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Influence of integrated nutrient management and foliar NPK application on growth, yield attributes and productivity of garden pea (*Pisum sativum* L.)

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Abstract

A field experiment was conducted during the Rabi season at Lalitpur, Uttar Pradesh, India, to assess the effect of inorganic nutrient management on growth and yield of garden pea (*Pisum sativum* L.). The study was laid out in a randomized block design with three replications and nine treatments comprising different levels of recommended dose of fertilizers (RDF) and foliar application of 1% NPK at flowering, pod formation, and both stages. Results revealed that nutrient management significantly influenced growth, yield attributes, and productivity, while initial plant population remained non-significant. Among treatments, application of 100% RDF along with 1% NPK foliar spray at both flowering and pod formation stages (T₈) recorded maximum plant height (74.25 cm), pods per plant (36.80), seeds per pod (8.65), and seed index (175.60 g). The same treatment also produced the highest seed yield (2720 kg ha⁻¹), stover yield (3180 kg ha⁻¹), biological yield (5900 kg ha⁻¹), and harvest index (46.10%), along with earlier flowering (42.30 days). In contrast, control treatment recorded the lowest values. The study demonstrates that combined application of 100% RDF with foliar NPK spray improves nutrient use efficiency and enhances productivity of garden pea under semi-arid conditions.

Keywords: Garden pea, *Pisum sativum*, Integrated nutrient management, Foliar application, NPK, Yield, Productivity, RDF

Introduction

Garden pea (*Pisum sativum* L.) is an important cool-season vegetable and pulse crop cultivated widely for its high nutritional value, particularly protein, vitamins, and minerals. In addition to its dietary importance, pea plays a significant role in sustainable agriculture due to its ability to fix atmospheric nitrogen through symbiotic association with *Rhizobium*, thereby improving soil fertility and reducing dependence on synthetic nitrogen fertilizers. However, achieving its optimum yield potential requires efficient and balanced nutrient management, especially of macronutrients such as nitrogen (N), phosphorus (P), and potassium (K).

In recent years, integrated nutrient management (INM) has emerged as a sustainable approach to enhance crop productivity while maintaining soil health. INM involves the combined use of inorganic fertilizers, organic manures, and biofertilizers to ensure balanced nutrient supply and improved nutrient use efficiency. In pea cultivation, the integration of recommended doses of NPK fertilizers with farmyard manure (FYM), vermicompost, and biofertilizers such as *Rhizobium* and phosphate-solubilizing bacteria (PSB) has been reported to significantly enhance plant growth parameters including plant height, branching, nodulation, and biomass accumulation. These improvements ultimately translate into higher yield attributes such as number of pods per plant, seeds per pod, and overall green pod or seed yield compared to the sole application of either chemical fertilizers or organic sources (Kumar *et al.*, 2014; Mukherjee, 2016; Sahu *et al.*, 2024; Badr & Fayed, 2020; Choudhary *et al.*, 2024; Kumar *et al.*, 2025; Chandel *et al.*, 2023) [9, 13, 18, 1, 3, 10, 2].

Apart from soil-based nutrient management, foliar nutrition has gained increasing attention as an efficient method of supplying nutrients directly to the plant canopy during critical growth stages.

Foliar application of water-soluble NPK fertilizers or nano-NPK formulations enhances nutrient absorption efficiency, physiological activity, and nodulation in pea. This approach is particularly beneficial under conditions where soil nutrient availability is limited or nutrient losses are high. Several studies have demonstrated that foliar feeding, when combined with appropriate soil-applied recommended doses of fertilizers (RDF), significantly improves yield attributes such as pods per plant, seeds per pod, and grain yield (Rajiv *et al.*, 2022; Devi & Devi, 2024; Sepehya *et al.*, 2012; Nigam *et al.*, 2025; Youssef *et al.*, 2024; Ekka *et al.*, 2025) [15, 4, 19, 14, 23, 5]. Furthermore, recent research indicates that slightly higher levels of nutrient application, such as 125% of the recommended dose of fertilizers, may further enhance crop productivity and economic returns without causing adverse environmental effects, provided that nutrient application is tailored to soil conditions and crop requirements. The integration of higher-than-recommended NPK levels with organic and biological sources has shown promising results in improving both yield and profitability in pea cultivation systems (Shalu & Rattan, 2023; Sepehya *et al.*, 2012; Yermko *et al.*, 2024; Khan *et al.*, 2019) [24, 19, 22, 8].

