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Impact of soil-applied fertilizers and foliar nutrients on growth and yield of soybean in a soybean–linseed cropping sequence

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Abstract

Traditional fertilizer application can be inefficient due to soil properties limiting nutrient availability. The rising cost of commercial fertilizers underscores the potential of foliar fertilization as a viable alternative method. Foliar fertilization addresses deficiencies, optimizes nutrition, supports growth, enhances disease resistance, and improves crop quality. Advancements in agriculture focus on cost-effective production, soil quality maintenance, and agro-ecosystem health. The judicious use of nutrients ensures sustainability and efficiency. A field experiment was carried out during the 2022 kharif season at Birsa Agricultural University's experimental farm (kanke) in Ranchi, Jharkhand. The purpose of the experiment was to investigate the effectiveness of foliar nutrient treatment and various levels of soil fertilizer on the growth, yield attributes, and yield of soybean. A split plot design was used for the experiment, and it was replicated three times. The experiment consisted of three main plots, each of which received a different amount of fertilizer: 100% RDF (R₁), 50% RDF (R₂), and 0% RDF (R₃). The fertilizer was applied as a basal application at the time of sowing, and there were six subplots that were comprised of different foliar applications of nutrients. F₁- water spray, F₂- 0.5% nano-urea, F₃- 2% urea, F₄- 2% DAP, F₅- 2% NPK (18:18:18), and F₆- 2% seaweed sap were all sprayed foliarly during the pre-flowering and pod formation stages. According to the findings, soil application of 100% RDF had a substantial influence on soybean growth, yield characteristics, and yield when compared to 50% RDF and 0% RDF. In the case of foliar application, two foliar sprays of 2% NPK (18:18:18) during the pre-flowering and pod formation stages significantly improved growth and yield characteristics and resulted in the highest grain yield (1663 kg/ha) and straw yield (2466 kg/ha) above water spray (1127 kg/ha grain yield and 1809 kg/ha) under soybean-linseed sequence.

Keywords: Soybean, foliar nutrients, soil fertilizer application, NPK (18:18:18), growth

Introduction

Globally, one of the most important grain legume crop is the soybean (*Glycine max* L. Merr.). It is recognized for its wide range of industrial applications, great productivity, and profitability. A high-protein oilseed and legume crop, soybean have edible oil (18–20%) and high-quality proteins (38–40%) in their seeds. Because legumes fix nitrogen in the soil and reduce the demand for chemical fertilizers, they are essential in crop rotation and agriculture systems. It has the potential to assist in addressing national security challenges and can be grown in a range of climates Dass *et al.*, (2017) [8]. After mustard and rapeseed, soybean is the second most produced oilseed in India (130.62 lakh tons). (Economic and Statistics Directorate, 2023-24). A quarter of the edible oil produced worldwide comes from soybean. (Jaybhay *et al.*, 2021) [16]. India's soybean productivity is 1 t/ha (SOPA, 2023) [31], which is significantly lower than the global average productivity of 2.8 t/ha in 2023 (USDA). Among the many production-related elements, nutrition is crucial for plant growth and reproduction, directly affecting soybean production. Soil application of nutrient can help meet plant nutritional demands. However, in terms of the nutrients' bioavailability for plants, it has many drawbacks. Since most micronutrients and certain minerals, including potassium (K) and phosphorus (P), are primarily fixed on the soil

complex as insoluble forms, their availability in soil solution is comparatively low (Alshaal, T and EL-Ramady, 2017) ^[1]. Application of excessive fertilizer to the soil can cause imbalances, acidification, salinization, and soil microbe disruption, negatively affecting soil quality. Foliar fertilization, which allows for direct nutrient absorption by plant leaves, is a sustainable alternative to soil-based fertilization. It improves fertilizer usage efficiency, reduces environmental pollution, reduce nutrient losses through leaching and volatilization and encourages rapid nutrient uptake. Foliar spray is sustainable and encourages optimal plant growth without impacting soil health. Additionally, as soil fertilization alone may not fully meet plant nutrient demands, foliar application offers a fast and efficient method to enhance crop growth, facilitates nutrient availability during pod filling stage (Meena *et al.*, 2018) ^[20]. Although foliar fertilization of trace elements has been prioritized, it has been frequently noted that foliar application of macronutrients also positively affects plant metabolisms and, eventually, yield. Meena *et al.*, (2017) ^[19]. In soybean cultivation, foliar nutrition application is an efficient way to control flower senescence and inadequate pod filling. This approach increases plant health and production potential, especially during periods of high nutrient demand, by delaying flower senescence, increasing pod growth, and promoting seed filling (Singh *et al.*, 2018) ^[28]. This field experiment was conducted to increase soybean production by supplying nutrients by foliar application in order to find out the manner in which soybeans responded to foliar nutrition spray and to assess its effect on plant growth and yield.

