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Response of integrated nutrient management on yield attributes of Soybean (*Glycine max* L.)

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ABSTRACT

A field experiment was conducted during kharif 2025 at the College of Agriculture, Latur, Maharashtra, on a clayey Vertisol to evaluate the effect of integrated nutrient management (INM) on yield attributes and yield of soybean cv. MAUS-158. Seven treatments – control, recommended dose of fertilizers (RDF, 30:60:30 kg N:P₂O₅:K₂O ha⁻¹), and RDF combined with farmyard manure (FYM, 5 t ha⁻¹), neem cake powder (NC, 3 q ha⁻¹) and multi-micronutrient Grade-I (MMN, 25 kg ha⁻¹) – were tested in a randomized block design with three replications. RDF + FYM + NC + MMN (T₇) recorded the maximum pods (62.97 plant⁻¹), seeds (194.7 plant⁻¹), pod yield (38.20 g plant⁻¹) and seed yield (21.35 g plant⁻¹), at par with RDF + FYM + MMN (T₅) and RDF + NC + MMN (T₆). Seeds pod⁻¹, seed index and oil content were not significantly affected. T₇ produced the highest seed yield (4005 kg ha⁻¹), straw yield (5512 kg ha⁻¹) and oil yield (930.8 kg ha⁻¹); seed yield was 118.5% higher than the control and 37.9% higher than RDF, and at par with T₅ (3785 kg ha⁻¹) and T₆ (3625 kg ha⁻¹). Seed yield ha⁻¹ was significantly and positively correlated with all yield attributes ($r = 0.776-0.996$). INM increased soybean yield mainly through more pods and seeds per plant rather than through larger seeds or higher oil concentration.

Keywords: Soybean, Integrated nutrient management, Yield attributes, Seed yield, Harvest index, Oil yield, Correlation

Introduction

Soybean [*Glycine max* (L.) Merrill] is India's principal oilseed crop and the major kharif crop of Marathwada, Maharashtra, yet its productivity in the region is low and variable (SOPA, 2025) [1]. Imbalanced and inadequate nutrient application on Vertisols that have been cropped continuously with soybean is a key cause of this yield gap.

Seed yield of soybean is determined by the number of pods per plant, the number of seeds per pod and the weight of individual seeds. Nutrient supply affects each of these components by influencing flower production and retention, pod set and seed filling. Integrated nutrient management (INM), combining fertilizers with organic manures and micronutrients, has improved yield attributes and yield of soybean in several studies (Singh *et al.*, 2013; Narkhede *et al.*, 2017; Biswas *et al.*, 2024, 2025; Amanullah *et al.*, 2025) [2, 3, 4, 5]. Farmyard manure improves soil physical conditions in Vertisols (Bandyopadhyay *et al.*, 2010) [6], neem cake supplies slow-release nutrients, and micronutrients such as B and Zn are involved in pollen viability and pod set.

The present investigation examined the effect of combining FYM, neem cake and multi-micronutrients with RDF on the yield attributes, seed and straw yields, harvest index and oil yield of soybean, and the association of yield attributes with seed yield, on a Vertisol of Latur.

Materials and Methods

Experimental site, soil and weather

The field experiment was conducted during the kharif (rainy) season of 2025 at the Experimental Farm, Department of Agronomy, College of Agriculture, Latur, Maharashtra, India. Latur lies in the semi-arid tropical Marathwada region and receives a mean annual rainfall of about 795 mm. The soil of the experimental field was a medium-deep black Vertisol, clayey in texture (clay 44.21%, silt 29.53% and sand 25.68%), moderately alkaline (pH 7.4) and non-saline (EC 0.24 dS m⁻¹), with 0.58% organic carbon. It was low in available nitrogen (112.9 kg ha⁻¹; alkaline KMnO₄ method, Subbiah and Asija, 1956) [7], contained 7.46 kg ha⁻¹ Olsen-P (Olsen *et al.*, 1954) [8] and was high in available potassium (1145.6 kg ha⁻¹; neutral normal ammonium acetate, flame photometry; Jackson, 1967) [9]. Soybean-chickpea had been the preceding sequence on the field for the previous three years. A total of 1136.2 mm rainfall was received in 30 rainy days

during the crop season (standard meteorological weeks 29–43), and the weather was generally favourable for crop growth.