Despite these advancements, there remains a need to systematically evaluate the combined effects of soil-applied RDF and foliar NPK nutrition on growth, yield attributes, nutrient use efficiency, and economic returns in garden pea. Therefore, the present investigation was undertaken to: (i) assess the effects of integrated soil and foliar nutrient management on growth parameters such as plant height, number of branches, leaf area index, and dry matter accumulation (Shalu & Rattan, 2023; Rajiv *et al.*, 2022; Sepehya *et al.*, 2012) [24, 15, 19]; (ii) quantify their impact on yield attributes and productivity including pods per plant, seeds per pod, and green pod or seed

yield (Shalu & Rattan, 2023; Kumar *et al.*, 2014; Mukherjee, 2016; Sepehya *et al.*, 2012; Badr & Fayed, 2020; Chandel *et al.*, 2023) [24, 9, 13, 19, 1, 2], and (iii) evaluate the role of integrated and foliar nutrient supply in improving nutrient use efficiency and profitability in pea-based production systems (Devi & Devi, 2024; Mukherjee, 2016; Badr & Fayed, 2020; Youssef *et al.*, 2024) [4, 13, 1, 23].

Materials and Methods

Experimental Site

The field experiment was conducted during the Rabi season at the Agriculture Research Farm, Nehru Mahavidyalaya, Lalitpur, Uttar Pradesh, India. The experimental site is located in the Bundelkhand region, which falls under the semi-arid agro-climatic zone of central India. Geographically, Lalitpur is situated at approximately 24°41' N latitude and 78°25' E longitude, with an altitude of about 300 meters above mean sea level. The region experiences a semi-arid climate characterized by hot summers and cool winters. The average annual rainfall is about 800–900 mm, most of which is received during the south-west monsoon (June to September). The temperature ranges from a maximum of around 45 °C in summer to a minimum of 5–7 °C in winter, while the mean relative humidity varies between 40–60% throughout the year.

Experimental design and treatments

The experiment was laid out in a Randomized Block Design (RBD) with three replications. A total of nine treatments comprising different levels of recommended dose of fertilizers (RDF) and foliar application of NPK were evaluated.

The treatments were as follows:

Treatment	Treatment Description
T ₁	Control (No fertilizer)
T ₂	50% RDF (10:30:10 kg NPK ha ⁻¹)
T ₃	75% RDF (15:45:15 kg NPK ha ⁻¹)
T ₄	100% RDF (20:60:20 kg NPK ha ⁻¹)
T ₅	125% RDF (25:75:25 kg NPK ha ⁻¹)
T ₆	100% RDF + 1% NPK foliar spray at flowering stage
T ₇	100% RDF + 1% NPK foliar spray at pod formation stage
T ₈	100% RDF + 1% NPK foliar spray at flowering and pod formation stages
T ₉	75% RDF + 1% NPK foliar spray at flowering and pod formation stages

Crop management

A recommended package of practices was followed to raise the crop. The fertilizers were applied as per treatment through basal application at the time of sowing. Foliar sprays of 1% NPK solution were applied at specified growth stages (flowering and/or pod formation) using a hand sprayer. All intercultural operations, irrigation, and plant protection measures were carried out uniformly across all treatments.