Materials and Methods

Experimental site

During the 2022–2023 kharif season, a field experiment was conducted at Birsa Agricultural University's Agronomical Research Farm in Kanke, Ranchi 23°31'N, 85°19'E, 625 m above sea level) under Ph.D. research program. The area has a sub-humid climate characterized by hot summers and cold winters. On average, the location receives 1397.7 mm of rainfall annually (based on a 50-year average), with around 85% of the total rainfall occurring during the four monsoon months of June to September. During the cropping period from July to October 2022–2023, the area received 1683.2 mm of rainfall, with a maximum average temperature of 34.2°C and a minimum average temperature of 23.5°C. The initial soil conditions (0–15 cm) of the experimental field were sandy loam in texture (60.84% sand, 22.77% silt, and 16.39% clay), with an acidic pH of 5.56. The soil had low levels of available nitrogen (218.63 kg/ha), medium organic carbon (5.91 g/kg), and medium levels of available phosphorus (15.75 kg/ha) and potassium (178.32 kg/ha).

Experimental design and treatment details

The experiments were laid out in split plot design with three replications having eighteen treatment combinations viz. three levels of basal fertilizer application (R_1 – 0% RDF, R_2 – 50% RDF, R_3 – 100% RDF) in main plot and six different foliar spray of water soluble fertilizers at pre flowering stage and pod initiation stages F_1 – water spray, F_2 – 0.5% nano urea, F_3 – 2% urea, F_4 – 2% DAP, F_5 – 2% NPK (18:18:18), and F_6 – 2% seaweed sap. Recommended dose of fertilizer was 25:60:40:20 (N: P_2O_5 : K_2O : S kg/ha) was applied through, di-ammonium phosphate (DAP), muriate of potash (MOP) and gypsum respectively and were applied uniformly to all the plots, all fertilizer were applied in a single dose i.e. basal application. Two foliar spray of nutrient was done as per the treatments at

pre- flowering stage and pod initiation stage using knapsack sprayer.

Sowing and crop management

Soybean variety “RSC 10-46” released from IISR, Indore was seeded directly with a seed rate of 70 kg/ ha at row to row and plant-to-plant spacing of 30 cm and 10cm, respectively on 3rd July 2022 after basal application of fertilizer with a plot size of 5.4 m x 4.3 m. Before sowing, the seeds were first treated with *Bradyrhizobium japonicum* culture @5g/kg seed. Weeding and plant protection measures were undertaken when required. At physiological maturity crop was harvested plot-wise.

Collection of data on growth, yield and its attributes

The data on plant height (cm) and number of pods per plant were recorded at the time of harvest whereas, the data on seed per pod, 100 seed weight (g), seed yield (kg /ha), seed yield (kg/ha), harvest index (%) were recorded after harvest. The biometric observation were taken from 5 randomly selected plants of each plot. Data on number of root nodules per plant and nodule dry weight were recorded at 45 DAS. The plant dry weight destructive sampling procedure was followed and three soybean plants were uprooted from 2nd row at either side of plots from ground level at 90 DAS and at maturity. Then samples were dried, first in sun and then in an oven at $65 \pm 5^\circ\text{C}$ till constant weight obtained. Dry weight obtained was converted into g/m^2 .

Crop growth rate (CGR) is the increase in dry weight of a plant per unit time denotes overall growth rate of crop, expressed in gram of dry matter produce per sq. meter per day ($\text{g/m}^2/\text{day}$) and was calculated by using standard formulae as suggested by Watson (1952) ^[35]. It was calculated in time interval between 90 DAS maturity of Soybean crop by using formula:

$$\text{CGR (g/m}^2/\text{day)} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A}$$

Where W_1 and W_2 represent the dry weight of the plant at the beginning and end of the time interval T_1 and T_2 respectively, and A is unit area occupied by plants (m^2)

Harvest index (HI) is expressed in percentage and determined as the ratio of economic yield (grain yield) to biological yield (grain + straw yield) using the formula suggested by Singh and Stoskopt (1972) ^[29].

$$\text{Harvest Index (\%)} = \frac{\text{Grain Yield (kg/ha)}}{\text{Grain yield (kg/ha)} + \text{Straw yield (kg/ha)}} \times 100$$

Statistical analysis

The analysis of variance (ANOVA) method, as described by Gomez and Gomez (1984) ^[12], was used to statistically analyze the data collected for various attributes. The comparison's relevance was examined. A 5% probability of error was used to calculate the significant difference values. Critical difference (CD) values were calculated for the comparison of the treatment means in cases where the variance ratio (F value) was determined to be significant.

