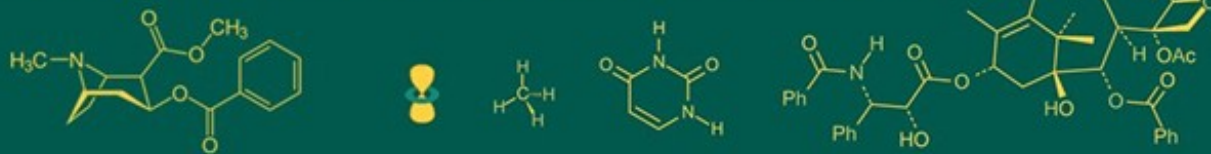


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Harshal Sudhir Adasole

M.Sc. Scholar, Department of
Agronomy, College of
Agriculture Dhule,
Maharashtra, India

PP Girase

Associate Professor of
Agronomy, Department of
Agronomy, College of
Agriculture Dhule,
Maharashtra, India

SC Wadile

Associate Professor of
Agronomy, Department of
Agronomy, College of
Agriculture Nandurbar,
Maharashtra, India

PP Pawar

Associate Professor of
Agronomy, Department of
Agronomy, College of
Agriculture Dhule,
Maharashtra, India

VP Bhalerao

Associate Professor of Soil
Science, Department of Soil
Science and Agricultural
Chemistry, College of
Agriculture Dhule,
Maharashtra, India

Effect of micronutrients on growth and yield of kharif soybean (*Glycine max* L.)

Harshal Sudhir Adasole¹, PP Girase², SC Wadile³, PP Pawar⁴, VP Bhalerao⁵

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ABSTRACT

During the kharif season of 2025, a field trial was executed at post graduate research farm under the Department of Agronomy, College of Agriculture Dhule, to assess how micronutrient supplementation influences the vegetative growth and seed output of kharif soybean (*Glycine max* L.). The experiment was laid out in a randomized block design with eight treatments replicated three times. Results demonstrated that various micronutrient regimes significantly affected overall growth dynamics and yield parameters, including plant height, primary branching, canopy width, total biomass build-up, pods per plant, seeds per pod, individual seed weight, test weight and total grain and stover yield (q ha^{-1}). Integrating GRDF with soil applied phule micronutrient grade I (25 kg ha^{-1}) along with two foliar sprays of phule micronutrient grade II (1% at 30 and 45 DAS) achieved superior growth performance and yield attributes i.e. plant height (95.81 cm), number of branches plant-1 (10.05), plant spread (41.33 cm), dry matter accumulation (41.46 g), number of pods plant-1 (52.43), number of seeds pod-1 (3.06), weight of seeds plant-1 (26.03 g), 100 seed weight (16.34 g) grain and straw yield of soybean (28.53 q ha^{-1} and 42.79 q ha^{-1}) as compared to rest of the treatments.

Keywords: Soybean, Phule micronutrient grade I, Phule micronutrient grade II, Growth, Yield

Introduction

Soybean (*Glycine max*. L., Merrill) is a principal leguminous crop belongs to the papilionaceae sub-family of the broader Leguminosae family. Originating historically in the regions of China and India, this annual legume has achieved global prominence as both a key pulse and major oilseed crop adaptable to various agro-climatic conditions. As a leading oilseed crop, it has become a dominant force in the 21st century, especially in India, where it has held a prominent position since 2006. It represents an exceptionally dense source of energy and nutrients for both human diets and animal feed, uniquely composed of roughly 40% high quality protein, 20% oil, 23% carbohydrates and zero cholesterol. (ICAR-IISR, 2024) [1].

A defining attribute of soybean protein is its high concentration of the essential amino acids lysine (accounting for 5%), which effectively balances the lysine deficiencies commonly found in traditional cereal crops. Its lipid fraction is highly rich in polyunsaturated fatty acids, which make up nearly 60% of its total oil composition- specifically consisting of 52.8% linoleic acid and 7.2% linolenic acid. From a caloric perspective, a 100 gm. portion of digestible soy protein releases roughly 350 calories, establishing a nutritional parity with major cereals. This high density of cheap protein has earned it the moniker "Poor man's meat". Beyond raw agricultural value, soybean are processed into a vast array of global and regional foodstuffs, including milk, specialized breads, chapattis, pastries and confectionery items, alongside extensive industrial processing into soybean oil and vanaspati ghee. (ICAR-IISR, 2024) [1].