Observations recorded

Growth parameters

Initial plant population (m⁻²) was recorded after complete germination by counting the number of plants in a unit area using randomly placed quadrats within each plot and converting the values to per square meter basis. This observation was taken to assess uniformity of crop establishment. Plant height (cm) was measured at 30, 45 and 60 days after sowing (DAS), and at harvest. The height of five randomly selected plants from each plot was measured from ground level

to the apical tip using a measuring scale, and the mean value was expressed in centimeters. This parameter was used to evaluate vegetative growth influenced by nutrient treatments.

Phenological and yield attributes

Days to 50% flowering was recorded as the number of days from sowing to the stage when approximately 50% of plants in each plot exhibited flowering. This parameter reflects the effect of nutrient management on crop phenology. The number of pods per plant was determined by counting the total pods from five randomly selected plants at maturity and calculating the average. The number of seeds per pod was recorded by counting seeds from randomly selected pods and averaging the values. Seed index (g), representing 100-seed weight, was determined by weighing a random sample of seeds using an electronic balance.

Yield parameters

Seed yield (kg ha⁻¹) was recorded from the net plot area after

harvesting, threshing, and cleaning of seeds, and subsequently converted into yield per hectare. Stover yield (kg ha^{-1}) was obtained by weighing the remaining plant biomass after seed separation and converting it to hectare basis. Biological yield (kg ha^{-1}) was calculated as the sum of seed yield and stover yield. Harvest index (%) was computed using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

The experimental data were analyzed using analysis of variance (ANOVA) appropriate for Randomized Block Design (RBD) as described by standard statistical procedures. The significance of treatment differences was tested using the F-test, and critical difference (CD) values were calculated at $P = 0.05$ level of significance. Standard error of mean ($\text{SEm} \pm$) was also computed for each parameter.

Results

Growth parameters

The data presented in (Table 1) revealed that integrated nutrient management along with foliar NPK application significantly influenced plant growth parameters of garden pea, except Plant population did not differ significantly among treatments, as indicated by non-significant CD values. However, a slight increasing trend was observed with improved nutrient application. The highest population (32.80 m^{-2}) was recorded in treatment T_8 (100% RDF + foliar spray at flowering and pod development stages), while the lowest (29.40 m^{-2}) was noted under control (T_1). This indicates that nutrient treatments had minimal effect on germination and plant establishment. Plant height increased progressively from 30 DAS to harvest and was significantly affected by integrated nutrient management practices. Among the treatments, T_8 (100% RDF + foliar spray at flowering and pod stages) consistently recorded the maximum plant height at all growth stages, with values of 26.80 cm at 30 DAS, 51.75 cm at 45 DAS, 69.85 cm at 60 DAS, and 74.25 cm at harvest. This treatment was statistically at par with T_7 (100% RDF + spray at pod stage) and T_6 (100% RDF + spray at flowering stage) at later growth stages but remained superior to the rest of the treatments. In contrast, the minimum plant height was recorded under control (T_1), with values of 18.25 cm, 34.50 cm, 44.20 cm, and 48.20 cm at 30 DAS, 45 DAS, 60 DAS, and harvest, respectively.

Phenological and yield attributes

The data presented in Table 2 revealed that integrated nutrient management along with foliar NPK application significantly influenced phenological and yield attributes of garden pea. Days to 50% flowering was significantly reduced with increasing levels of nutrient application and foliar feeding. The earliest flowering (42.30 days) was recorded under T_8 (100% RDF + foliar spray at flowering and pod stages), which was significantly superior to most treatments, while the maximum number of days (51.80 days) was observed in control (T_1). Treatments T_7 (43.95 days) and T_6 (44.60 days) were statistically at par with T_8 , indicating that foliar nutrition accelerated crop phenology. The number of pods per plant increased significantly with improved nutrient supply. The highest number of pods per plant (36.80) was recorded in T_8 , followed by T_7 (34.25) and T_6 (33.60), all of which were significantly superior to other

treatments. The lowest number (18.40) was observed under control (T_1).