Results and Discussion

Growth attributes

Plant height

Plant height at harvest as influenced by various levels of soil

fertilizer and foliar application is evident from the data are presented in Table 1. As the crop matured, the plant's height gradually increased. Among the various levels of soil fertilizer, R₃- 100% RDF produced taller plant (78.30 cm) and showed its significant superiority over R₂- 50% RDF (66.48 cm). The plant height was found to be lowest and were failed to cause significant variation with R₁- 0% RDF (54.72 cm) at maturity. This increase in plant height might be due to greater availability of nutrient which helped in acceleration of various metabolic processes with higher level of fertilizer application. Secondly it might be the availability of optimum levels of N, P and K which helped in better absorption of nutrients coupled with proper distribution of assimilates the plant exhibited increased growth and development, including the elongation of stems and an overall taller stature (Taiz *et al.*, 2015)^[32] and (Shinde *et al.*, 2015)^[27]. This enhanced nutrient supply supports greater cell division and expansion, promoting the upward growth of the plant, which ultimately results in increased plant height. (Pandao *et al.*, 2025).

Foliar applications applied at both the pre-flowering and capsule formation stages had a notable impact on plant height, with significant improvements observed. the two sprays of F5- 2% NPK (18:18:18) recorded significantly taller plant (73.31 cm) which was statistically at par with F2-0.5% Nano urea (72.84 cm) and F6- 2% seaweed sap (68.63 cm) and statistically the lowest plant height (55.14 cm) was obtained with the application of water spray. It could be due to the availability of nitrogen, phosphorus, and potassium by foliar spray of 18:18:18 NPK fertilizer; its balanced application plays crucial roles in plant metabolism, cell division, and elongation, supporting vigorous plant growth, floral development, and flower bearing. Additionally, nitrogen increases photosynthetic activity and helps maintain auxin levels, promoting cell division, multiplication, and tissue differentiation. Which improves overall plant development and eventually increases plant height. The results are in line with the findings of Singh *et al.*, (2018)^[28] and Sarika *et al.*, (2022)^[26].

Nodule count and nodule weight.

The buildup of nodule count and weight is crucial for the growth and development of leguminous plants, as root nodules play a key role in nitrogen fixation. Scrutiny of the data (Table 1. Fig 1) revealed that soil application of higher level of fertilizer i.e. application of 100% RDF nutrients significantly influenced the nodule count (51.29) and nodule weight (0.175 g) at 45 DAS which remained comparable to 50% RDF, i.e. nodule count (44.93) and nodule weight (0.162 g). However, the lowest nodule count and weight were reported with 0% RDF. It seems possible that 100% RDF ensures that the plant has access to an adequate and balanced supply of essential nutrients particularly nitrogen, phosphorus, and potassium Phosphorus increases the number of nodules per plant, enhancing rhizobial activity and promoting plant growth, supporting the bacteria's efficiency and encouraging the formation of more nodules This promotes better overall plant growth, including the development of a stronger and more extensive root system, which provides more space for nodule formation and significantly improves both the number and weight of the nodules. The similar results of increment in nodule count and weight due application of higher level fertilizer in chickpea was reported by Jat *et al.*, (2023)^[15]. The results corroborate the findings of Rathore *et al.*, (2010)^[25].

Further analysis of data (Table 2) revealed that various foliar applications of nutrients failed to cause significant variation in the nodule count and nodule weight of soybeans and were non-

significant. Through the two sprays of F5-2% NPK (18:18:18) at the pre-flowering and pod initiation stage maximum nodule count (42.41) and nodule weight (0.163 g) at 45 DAS was recorded. Foliar application of nutrient helps in expanding of root system and creating more sites for rhizobia infection and proliferation in the rhizosphere, enhancing more effective nodules formation, and increasing dry weight. Higher in weight and nodule count since availability of necessary nutrients readily and quickly helps soybean plants. Similar results were reported by Meena *et al.*, (2017)^[19] and Jaybhay *et al.*, (2021)^[16]. The interaction effect was found non-significant in respect of nodule count and weight at any stage of growth stages.