Treatments and experimental design

The experiment was laid out in a randomized block design (RBD) with seven treatments replicated three times: T₁, control (no fertilizer); T₂, 100% recommended dose of fertilizers (RDF, 30:60:30 kg N:P₂O₅:K₂O ha⁻¹); T₃, RDF + farmyard manure (FYM) @ 5 t ha⁻¹; T₄, RDF + neem cake powder (NC) @ 3 q ha⁻¹; T₅, RDF + FYM @ 5 t ha⁻¹ + multi-micronutrient Grade-I (MMN) @ 25 kg ha⁻¹; T₆, RDF + NC @ 3 q ha⁻¹ + MMN @ 25 kg ha⁻¹; and T₇, RDF + FYM @ 5 t ha⁻¹ + NC @ 3 q ha⁻¹ + MMN @ 25 kg ha⁻¹. The gross and net plot sizes were 5.4 m × 4.5 m and 4.5 m × 3.9 m, respectively. Nitrogen, phosphorus and potassium were supplied through urea (46% N), single superphosphate (16% P₂O₅) and muriate of potash (60% K₂O), respectively, and were applied as basal dose at sowing along with the organic sources and the micronutrient mixture as per treatment.

Crop management

The land was ploughed to 20 cm depth with a tractor-drawn reversible mould-board plough and harrowed twice. Soybean cv. MAUS-158 was sown on 18 July 2025 by dibbling at 45 cm × 5 cm spacing using a seed rate of 65 kg ha⁻¹, after seed treatment with fungicide. Gap filling and thinning were done 10 days after sowing. One hand weeding and one hoeing were given. Insect pests and foliar diseases were managed with need-based sprays of thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC, emamectin benzoate 5% SG, tebuconazole 10% + sulphur 65% WG and flubendiamide 20% WG. The crop was harvested at physiological maturity on 27 October 2025 (101 DAS), sun-dried and threshed manually.

Observations

Pods plant⁻¹ were counted on five tagged plants per net plot at 45, 60 and 75 DAS. At harvest, the same plants were used to record pod yield, seed yield and number of seeds plant⁻¹, and seeds pod⁻¹; seed index (100-seed weight, g) was determined from the net-plot produce. Seed and straw yields were recorded on net-plot basis and converted to kg ha⁻¹; biological yield = seed + straw yield, and harvest index (%) = $\frac{\text{seed yield}}{\text{biological yield}} \times 100$. Seed oil content was estimated by nuclear magnetic resonance (NMR) at [name of laboratory, Raichur, Karnataka], and oil yield (kg ha⁻¹) = oil content (%) × seed yield (kg ha⁻¹)/100. Simple correlation coefficients between seed yield ha⁻¹ and the yield attributes were computed from treatment means ($n = 7$) and tested at 5 degrees of freedom (Snedecor *et al.*, 1967) [10].

Statistical analysis

Data were analysed by the analysis of variance technique appropriate to RBD (Panse *et al.*, 1967) [11]. Treatment means were compared using critical difference (CD) at 5% probability wherever the *F*-test was significant.

Results and Discussion

Pods plant⁻¹

Pod number increased with crop age and was significantly influenced by the treatments at all stages (Table 1). At 75 DAS, T₇ bore 62.97 pods plant⁻¹, at par with T₅ (58.73) and T₆ (58.70) and significantly higher than T₁–T₄ (49.40–51.07). The three MMN-containing treatments produced 18–26% more pods than RDF alone, whereas adding FYM or neem cake to RDF without MMN did not increase pod number significantly at 60 or 75 DAS. This points to micronutrients, especially boron and zinc, which govern pollen germination, flower retention and pod set, as a limiting factor for pod formation on this soil.

Table 1. Number of pods plant⁻¹ of soybean at different growth stages as influenced by integrated nutrient management

Treatment	45 DAS	60 DAS	75 DAS
T ₁ : Control	35.20	42.83	49.40
T ₂ : RDF	40.57	43.17	49.90
T ₃ : RDF + FYM	43.60	45.13	50.33
T ₄ : RDF + NC	48.73	45.90	51.07
T ₅ : RDF + FYM + MMN	51.53	50.43	58.73
T ₆ : RDF + NC + MMN	51.20	50.03	58.70
T ₇ : RDF + FYM + NC + MMN	54.20	53.87	62.97
SE(m) ±	1.20	2.07	3.22
CD (<i>P</i> = 0.05)	3.60	6.21	9.65
Mean	46.43	47.34	54.44

RDF, recommended dose of fertilizers (30:60:30 kg N:P₂O₅:K₂O ha⁻¹); FYM, farmyard manure @ 5 t ha⁻¹; NC, neem cake powder @ 3 q ha⁻¹; MMN, multi-micronutrient Grade-I @ 25 kg ha⁻¹; DAS, days after sowing; NS, non-significant.