On the international stage, total soybean output expanded robustly through the early 2020s, with a global production culminating at approximately 427.89 million metric tons by the 2024/2025 marketing year. Globally, South America production dominates, with Brazil leading global output at a 42% share (180 million metric tons), followed by the United States at 27% (115.99 million metric tons), and Argentina at 11% (48 million metric tons). India has firmly established itself within the top tier of worldwide producers, maintaining the fifth largest harvested acreage globally and contributing roughly 3% (11.03 million metric tons) to total worldwide production. (USDA, 2025) [2].

The amount of soybean yield loss due to nutrient insufficiency varies depending upon the nutrients N, P, Fe, B and S nutrient deficiencies in soybean can result in yield losses of up to 10 per cent, 29-45 per cent, 29-90 per cent, 100 per cent depending on soil fertility status, environment and plant variables. Soil salinity is one of the most important limiting variables in semi-arid soybean production and salinity of chloride has a great impact on output than sulphate salinity. The purpose of nutrient management is to increase soybean yield while reducing environmental impact. Balanced and timely nutrient management strategies for soybeans help to long term production and quality increase, as well as plant health and environmental risk reduction.

Corresponding Author:**Harshal Sudhir Adasole**

M.Sc. Scholar, Department
of Agronomy, College of
Agriculture Dhule,
Maharashtra, India

Balanced nutrition and mineral fertilization can help with integrated pest management by reducing damage from pest and disease infestation and reducing the amount of inputs needed to control them. Farmers benefit from balanced fertilization not necessarily because they use fewer inputs. Education and extension have a critical, demanding and on-going role in disseminating up-to-date knowledge on nutrient management.

Materials and methods

Field research was carried out at the Agronomy Section's post graduate research farm, College of Agriculture, Dhule. Situated within Northern Maharashtra's Scarcity Zone (Agro-climatic Zone-6), the site is geographically positioned at 20.4° N latitude and 74° E longitude, elevation 258 m above sea level. It is situated at the crossing of National Highway No. 3 and 6. Climatically, the zone exhibits sub-tropical weather patterns. Monsoon precipitation typically starts during the mid-to-late part of June and concludes by late september, averaging 607 mm of annual rainfall. This is entirely due to South-West monsoon. The rainfall is mostly received in 34 to 40 rainy days in a year. Recorded mean annual temperatures range from a peak maximum of 46.6°C to a low of 6.8°C. Daily evaporation levels fluctuate between 0.7 mm and 18.0 mm, while sunshine hours reach up to 10.4 hours per day.

The experiment consists of eight treatments laid out in a randomized block design with three replications. The treatments consist of an Absolute control, GRDF (50:75:45 N, P₂O₅ and K₂O kg ha⁻¹ + FYM 10 t ha⁻¹), GRDF + soil application of FeSO₄ @ 25 kg ha⁻¹, GRDF + soil application of ZnSO₄ @ 20 kg ha⁻¹, GRDF + soil application of phule micronutrient grade I @ 25 kg ha⁻¹, GRDF + soil application of FeSO₄ @ 25 kg ha⁻¹ + two foliar spray of phule micronutrient grade II 1% at 30 and 45 DAS, GRDF + soil application of ZnSO₄ @ 20 kg ha⁻¹ + two foliar sprays of phule micronutrient grade II @ 1% at 30 DAS and 45 DAS, GRDF + soil application of phule micronutrient grade I @ 25 kg ha⁻¹ + two foliar sprays of phule micronutrient grade II @ 1% at 30 DAS and 45 DAS were used in this experiment.

Results and discussion

The results recorded from the during investigation are summarized below.