Dry matter accumulation

Dry matter accumulation is a crucial indicator of crop growth rate and biomass production, indicating a plant's capacity to convert energy into usable tissue. As soybeans grow, this accumulation increases steadily reaching its peak at harvest, indicating maximum growth and biomass production. It is evident from close observation of data (Table 1) that the application of different fertilizer levels as soil application significantly influenced dry matter accumulation at harvest. The maximum dry matter accumulation was recorded with R₃-100% RDF (550.51 g/m²), which showed its significant superiority over 50% RDF (405.76 g/m²) and 0% RDF (238.26 g/m²). This might be attained as a result of substantially increased crop growth contributing characteristics across all growth stages. Higher fertility levels made nutrients more readily available and easier for plants to absorb, which led to more vegetative growth. The plant grew taller because of greater cell division, enlargement, and elongation brought on by improved photosynthesis, which improved the interception, absorption, and utilization of light energy. As a result, it increased the accumulation of dry matter. The presented results about soybean are also analogous to the findings of Sarika *et al.*, (2022)^[26] Dehury *et al.*, (2024)^[10] and Nataraja *et al.*, (2021)^[21].

Correspondingly, analysis of data revealed that dry matter accumulation of soybean increases progressively and was significantly influenced by foliar application, application of 2% NPK (18:18:18) at pre- flowering and pod initiation stage resulted in maximum dry matter accumulation (474.88 g/m²) closely followed by 0.5% Nano-urea (448.07 g/m²) and 2% seaweed sap (424.88 g/m²). However, F1-water spray, was shown to have the lowest dry matter accumulation. Foliar fertilization increases dry matter production per square meter by enhancing crop growth and photosynthetic activity. Foliar fertilization provides a balanced proportion of macronutrients at the appropriate vegetative stage, resulting in better crop growth, photosynthetic activity, and better supply of photosynthates. This leads to better supply of carbohydrates and higher dry matter production Jat *et al.*, (2022)^[15]. Additionally, overall plant growth, including height, nodule count, and leaf size, contributes to higher chlorophyll area and improved photosynthetic efficiency, resulted in higher dry matter accumulation. This result also confirmed in soybean by Singh *et al.*, (2018)^[28] and Bayal *et al.*, (2022). Interaction between the soil application of different level of nutrients and foliar application of nutrients did not cause significant effects on nodule count and nodule weight.

Crop growth rate

Any crop's exponential growth is determined by its crop growth rate (CGR) (Table1). After ninety days, soybeans enter their maturation phase. The seeds grow inside the pods as the plant

dries out. The plant's growth rate has significantly slowed since its energy is now focused on seed filling and ripening. After ninety days, the plant will be nearly ready for harvest. Significant variance in crop growth rate (CGR) was noted during the 90 DAS-at harvest period. The results showed that increasing the level of fertilizer applied to the soil enhanced soybean crop growth rate substantially. 100% RDF provided the significantly maximum crop growth rate (5.07 g/m²/day) and showed to be significantly superior to 50% RDF (3.65 g/m²/day) and lowest crop growth rate was calculated with 0% RDF (2.36 g/m²/day). The application of a higher level of nutrients might have helped the plants make better use of available resources. This benefit of additional nutrients contributed to an improvement in the crop growth rate (CGR). This result is in cognizance with finding of Singh *et al.*, (2023) ^[30] and Balwan *et al.*, (2017) ^[2]. Applying the complete RDF ensures that the crop obtains an adequate supply of all essential nutrients. This results in improved root development, stronger vegetative growth, more effective photosynthesis, and enhanced dry matter accumulation throughout the growth period, leading to higher crop growth rates. Similar results confirm the prior observation made by Vishwakarma (2023) ^[34] and Dass *et al.*, (2022) ^[9].

Comparably, among different foliar applications, the application of 2% NPK (19:19:19) had the significantly higher CGR (4.52 g/m²/day) was noted during the 90 DAS-at harvest period over the application of water spray (2.80 g/m²/day), regardless of fertilizer sprays. This was comparable to the estimation of 0.5% nano-urea and 2% seaweed sap (Table 1). This could be due to availability of nutrients and efficient macronutrient conversion at the photosynthesis site, along with maximum photosynthate accumulation toward dry matter accumulation through ongoing photosynthesis, may have contributed to the notable improvement in CGR. In cluster frontline demonstration, similar results were reported for other crops by Banerjee *et al.*, (2021) ^[3] in peas and Prajapati *et al.*, (2019) ^[24]. The soybean crop growth rate was not significantly impacted by the interaction between soil application of different level of nutrients and foliar application of nutrients.