Similarly, seeds per pod showed a significant increasing trend with enhanced nutrient management. The maximum number of seeds per pod (8.65) was recorded in T_8 , which was significantly higher than all other treatments, while the minimum (5.20) was found in control.

The seed index (g) also improved significantly with integrated nutrient application. Treatment T_8 recorded the highest seed index (175.60 g), followed by T_7 (171.25 g) and T_6 (169.80 g), whereas the lowest value (145.20 g) was recorded in control.

Yield parameters

The data presented in Table 3 indicated that integrated nutrient management along with foliar NPK application significantly influenced seed yield, stover yield, biological yield, and harvest index of garden pea.

Seed yield (kg ha^{-1}) increased significantly with higher levels of nutrient application and foliar feeding. The highest seed yield (2720 kg ha^{-1}) was recorded under T_8 (100% RDF + foliar spray at flowering and pod stages), which was significantly superior to all other treatments. This was followed by T_7 (2555 kg ha^{-1}) and T_6 (2480 kg ha^{-1}), while the lowest seed yield (1350 kg ha^{-1}) was observed in control (T_1).

A similar trend was observed in stover yield (kg ha^{-1}), where T_8 recorded the maximum value (3180 kg ha^{-1}), followed by T_7 (3080 kg ha^{-1}) and T_6 (3040 kg ha^{-1}). The minimum stover yield (2300 kg ha^{-1}) was recorded under control.

The biological yield (kg ha^{-1}) also showed significant improvement with integrated nutrient management. Treatment T_8 recorded the highest biological yield (5900 kg ha^{-1}), which was significantly higher than other treatments, while the lowest (3650 kg ha^{-1}) was noted in control.

The harvest index (%) increased progressively with improved nutrient supply and foliar application. The highest harvest index (46.10%) was recorded under T_8 , which was statistically at par with T_7 (45.34%) and T_6 (44.93%), but significantly superior to the remaining treatments. The lowest harvest index (36.98%) was observed in control.

Discussion

Application of integrated nutrient management and foliar NPK sprays exerted a pronounced positive effect on the growth attributes of garden pea. Plant population m^{-2} was only marginally influenced and remained statistically non-significant, indicating that nutrient management mainly affected subsequent vegetative growth rather than initial stand establishment. This agrees with studies where fertilizer regime rarely alters final plant density but strongly modifies growth and yield traits in pea. Plant height increased consistently with incremental levels of RDF from 50% to 125%, with 100% RDF (T_4) and 125% RDF (T_5) recording substantially taller plants at all observation stages compared with the unfertilized control (T_1). This trend reflects improved nutrient supply, particularly nitrogen and phosphorus, which enhances cell division, leaf area development, and dry matter accumulation, leading to more vigorous vegetative growth (Kumar *et al.*, 2025; Reddy *et al.*, 2023; Khan *et al.*, 2019) [10, 16, 8]. Similar significant increases in pea plant height with higher NPK levels up to 125% RDF have been reported under different agro-ecological conditions (Kumar *et al.*, 2025; Badr & Fayed, 2020) [10, 1]. Beyond basal fertilization, foliar NPK application further amplified plant height. Treatments receiving 100% RDF combined with foliar spray at flowering (T_6), at pod stage (T_7), and especially at both