Seeds, pod yield, seed yield plant⁻¹ and seed index

Seeds pod⁻¹ (2.70–3.20) and seed index (11.48–12.16 g) were not significantly influenced by the treatments (Table 2), being largely genetically controlled characters of the variety. Seeds plant⁻¹, pod yield plant⁻¹ and seed yield plant⁻¹, however, differed significantly. T₇

recorded the highest values (194.7 seeds, 38.20 g pods and 21.35 g seeds plant⁻¹), at par with T₅ and T₆ and significantly superior to the remaining treatments. Seed yield plant⁻¹ under T₇ was 69.4% higher than the control and 36.7% higher than RDF. Because seeds pod⁻¹ and seed weight were stable, the improvement in seed yield plant⁻¹ came mainly from more pods and therefore more seeds per plant, which in turn followed from better branching, larger leaf area and greater dry matter production under INM. Similar findings were reported by Singh *et al.* (2013) [5], Biswas *et al.* (2024) [2] and Amanullah *et al.* (2025) [12].

Table 2. Yield attributes of soybean as influenced by integrated nutrient management

Treatment	Seeds pod ⁻¹	Seeds plant ⁻¹	Pod yield plant ⁻¹ (g)	Seed yield plant ⁻¹ (g)	Seed index (g)
T ₁ : Control	2.70	125.0	17.40	12.60	11.48
T ₂ : RDF	2.88	145.0	28.90	15.62	11.72

(continued on next page)

Treatment	Seeds pod ⁻¹	Seeds plant ⁻¹	Pod yield plant ⁻¹ (g)	Seed yield plant ⁻¹ (g)	Seed index (g)
T ₃ : RDF + FYM	3.00	160.0	31.80	17.10	11.89
T ₄ : RDF + NC	3.06	169.5	33.60	18.45	11.95
T ₅ : RDF + FYM + MMN	3.14	188.8	36.50	20.15	12.08
T ₆ : RDF + NC + MMN	3.16	184.3	35.80	19.50	12.02
T ₇ : RDF + FYM + NC + MMN	3.20	194.7	38.20	21.35	12.16
SE(m) ±	0.11	7.85	1.24	0.66	0.21
CD (<i>P</i> = 0.05)	NS	23.85	3.78	2.01	NS
Mean	3.02	166.8	33.46	17.82	11.90

RDF, recommended dose of fertilizers (30:60:30 kg N:P₂O₅:K₂O ha⁻¹); FYM, farmyard manure @ 5 t ha⁻¹; NC, neem cake powder @ 3 q ha⁻¹; MMN, multi-micronutrient Grade-I @ 25 kg ha⁻¹; DAS, days after sowing; NS, non-significant.

Seed, straw and biological yield and harvest index

Seed yield ranged from 1833 kg ha⁻¹ in the control to 4005 kg ha⁻¹ in T₇ (Table 3). RDF alone increased seed yield by 58.5% over the control, confirming the strong response of soybean to NPK on this soil low in available nitrogen. All INM combinations further improved yield over RDF: FYM (T₃) and neem cake (T₄) raised it by 9.5 and 18.2%, their combination with MMN (T₅, T₆) by 30.3 and 24.8%, and T₇ by 37.9%. T₇ was at par with T₅ and T₆ and significantly superior to all other treatments. Straw yield followed the same trend, T₇ (5512 kg ha⁻¹), T₅ (5331 kg ha⁻¹) and T₆ (5310 kg ha⁻¹)

being at par. Harvest index (35.1–43.8%) was lowest in the unfertilized control and varied within a narrow range among the fertilized treatments, indicating that INM increased biomass and seed yield in similar proportion.

The superiority of the MMN-containing INM treatments reflects their cumulative effects on nodulation, canopy development, dry matter accumulation and pod set. Slow release of nutrients from FYM and neem cake matches the prolonged nutrient demand of soybean during pod filling better than a single basal fertilizer dose, while MMN corrects micronutrient constraints common in calcareous Vertisols. Comparable yield gains from integrating organic sources with fertilizers in soybean were reported by Singh *et al.* (2013) [5], Narkhede *et al.* (2017) [4], Biswas *et al.* (2024, 2025) and Amanullah *et al.* (2025) [12].