Yield attributes

Analysis of the data on yield attributes as influenced by application of different fertilizer level applied to soil are presented in Table 2 revealed that application of fertility level of 100% RDF to the soil significantly increased yield attributes character like pod per plant (45.87). However failed to cause significant variation in number of seed per pod and 100 seed weight. The maximum number of seed per pod (2.29) and 100 seed weight (10.26 g) was recorded with 100% RDF. The increased dose of fertility levels likely promotes better crop growth, leading to higher soybean production. The positive effects of this higher fertility enable the plants to absorb more nutrients and moisture, which enhances their ability to produce a greater amount of photosynthates for the plant. This improvement in crop growth results in better yield-contributing factors, such as improved seed setting, which in turn increases the 100-seed weight. The nutrient levels had a significant impact on both grain and straw yield. Malik *et al.*, (2008) ^[18] and Joshi and Billore (2004) ^[17] and Sarika *et al.*, (2022) ^[26]

Similarly, among various foliar application two spray of 2% NPK foliar spray of 18:18:18 at pre flowering and pod initiation stage was shown to be considerably more efficient in increasing

yield contributing characteristics such as pod per plant (41.46), but it did not significantly affect the number of seeds per pod and 100 seeds weight. However, F4- 2% NPK (18:18:18) was found to recorded the maximum number of seeds per pod (2.22) and 100 seed weight (10.22 g). Whereas, lowest seed per pod (2.14) and 100 seed weight (9.55 g) was received from water spray. The probable reason may be due to balanced NPK treatment promoted tissue differentiation, cell division, and multiplication, leading to increased plant height and branching. This resulted in increased capsules per plant, seeds per capsule, and seed weight. Spraying the optimal amount of nutrients at the right growth stage may increase yield-contributing characteristics. Optimal foliar supply enhances photosynthesis transfer, resulting in better yield attributing characteristics and yield. Jadhav and Kulkarni (2016) ^[13], Das and Jana (2015) ^[7] and Dass *et al.*, (2022) ^[9]. The interaction of foliar and soil fertilizer application at varying levels did not significantly affect the yield attributes of the soybean crop

Yield

It is evident from data (Table 2. Fig 2 and 3) revealed that different level of fertilizer applied to soil exhibited significant variation in grain yield and straw yield. Among fertilizer levels, 100% RDF produced the highest grain yield (1894 kg/ha) and straw yield (2781 kg/ha, Fig 2) of soybean, but it superior to 50% RDF significantly. Minimum grain yield (884 kg/ha) and straw yield (1428 kg/ha) was observed in 0% RDF. However, the harvest index was determined to be non-significant. The increase in soybean grain and straw yield may be due to nutrient supply, improved absorption and translocation within the plant system, and improved pod and seed setting from higher level of fertilizer application. Higher fertilizer application also has a profound effect on straw yield, as it increases plant height, branching, and dry matter accumulation, leading to better pod and seed setting and ultimately higher grain yield. This is attributed to the improved yield attributes and proper development of soybean plants. This results are inconformity by Choudhary and Yadav (2011) ^[6] and Bhanwariya *et al.*, (2013) ^[4].

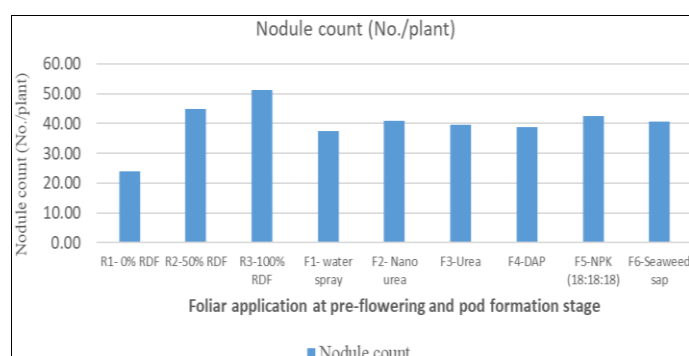
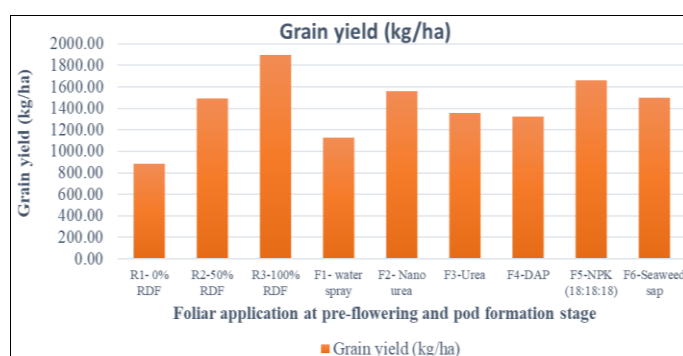
Foliar fertilizer application was found to have a substantial effect on yield. While 2% NPK (18:18:18) was statistically equivalent to 0.5% Nano urea, it produced the highest grain (1663 kg/ha) and straw (2466 kg/ha) yields. The water spray treatment, however, produced the least amount of grain and straw (1127.43 kg/ha and 1809 kg/ha). The harvest index was found to have an insignificant effect in regard to this. According to Paikra *et al.* (2018) ^[22], optimal foliar nutrient supply improves photosynthate translocation, leading to better yield attributes and higher yield. Balanced foliar fertilization increases nutrient uptake and efficient translocation to the reproductive areas, enhancing dry matter accumulation, branch number, pod count, seed number per pod, and seed weight, which boost both grain and straw yields. Further emphasizes that this treatment ensures proper absorption of NPK minerals, preventing deficiencies and promoting enhanced growth, productivity, and physiological traits, ultimately improving grain and straw yield. This perspective is cognizant of the finding of Sarika *et al.*, (2022) ^[26] and Hemida *et al.*, (2023) ^[14]. The soybean crop's yield characteristics were not considerably impacted by the interaction of foliar and soil fertilizer application at different levels.