Growth parameters

- 1. Plant height:** Periodic observations regarding soybean plant height as affected by evaluation treatments are detailed in Table 1. Maximum plant height across all sampling intervals (33.93, 76.03, 96.06 and 95.81 cm) was observed under the treatment combining GRDF, soil applied phule micronutrient grade I (25 kg ha⁻¹) and two foliar sprays of phule micronutrient grade II at 30 and 45 DAS. Whereas the minimum plant height (25.27, 50.20, 78.40 and 77.73 cm respectively) of soybean was recorded in the treatment absolute control.

This increase in vertical growth can be attributed to enhanced micro-element nutrition; both phule grade I and grade II formulations deliver balanced levels of essential trace elements (Zn, Cu, Mn, B and Mo). supplementing these with 10 t ha⁻¹ FYM further improved soil chelation and root uptake. While RDF supplied essential macro-elements, combining them with micro-nutrients promoted vigorous crop growth. Biochemically, iron drives chlorophyll synthesis, zinc governs carbohydrate processing and protein assembly, boron directs cell division and membrane sugar transport; concurrently, copper and manganese regulate photosynthetic electron transfer, with copper boosting root nodulation and manganese sustaining cellular protoplast activity.

The results are in association with Amar *et al.*, (2024) [3], Bhosale *et al.*, (2024) [4]

- 2. Plant spread:** Across all evaluation stages 30, 60, 90 DAS, and at harvest canopy spread reached its maximum (22.32 cm, 32.73 cm, 42.70 cm and 41.33 cm respectively) when the plots received GRDF along with soil application of Phule micronutrient grade I (25 kg ha⁻¹) and phule micronutrient grade II (1% at 30 and 45 DAS). This treatment was significantly superior over all other treatments followed by treatment T₅ and T₇. In contrast, the absolute control treatment (T₁), which included no fertilizer, and no micronutrient application, resulted in significantly lower plant spread measurements of 12.87 cm, 22.42 cm, 31.74 cm, and 30.53 cm at 30, 60, 90 DAS and at harvest respectively.

This response likely stems from boosted symbiotic N₂ fixation and favorable root zone pH conditions, which collectively optimize nutrient mobility during key developmental phases. Canopy spread expanded continuously until 90 DAS, followed by a slight reduction near crop maturity due to leaf senescence. The results are in association with Yan *et al.*, (2015) [5] and Yadravi *et al.* (2015) [6].

- 3. Number of branches plant⁻¹** Data outlining lateral branching count per plant across different evaluation stages are listed in Table 1. Treatment T₈ (GRDF + soil applied phule micronutrient grade I @ 25 kg ha⁻¹ and two foliar sprays of phule micronutrient grade II at 30 and 45 DAS) recorded the highest branch numbers across sampling dates (5.63, 9.26, 10.05 and 10.05 branches per plant, respectively), significantly outperforming all other treatments.

In contrast, the significantly minimum branches per plant (1.78, 5.45, 5.65, and 5.65) at 30, 60, 90 DAS, and at harvest, respectively, were observed in the absolute control treatment (T₁). The significant proliferation of lateral branches in this treatment is attributable to improved nutrient absorption, boosted physiological activity and intensified nodule activity. This enhanced nutrition likely supported greater branching in the plants. Similar findings were observed by Ghare *et al.* (2014) [7], Shinde *et al.*, (2015) [8], Thite and Murumkar, (2023) [9], Amar *et al.*, (2024) [3], Bhosale *et al.*, (2024) [4].

- 4. Dry matter accumulation plant⁻¹ (g):** Among tested schedules, treatment T₈ (GRDF + soil applied phule micronutrient grade I @ 25 kg ha⁻¹ and two foliar sprays of phule micronutrient grade II at 30 and 45 DAS) yielded significantly higher dry biomass accumulation per plant (4.62 g, 23.56 g, 43.46 g and 41.46 g at 30, 60, 90 DAS and at harvest). Whereas the significantly minimum dry matter per plant at all stages of soybean was recorded in absolute control at 30, 60, 90 DAS and at harvest (1.49, 9.32, 27.18 and 26.07 g respectively).