stages (T_8), recorded the maximum plant height at 45, 60 DAS and at harvest. This suggests that supplemental foliar feeding at critical reproductive stages effectively meets peak nutrient demand when root uptake alone may be insufficient. Comparable responses have been documented where foliar sprays of NPK or micronutrients (e.g., B, Zn) with 100% RDF significantly increased plant height, leaf number, dry matter, and yield attributes in field pea (Reddy *et al.*, 2023; Nigam *et al.*, 2025; Badr & Fayed, 2020) [16, 14, 11]. Studies on foliar phosphorus and potassium nutrition in pea likewise show improved chlorophyll status, photosynthetic efficiency, and biomass accumulation, translating into taller plants and higher yields (Škarpa *et al.*, 2021; J *et al.*, 2022) [21, 7]. The superiority of combined soil and foliar nutrition over sole RDF or control treatments supports the concept of integrated nutrient management, wherein balanced basal NPK, complemented by timely foliar feeding, optimizes nutrient availability, promotes sustained vegetative growth, and prepares the crop for better yield expression (Sepehya *et al.*, 2012; Sepehya *et al.*, 2015; Rajiv *et al.*, 2022) [19, 20, 15].

Days to 50% flowering decreased progressively with increasing fertilizer levels and were minimum under 100% RDF with foliar spray at both flowering and pod stages (T_8), followed by 100% RDF + spray at pod (T_7). This earliness under higher and well-timed nutrient supply reflects improved vegetative vigor and quicker transition to reproductive phase, similar to reports where integrated NPK and organics significantly reduced days to 50% flowering in pea (Shalu & Rattan, 2023; Mahmoud *et al.*, 2020) [24, 12]. Yield components responded strongly and significantly. Pods plant⁻¹, seeds pod⁻¹ and seed index increased steadily from control through 50, 75 and 100% RDF, with 125% RDF (T_5) giving further, though smaller, gains over 100% RDF (T_4). This pattern is consistent with studies where higher or optimized NPK levels raised pod number, seeds per pod and test weight in field and garden pea (Reddy *et al.*, 2023; Kumar *et al.*, 2025; Sepehya *et al.*, 2012; Janusauskaite, 2023) [16, 10, 19, 6]. Enhanced nutrient availability improves flower retention, pod set and seed filling, leading to more pods and heavier seeds (Reddy *et al.*, 2023; Kumar *et al.*, 2025; Sahoo *et al.*, 2024) [16, 10, 17]. Superiority of combined soil and foliar nutrition is clearly evident. Treatments with 100% RDF plus foliar NPK at flowering (T_6), at pod stage (T_7) and especially at both stages (T_8) recorded the highest pods plant⁻¹, seeds pod⁻¹ and seed index, with T_8 (36.8 pods plant⁻¹, 8.65 seeds pod⁻¹ and 175.6 g seed index) outperforming all other treatments. Similar synergistic effects of basal NPK with foliar NPK or KNO₃ in pea particularly when applied at flowering and pod development have been shown to significantly enhance pod number, seeds pod⁻¹, test weight, seed yield and energy productivity (J *et al.*, 2022) [7]. Studies using foliar NPK 19:19:19 or P/K-rich sprays at pre-flowering and pod initiation likewise report maximum pods plant⁻¹ and seeds pod⁻¹ under the highest fertility plus foliar regimes (Škarpa *et al.*, 2021) [21]. These results reinforce the concept that integrated nutrient management, combining adequate basal RDF with stage-specific foliar feeding, optimizes nutrient supply during critical reproductive stages, thereby improving flowering behavior, pod set, seed formation and seed size. Such integrated strategies have repeatedly been associated with superior yield attributes and productivity in pea under diverse environments (Reddy *et al.*, 2023; Kumar *et al.*, 2025; Shalu & Rattan, 2023; Sepehya *et al.*, 2012; Sahoo *et al.*, 2024) [16, 10, 24, 19, 17].

Seed, stover and biological yields of garden pea responded markedly to increasing levels of RDF and to foliar NPK

application. Seed yield rose from 1350 kg ha⁻¹ in the unfertilized control (T_1) to 2325 kg ha⁻¹ at 125% RDF (T_5), and further to 2720 kg ha⁻¹ when 100% RDF was combined with foliar NPK sprays at both flowering and pod stages (T_8). This pattern indicates that while higher basal fertilization improves productivity, synchronizing additional NPK supply with peak reproductive demand optimizes assimilate production and partitioning to seeds. Similar yield enhancement with 125% RDF over 75-100% RDF, and with foliar NPK at pre-flowering and pod initiation, has been reported in fieldpea under Rajasthan conditions, where 125% RDF and NPK (19:19:19) @ 0.5% gave the highest grain yield and yield attributes.