Table 1: Effect of soil application of different levels of fertilizer and foliar application of nutrients on growth attributes of soybean in soybean – linseed sequence during rabi season 2022- 2023.

Treatments	Plant height (cm)	Nodule count (No./plant)	Nodule weight/plant (g)	Dry matter accumulation g/m ²	CGR (g/m ² /day)
	At harvest	45 DAS	45 DAS	At harvest	90 DAS- At harvest
A: Soil application of nutrients					
R1: 0% RDF	54.72	23.81	0.127	238.26	2.36
R2: 50% RDF	66.48	44.93	0.162	405.76	3.65
R3: 100% RDF	78.30	51.29	0.175	550.51	5.07
S.Em+	1.99	2.03	0.003	5.068	0.12
CD (P=0.05)	7.25	7.38	0.013	18.43	0.45
B: Foliar application of nutrients					
F1: Water spray	55.14	37.50	0.149	308.52	2.80
F2: 0.5% Nano urea	72.84	41.03	0.160	448.07	4.25
F3: 2% Urea	64.74	39.60	0.151	371.87	3.36
F4: 2% DAP	64.33	38.91	0.150	360.81	3.34
F5: 2% NPK (18:18:18)	73.31	42.41	0.163	474.88	4.52
F6: 2% Seaweed sap	68.63	40.62	0.156	424.92	3.89
S.Em+	2.74	1.46	0.005	13.37	0.18
CD (P=0.05)	7.91	NS	NS	38.60	0.52
CV (%)	12.35	10.94	10.45	10.07	14.75
Interaction (A x B)					
S.Em+	4.743	2.53	0.009	23.15	0.32
CD (P=0.05)	NS	NS	NS	NS	NS

Table 2: Effect of soil application of different levels of fertilizer and foliar application of nutrients on yield attributes of soybean in soybean-linseed sequence during kharif season 2022- 2023.

Treatments	Pod per plant (No.)	Seed per pod (No.)	100 seed weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
A: Soil application of nutrients						
R1: 0% RDF	28.06	2.09	9.46	884	1428	38.14
R2: 50% RDF	38.16	2.15	9.67	1490	2334	38.94
R3: 100% RDF	45.87	2.29	10.26	1894	2781	40.43
S.Em+	0.61	0.06	0.351	21.86	49.52	0.71
CD (P=0.05)	2.20	NS	NS	79.47	180.04	NS
B: Foliar application of nutrients						
F1: Water spray	30.93	2.14	9.55	1127	1809	38.03
F2: 0.5% Nano urea	40.05	2.19	10.16	1562	2372	39.49
F3: 2% Urea	36.90	2.17	9.59	1360	2105	39.10
F4: 2% DAP	36.07	2.15	9.56	1321	2071	38.80
F5: 2% NPK (18:18:18)	41.46	2.22	10.22	1663	2466	40.13
F6: 2% Seaweed sap	38.76	2.18	9.69	1502	2262	39.47
S.Em+	1.10	0.09	0.31	58.98	89.02	0.81
CD (P=0.05)	3.18	NS	NS	170.33	257.08	NS
CV (%)	8.84	12.93	9.47	12.44	12.25	6.21
Interaction (A x B)						
S.Em+	1.91	0.162	0.524	102.16	154.18	1.47
CD (P=0.05)	NS	NS	NS	NS	NS	NS

**Fig 1:** Effect of different levels of fertilizer applied to soil and foliar application of nutrients on Nodule count of soybean in soybean linseed sequence**Fig 2:** Effect of different levels of fertilizer applied to soil and foliar application of nutrients on grain yield of soybean in soybean linseed sequence

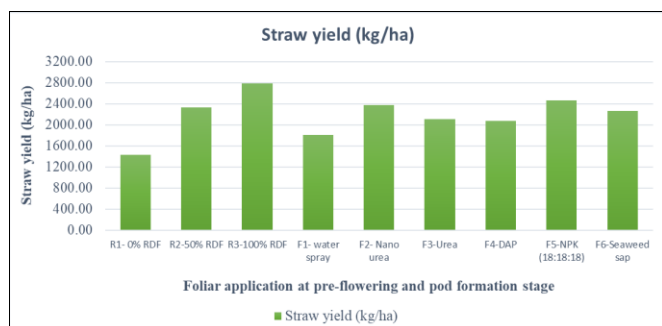


Fig 3: Effect of different levels of fertilizer applied to soil and foliar application of nutrients on straw yield of soybean in soybean linseed sequence.