Synergy between balanced primary fertilization and micro-element enrichment strengthened photosynthetic activity and biomass partitioning, leading to sustained dry matter accumulation throughout the cropping period. This led to increased dry matter production and its continuous buildup in the soybean crop as it progressed through its growth stages. Similar findings were observed by Yadav, (2003) [10], Dash *et al.*, (2005) [11], Thite and Murumkar, (2023) [9], Amar *et al.*, (2024) [3], Bhosale *et al.*, (2024) [4].

5) Yield and yield contributing characters

- 5.1) Number of pods plant⁻¹** Plot treatment with GRDF alongside phule micronutrient grade I (25 kg ha⁻¹) and two foliar sprays of phule micronutrient grade II (1% at 30 and 45 DAS) produced the highest pod load (52.43 pods per plant). This was statistically superior over all other treatments. These finding are similar to the results of Thite and Murumkar, (2023) [9], Amar *et al.*, (2024) [3], Wasmatar *et al.*, (2002) [12], Bhosale *et al.*, (2024) [4].

Table 1. Effect of micronutrients on growth contributing characters

Treatment Details		Plant height (cm)	Plant Spread (cm)	Number of branches plant ⁻¹	Dry matter plant ⁻¹ (g)
		At harvest	At harvest	At harvest	At harvest
T ₁	Absolute control	77.73	30.53	5.65	26.07
T ₂	GRDF (50:75:45 N:P ₂ O ₅ :K ₂ O kg ha ⁻¹ + FYM 10 t ha ⁻¹)	80.53	32.27	6.86	29.29
T ₃	GRDF + soil application of FeSO ₄ @ 25 kg ha ⁻¹	86.53	33.09	7.05	32.66
T ₄	GRDF + soil application of ZnSO ₄ @ 20 kg ha ⁻¹	86.53	34.72	8.39	33.83
T ₅	GRDF + soil application of phule micronutrient grade I @ 25 kg ha ⁻¹	93.50	39.33	9.15	38.60
T ₆	GRDF + soil application of FeSO ₄ @ 25 kg ha ⁻¹ + two foliar spray of phule micronutrient grade II 1% at 30 and 45 DAS	90.93	35.27	8.83	36.13
T ₇	GRDF + soil application of ZnSO ₄ @ 20 kg ha ⁻¹ + two foliar spray of phule micronutrient grade II 1% at 30 and 45 DAS	93.10	39.47	8.99	38.54
T ₈	GRDF + soil application of phule micronutrient grade I @ 25 kg ha ⁻¹ + two foliar spray of phule micronutrient grade II 1% at 30 and 45 DAS	95.81	41.33	10.05	41.46
SE(m)		0.60	1.04	0.27	0.75
C. D. @5%		1.83	3.17	0.82	2.27
General Mean		88.09	35.75	8.12	34.57

5.2) Number of seeds pod⁻¹

Seed density per pod peaked at 3.06 under treatment T₈ which includes soil application of phule micronutrient grade I and two foliar sprays of phule micronutrient grade II proving significantly superior to all other nutritional options. Conversely, the unfertilized control (T₁), produced the lowest seed count per pod (2.07). These results are in agreement with the findings of [Amar et al., \(2024\)](#) [3] and [Bhosale et al., \(2024\)](#) [4].

5.3) Seed weight plant⁻¹

Individual seed weight per plant reached its maximum (26.03 g) with treatment T₈, significantly outperforming all other options. On the other hand, control plots (T₁) yielded a significantly lower seed mass of 11.50 g per plant. These results were in agreement with the findings of [Vyas et al. \(2003\)](#) [13], [Billore et al., \(2005\)](#) [14], [Shirpurkar et al., \(2006\)](#) [15], [Amar et al., \(2024\)](#) [3].

5.4) Test weight

Test weight showed no statistically significant differences across micronutrient applications. The highest numerical values (16.34 g) occurred in treatment T₈, followed closely by treatments T₅ and T₇. These results were in agreement with the findings of [Vyas et al. \(2003\)](#) [13], [Billore et al., \(2005\)](#) [14], [Shirpurkar et al., \(2006\)](#) [15], [Amar et al., \(2024\)](#) [3].