The data clearly indicate that both increasing levels of RDF and foliar NPK application significantly enhanced seed, stover and biological yields, as well as harvest index of garden pea. Seed yield increased from 1350 kg ha⁻¹ in the control (T_1) to 2325 kg ha⁻¹ at 125% RDF (T_5), demonstrating that the crop was strongly nutrient-limited and responded positively to higher basal NPK. Similar yield benefits from 120-125% of recommended NPK have been reported in garden pea and fieldpea, where 125% RDF maximized growth and yield attributes under different agro-climatic conditions (Kumar *et al.*, 2025; Chandel *et al.*, 2023) [10, 2]. Beyond basal fertilization, foliar NPK sprays further improved performance. At the same 100% RDF, seed yield increased from 2240 kg ha⁻¹ (T_4) to 2480 and 2555 kg ha⁻¹ when foliar NPK was applied at flowering (T_6) or pod stage (T_7), and peaked at 2720 kg ha⁻¹ when sprays were given at both stages (T_8). Stover and biological yields followed the same trend, rising from 2910 and 5150 kg ha⁻¹ (T_4) to 3180 and 5900 kg ha⁻¹ (T_8), indicating improved total biomass production. These responses agree with studies in pea and fieldpea where foliar NPK, particularly NPK 19:19:19 applied at pre-flowering and pod initiation, significantly increased pods per plant, seed yield and total biomass over RDF alone (Reddy *et al.*, 2023; J *et al.*, 2022) [16, 7]. Harvest index improved progressively from 36.98% in the control to 44.03% at 125% RDF (T_5) and reached a maximum of 46.10% with 100% RDF plus two foliar sprays (T_8), showing not only greater biomass but also more efficient partitioning of assimilates to seeds. Comparable increases in harvest index under higher fertility and integrated nutrient management have been documented in pea and fieldpea when 100–125% RDF is combined with foliar nutrients or micronutrients (Reddy *et al.*, 2023; Sepehya *et al.*, 2012; Kumari *et al.*, 2012; Chandel *et al.*, 2023) [16, 19, 11, 2]. Overall, the results corroborate broader evidence that optimizing pea productivity requires both adequate or slightly supra-optimal basal NPK and timely foliar nutrient supply at critical reproductive stages, which together enhance growth, yield components, total biomass and harvest index more than basal fertilization alone (Reddy *et al.*, 2023; Kumar *et al.*, 2025; J *et al.*, 2022; Kumari *et al.*, 2012; Chandel *et al.*, 2023) [16, 10, 7, 11, 2].

Conclusion

The present investigation clearly demonstrated that integrated nutrient management combined with foliar application of NPK significantly improved growth, yield attributes, and productivity of garden pea (*Pisum sativum* L.) under semi-arid conditions. Among all treatments, application of 100% recommended dose of fertilizers (RDF) along with 1% NPK foliar spray at both flowering and pod formation stages (T_8) proved to be the most effective. This treatment resulted in maximum plant height, number of pods per plant, seeds per pod, and seed index, which ultimately translated into higher seed yield (2720 kg ha⁻¹), stover yield, biological yield, and harvest index. The improvement can

be attributed to enhanced nutrient use efficiency, better physiological activity, and timely availability of nutrients during critical growth stages. While higher basal fertilizer levels (125% RDF) also improved performance, the combined approach of optimum RDF with foliar feeding was more efficient and sustainable. Therefore, it can be concluded that integration of 100% RDF with foliar NPK application at flowering and pod formation stages is a promising strategy for maximizing productivity and nutrient use efficiency in garden pea cultivation.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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