Conclusion

The study clearly demonstrated that higher levels of nitrogen application, especially when applying 100% RDF (20 N: 60 P₂O₅: 40 K₂O: 20 S kg/ha), had a significant and consistent positive impact on various growth and yield parameters of soybean plants. This led to increased plant height, dry matter accumulation, nodule count, nodule weight, grain yield, and straw yield. The optimal nitrogen levels directly influenced key growth attributes. Additionally, the study also highlighted the benefits of foliar applications of nutrients, particularly a 2% NPK (18:18:18) solution, which further improved soybean growth and yield. Foliar NPK applications deliver essential nutrients directly to leaves, facilitating rapid uptake and utilization. The study underscores the importance of a well-balanced and strategic nutrient management approach in soybean cultivation.

References

1. Alshaal T, El-Ramady H. Foliar application: from plant nutrition to biofortification. *Environment, Biodiversity and Soil Security*. 2017;1:71-83.
2. Balwan Yadav LR, Verma HP, Kumar R, Yadav SS. Effect of fertility levels and antitranspirants on productivity and profitability of wheat (*Triticum aestivum*) varieties. *Indian Journal of Agronomy*. 2017;62(1):45-48.
3. Banerjee P, Venugopalan VK, Gaber A, Nath R, Chakraborty PK, Alsanie WF, *et al.* Seed priming and foliar application of nutrients influence the productivity of relay grass pea (*Lathyrus sativus* L.) through accelerating the photosynthetically active radiation (PAR) use efficiency. *Agronomy*. 2022;12:1125. <https://doi.org/10.3390/agronomy12051125>
4. Bhanwariya B, Ram M, Kumawat N, Kumar R. Influence of fertilizer levels and biofertilizers on growth and yield of linseed (*Linum usitatissimum* L.) under rainfed condition of South Gujarat. *Madras Agricultural Journal*. 2013;100(4-6):403-406.
5. Bhayal L, Aakash, Jain MP, Bhayal D, Menna K. Impact of foliar spray of NPK and Zn on soybean for growth, yield, quality, energetics and carbon footprint under dryland condition at Indore. *Legume Research*. 2022;45(2):174-181.
6. Choudhary GL, Yadav LR. Effect of fertility levels and foliar nutrition on cowpea productivity. *Journal of Food Legumes*. 2011;24(1):67-68.
7. Das SK, Jana K. Effect of foliar spray of water soluble fertilizer at pre flowering stage on yield of pulses. *Agricultural Science Digest*. 2015;35(4):275-279.
8. Dass A, Bhattacharyya R. Wheat residue mulch and anti-transpirants improve productivity and quality of rainfed soybean in semi-arid north-Indian plains. *Field Crops Research*. 2017;210:9-19.
9. Dass A, Rajanna GA, Babu S, Lal SK, Choudhary AK, Singh R, *et al.* Foliar application of macro- and micronutrients improves the productivity, economic returns, and resource-use efficiency of soybean in a semiarid climate. *Sustainability*. 2022;14:5825. <https://doi.org/10.3390/su14105825>
10. Dehury C, Alam MP, Kumari M, Pandey SK, Bhagat B, Kar SP, *et al.* Effect of foliar spray of nano urea on growth parameters, quality attributes and yield of linseed. *International Journal of Research in Agronomy*. 2024;7(7):186-190.
11. Department of Agriculture and Farmers Welfare (DA&FW). Final estimates of production of foodgrains, oilseeds and other commercial crops for 2023-24.
12. Gomez KA, Gomez AA. Statistical procedures for agricultural research. New York: John Wiley and Sons; 1984.
13. Jadhav RL, Kulkarni S. Effect of foliar spray of nutrients on productivity of greengram (*Vigna radiata*) in North Eastern transitional zone of Karnataka, India. *Legume Research*. 2016;39(5):817-819.
14. Hemida KA, Eloufeyb AZA, Hassanc GM, El-Sadek AN, Abdelfattah MA. Integrative NPK soil and foliar application improves growth, yield, antioxidant, and nutritional status of *Capsicum annum* L. in sandy soils under semi-arid condition. *Journal of Plant Nutrition*. 2023;46(6):1091-1107. <https://doi.org/10.1080/01904167.2022.2046060>
15. Jat KK, Jadon CK, Singh P, Ram B, Yadav RK, Meena CB. Effect of fertility levels and foliar nutrition on performance of chickpea (*Cicer arietinum* L.) under south-eastern Rajasthan. *International Journal of Current Microbiology and Applied Sciences*. 2023;12(4):9-14.
16. Jaybhay SA, Varghese P, Taware SP. Influence of foliar application of nutrient on growth, yield, economics, soil nutritional status and nutrient uptake of soybean. *Legume Research*. 2021;44(11):1322-1327.
17. Joshi OP, Billore SD. Fertilizer management in soybean (*Glycine max* L.)-wheat (*Triticum aestivum*) cropping systems. *Indian Journal of Agronomy*. 2004;56(3):209-216.
18. Malik YP, Hussain K, Alam K. Impact of spacings and fertilizer application on linseed and infestation of budfly, *Dasyneura lini* Barnes. *Journal of Oilseeds Research*. 2008;25(1):106-107.
19. Meena D, Chandra B, Anil S, Choudhary S, Sirazuddin. Effect of foliar application of nutrients on nodulation, yield attributes, yield and quality parameters of urdbean (*Vigna mungo* L.). *The Bioscan*. 2017;12(1):411-414.
20. Meena DS, Narolia RS, Jadon C, Ram B. Impact of foliar spray of nutrients on yield and economics of soybean (*Glycine max* L.). *Soybean Research*. 2018;16(1-2):57-62.
21. Nataraja TH, Naika R, Shankarappa SK, Reddy KV, Abdelmohsen SAM, Al-Harbi FF, *et al.* Productivity of paddies as influenced by varied rates of recommended nutrients in conjunction with biofertilizers in local landraces. *Agronomy*. 2021;11:1165. <https://doi.org/10.3390/agronomy11061165>
22. Paikra IR, Lakpale R. Effect of foliar nutrition on productivity and profitability of soybean (*Glycine max*). *Indian Journal of Agronomy*. 2018;63(4):535-537.
23. Pando MR, Deshmukh PW, Bhojar SM, Sajid M, Giri MD, Nayghare NR. Effect of different RDF regimes and nano DAP on growth, yield and nutrient dynamics of chickpea