5.5) Seed yield (q ha⁻¹) Grain productivity varied markedly across treatments, peaking at 28.53 q ha⁻¹ under the combined basal and foliar application of phule micronutrient regime (T₈). This was significantly superior over all other treatments followed by treatment T₅ and T₇. The lowest grain yield (11.80 q ha⁻¹) was recorded under the Absolute Control treatment (T₁), which involved no fertilizers or micronutrient application. Similar result was reported by [Heidaria et al., \(2011\)](#) [16], [Faisal et al., \(2011\)](#) [17], [Amar et al., \(2024\)](#) [3], [Bhosale et al., \(2024\)](#) [4].

5.6) Straw yield (q ha⁻¹) The highest straw yield was achieved with the application of General Recommended Dose of Fertilizer (GRDF) + soil application of phule micronutrient grade I @ 25 kg ha⁻¹ + two foliar sprays of phule micronutrient grade II @ 1% at 30 and 45 days after sowing (DAS) (T₈), recording a yield of 42.79 q ha⁻¹. This was statistically superior over all other treatments followed by treatment T₅ and T₇. The lowest straw yield (15.60 q ha⁻¹) was recorded under the Absolute Control treatment (T₁), which involved no fertilizers or micronutrient application.

Balanced fertilization integrating macro-nutrients and trace element sprays promoted robust vegetative development and biomass synthesis, directly translating into maximal stover production. Similar findings were observed by [Shinde et al., \(2011\)](#) [18] and [Rajendran et al., \(2012\)](#) [19].

Table 2. Effect of micronutrients on yield and yield contributing characters of soybean (*Glycine max* L)

Treatment Details		Number of pods plant ⁻¹	Number of grain pod ⁻¹	Weight of grain plant ⁻¹ (g)	100 grain weight (g)	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)
T ₁	Absolute control	22.67	2.07	11.50	15.20	11.80	15.60
T ₂	GRDF (50:75:45 N:P ₂ O ₅ :K ₂ O kg ha ⁻¹ + FYM 10 t ha ⁻¹)	34.20	2.24	14.26	15.40	22.50	30.40
T ₃	GRDF + soil application of FeSO ₄ @ 25 kg ha ⁻¹	36.08	2.33	16.38	15.55	24.00	33.00

(continued on next page)

	Treatment Details	Number of pods plant ⁻¹	Number of grain pod ⁻¹	Weight of grain plant ⁻¹ (g)	100 grain weight (g)	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)
T ₄	GRDF + soil application of ZnSO ₄ @ 20 kg ha ⁻¹	36.66	2.39	16.74	15.65	24.75	35.40
T ₅	GRDF + soil application of phule micronutrient grade I @ 25 kg ha ⁻¹	47.18	2.78	24.10	15.90	26.00	38.15
T ₆	GRDF + soil application of FeSO ₄ @ 25 kg ha ⁻¹ + two foliar spray of phule micronutrient grade II 1% at 30 and 45 DAS	41.54	2.40	18.61	15.75	25.50	37.60
T ₇	GRDF + soil application of ZnSO ₄ @ 20 kg ha ⁻¹ + two foliar spray of phule micronutrient grade II 1% at 30 and 45 DAS	47.72	2.85	24.23	16.00	26.04	39.15
T ₈	GRDF + soil application of phule micronutrient grade I @ 25 kg ha ⁻¹ + two foliar spray of phule micronutrient grade II 1% at 30 and 45 DAS	52.43	3.06	26.03	16.34	28.53	42.79
	SE(m)	1.07	0.03	0.42	0.04	0.58	1.08
	C. D. @5%	3.25	0.11	1.29	NS	1.75	3.25
	General Mean	39.81	2.52	18.98	15.72	23.64	34.25

Conclusion

Based on this single season evaluation, it can be concluded that integrating GRDF with soil application of phule micronutrient grade I (25 kg ha⁻¹) and two foliar spray of phule micronutrient grade II (1% at 30 and 45 DAS) represents the most effective management strategy for maximizing soybean grain yield, stover biomass, crop quality and post harvest soil nutrient balance.

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