Table 3. Seed, straw and biological yields (kg ha⁻¹) and harvest index (%) of soybean as influenced by integrated nutrient management

Treatment	Seed yield	Increase over RDF (%)	Straw yield	Biological yield	Harvest index (%)
T ₁ : Control	1833	-36.9	3389	5222	35.10
T ₂ : RDF	2905	–	4022	6927	41.94
T ₃ : RDF + FYM	3180	9.5	4084	7264	43.78
T ₄ : RDF + NC	3435	18.2	4497	7932	43.31
T ₅ : RDF + FYM + MMN	3785	30.3	5331	9116	41.52
T ₆ : RDF + NC + MMN	3625	24.8	5310	8935	40.57
T ₇ : RDF + FYM + NC + MMN	4005	37.9	5512	9517	42.08
SE(m) ±	127	–	217	[re-run]	[re-run]
CD (<i>P</i> = 0.05)	382	–	650	[re-run]	[re-run]
Mean	3253	–	4592	7845	41.19

Biological yield = seed + straw yield; harvest index = seed yield/biological yield × 100. RDF, recommended dose of fertilizers (30:60:30 kg N:P₂O₅:K₂O ha⁻¹); FYM, farmyard manure @ 5 t ha⁻¹; NC, neem cake powder @ 3 q ha⁻¹; MMN, multi-micronutrient Grade-I @ 25 kg ha⁻¹; DAS, days after sowing; NS, non-significant.

Oil content and oil yield

Seed oil content (21.98–24.04%) was not significantly affected by the treatments (Table 4), suggesting that oil concentration in MAUS-158 was governed mainly by genotype and the seed-filling environment.

Improved nitrogen nutrition through better nodulation may also favour protein over oil accumulation, offsetting any positive effect of nutrition on oil concentration. Oil yield, however, followed seed yield closely: T₇ recorded the highest oil yield (930.8 kg ha⁻¹), 131.0% more than the control and 42.5% more than RDF, and was at par with T₅ (850.9 kg ha⁻¹). Amanullah *et al.* (2025) [12] similarly found that INM raised soybean oil yield mainly through higher seed yield.

Table 4. Oil content and oil yield of soybean as influenced by integrated nutrient management

Treatment	Oil content (%)	Oil yield (kg ha ⁻¹)
T ₁ : Control	21.98	402.89
T ₂ : RDF	22.48	653.04
T ₃ : RDF + FYM	24.04	764.47
T ₄ : RDF + NC	22.26	764.63
T ₅ : RDF + FYM + MMN	22.48	850.87
T ₆ : RDF + NC + MMN	22.13	802.21
T ₇ : RDF + FYM + NC + MMN	23.24	930.76
SE(m) ±	1.23	32.19

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Treatment	Oil content (%)	Oil yield (kg ha ⁻¹)
CD ($P = 0.05$)	NS	96.86
Mean	22.66	738.41

RDF, recommended dose of fertilizers (30:60:30 kg N:P₂O₅:K₂O ha⁻¹); FYM, farmyard manure @ 5 t ha⁻¹; NC, neem cake powder @ 3 q ha⁻¹; MMN, multi-micronutrient Grade-I @ 25 kg ha⁻¹; DAS, days after sowing; NS, non-significant.

Association of yield attributes with seed yield

Seed yield ha⁻¹ was positively and significantly correlated with all yield attributes (Table 5). The strongest associations were with pod yield plant⁻¹ ($r = 0.996$), seed index (0.990), seed yield plant⁻¹

(0.987), seeds pod⁻¹ (0.983) and seeds plant⁻¹ (0.971), whereas pods plant⁻¹ at 75 DAS showed a weaker but significant association (0.776). Seed index and seeds pod⁻¹ correlated strongly with yield even though their treatment differences were non-significant, because correlation among treatment means reflects consistent ranking of treatments rather than the magnitude of differences; the yield gain itself arose mainly from more seeds per plant.

Table 5. Correlation coefficients (r) of yield attributes with seed yield (kg ha⁻¹) of soybean under integrated nutrient management ($n = 7$)

Yield attribute	r with seed yield ha ⁻¹
Pods plant ⁻¹ (75 DAS)	0.776*
Seeds pod ⁻¹	0.983**
Seeds plant ⁻¹	0.971**
Pod yield plant ⁻¹	0.996**
Seed yield plant ⁻¹	0.987**
Seed index	0.990**

* and ** significant at $P = 0.05$ ($r = 0.754$) and $P = 0.01$ ($r = 0.874$), respectively, at 5 degrees of freedom.

Conclusion

Application of RDF with FYM @ 5 t ha⁻¹, neem cake powder @ 3 q ha⁻¹ and multi-micronutrient Grade-I @ 25 kg ha⁻¹ produced the highest pods, seeds and seed yield per plant, and the highest seed (4005 kg ha⁻¹), straw and oil yields of soybean on the Vertisol of Latur. RDF + FYM + MMN and RDF + NC + MMN were statistically at par and are practical alternatives. INM raised yield chiefly by increasing seed number per plant. These single-season results require confirmation.

Conflict of Interest

The authors declare no conflict of interest.

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