- (*Cicer arietinum*). International Journal of Plant and Soil Science. 2025;37(2):69-77.
24. Prajapati N, Rawat GS. Effect of tillage practices and fertility levels on growth analysis, yield of clusterbean and residual soil nutrients. International Journal of Chemical Studies. 2019;7(5):3255-3258.
 25. Rathore RS, Singh RP, Nawange DD. Effect of land configuration, seed rates and fertilizer doses on growth and yield of black gram (*Vigna mungo* L.). Legume Research. 2010;33(4):274-278.
 26. Sarika TW, Prasanna J, Sonawane DA, Ghodke PB, Ubale SP. Effect of fertilizer levels and foliar nutrition on growth and yield of soybean (*Glycine max* L.). International Journal of Plant and Soil Science. 2022;34(14):13-18.
 27. Shinde RN, Karanjikar PN, Gokhale DN. Effect of different levels fertilizer and micronutrients on growth, yield and quality of soybean. Journal of Crop and Weed. 2015;11(1):213-215.
 28. Singh AK, Singh CS, Singh AK, Karmakar S. Soybean productivity as influenced by foliar application of nutrients. Journal of Pharmacognosy and Phytochemistry. 2018;7(1S):413-415.
 29. Singh ID, Stockopf NC. Harvest index in cereals. Agronomy Journal. 1971;63:224-226.
 30. Singh P, Chitale S, Lakpale R, Singh A. Effect of different NPK levels, splitting of soil application and foliar feeding of NPK (19:19:19) fertilizer on growth and yield of wheat (*Triticum aestivum* L.). The Pharma Innovation Journal. 2023;12(3):1344-1354.
 31. SOPA. The soybean processors association of India: all India state-wise soybean area, production and productivity. 2023.
 32. Taiz L, Zeiger E, Møller IM, Murphy A. Plant physiology and development. Sunderland: Sinauer Associates; 2015.
 33. Tripathi L, Thomas T, Kumar S. Impact of nitrogen and phosphorus on growth and yield of chickpea (*Cicer arietinum* L.). Asian Journal of Soil Science. 2013;8(2):260-263.
 34. Vishwakarma M, Kulhare PS, Tagore GS, Gontia AS. Growth response of wheat as affected by different nutrient sources and NPK levels under vertisols. International Journal of Plant and Soil Science. 2023;35(21):835-845.
 35. Watson DJ. Physiological basis of variation in yield. Advances in Agronomy. 1952;4:101-145.