	1.18		7.52	10.10	
		CV:2.50			CV:2.24			CV:3.16	

*CV: coefficient of variation; CD: critical difference; FYM: Farm yard manure; PSB: Phosphorus solubilizing bacteria; ENPP: C; AP: Available phosphorus; AK: Available potassium.

Table 10. Scale score and percentage occurrence of powdery mildew and rust in pea varieties treated with of different concentration and types of Jeevamurta, organic amendments and biofertilizers.

	powdery mildew incidence scale scoring	rust scale scoring	PDI percentage of powdery mildew (%)	reaction	PDI percentage of rust (%)	reaction
GS-10						
Jeevamurta 5% + Rhizobium 25% + FYM	2	1	21.78	MR	16.00	MR
Jeevamurta 10% + Rhizobium 50% + FYM	1	0	10.89	R	0.00	R
Jeevamurta 15% + Rhizobium 75% + FYM	0	1	0.00	I	16.00	MR
Jeevamurta 20% + Rhizobium 100% + FYM	0	0	0.00	I	0.00	I
Jeevamurta 5% + PSB 25% + FYM	1	1	10.89	R	16.00	MR
Jeevamurta 10% + PSB 50% + FYM	1	0	10.89	R	0.00	I
Jeevamurta 15% + PSB 75% + FYM	0	0	0.00	I	0.00	I
Jeevamurta 20% + PSB 100% + FYM	0	0	0.00	I	0.00	I
PB-89						
Jeevamurta 5% + Rhizobium 25% + FYM	1	1	10.89	R	16.00	MR
Jeevamurta 10% + Rhizobium 50% + FYM	2	1	21.78	MR	16.00	MR
Jeevamurta 15% + Rhizobium 75% + FYM	0	0	0.00	I	0.00	I
Jeevamurta 20% + Rhizobium 100% + FYM	0	0	0.00	I	0.00	I
Jeevamurta 5% + PSB 25% + FYM	0	1	0.00	I	16.00	MR
Jeevamurta 10% + PSB 50% + FYM	1	0	10.89	R	0.00	I
Jeevamurta 15% + PSB 75% + FYM	0	0	0.00	I	0.00	I
Jeevamurta 20% + PSB 100% + FYM	0	0	0.00	I	0.00	I
control 1 (GS-10 + Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM)	1	0	10.89	R	0.00	I
control2 (PB-89 + Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM)	1	1	10.89	R	16.00	MR

*CV: coefficient of variation; CD: critical difference; FYM: Farm yard manure; PSB: Phosphorus solubilizing bacteria; ENPP: C; AP: Available phosphorus; AK: Available potassium.

bium 50% + FYM, Jeevamurta 5% + PSB 25% + FYM, Control 2 (PB-89 + Jeevamurta 2.5% + Rhizobium 10% + PSB 10% + FYM) in PB-89, while one the integrated module i.e. Jeevamurta 10% + Rhizobium 50% + FYM showed resistant reaction for rust incidence. However, except this resistant and moderately resistant integrated module reaction on two different pea varieties, all other treatment were shown the immune reaction for rust incidence.
Plant Growth Promoting Rhizobacteria (PGPR) is a diverse group of bacteria that colonise the rhizosphere and have the ability to enhance plant growth and development. They achieve this through direct mechanisms such as nutrient mobilisation, production of phytohormones like auxins, cytokinins, and gibberellins, improving plant nutrition through solubilisation and production of siderophores, reducing ethylene levels, and inducing systemic resistance (Sharma et al., 2022). Additionally, PGPR can indirectly promote plant growth by protecting plants from harmful microorganisms or root pathogens that hinder growth. This protection is achieved through antibiotic production, parasitism, competition for resources and niches in the rhizosphere, synthesis of extracellular enzymes to break down fungal cell walls, and reducing the toxicity of pollutants (Bhattacharyya and Jha, 2012; Brar et al., 2019).

4. Conclusion

The findings of the current study indicate that the utilisation of liquid bio formulations in conjunction with biofertilizers and organic manures led to significant variations in diverse aspects of growth, yield, quality characteristics, and soil nutrient levels. In this study, the effects of different treatment modules and their interactions were evaluated on two varieties of peas. Among these, the combination of variety "GS-10" with Jeevamurta 20%, Rhizobium 100%, and FYM, "GS-10 & PB-89" with Jeevamurta 20%, Phosphorus solubilising bacteria 100% and FYM showed the most promising results for most of the studied traits i.e. , plant height, number of pods per plant, single pod weight, total pod yield (q/ha), pod yield per plant (kg) and pod yield per plot (kg), shelling percentage, protein content, effective nodules per plant, available nitrogen and phosphorus content . Additionally, this combination was also found to be effective in controlling rust and powdery mildew disease in peas.

Authors Contributions
Conceptualization: Vandana Thakur., Parveen Sharma., Pardeep Kumar, and Sunny Sharma.; methodology, data collection and original data analysis: Vandana Thakur., Parveen Sharma., Pardeep Kumar and Payal Sharma; data presentation, writing: Vandana Thakur; Sartaj Ahmed Bhat, Rehan and Parveen Sharma; reviewing and editing: Vandana Thakur, Sunny Sharma and Shivender Thakur. All authors have read and agreed to the published version of the manuscript.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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