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Research Article

Effect of foliar application of micronutrients on seed quality and yield of soybean (*Glycine max* L.)

Amar G. Meher[1], Hitendrasinh J. Rajput[2], Ramesh S. Bhadane[3*], Vitthal R. Patil[4]

[1]Department of Agril. Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmadnagar-413 722, Maharashtra, India.
[2]Associate Professor of Agril. Botany, Zonal Agricultural Research Station, MPKV, Solapur-413 001, Maharashtra, India.
[3]Assistant Professor of Agril. Botany, Pulse and Oilseed Crops Research and Training Centre, MPKV, Pandharpur, Dist. Solapur 413 304, Maharashtra, India.
[4]Assistant Professor of Agril. Botany, Agricultural Research Station, MPKV, Mohol, Dist-Solapur-413 213, Maharashtra, India.

[*]**Correspondence**
Ramesh S. Bhadane
bhadaners@rediffmail.com

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Background: The application of micronutrients through foliar spraying proves beneficial in scenarios where roots fail to supply the required nutrients. Micronutrient foliar sprays enable the direct and efficient utilization of nutrients by plants through their leaves, manifesting observable effects within a short period which ultimately increases seed quality and yield in soybean.

Methods: The present investigation on "Effect of foliar application of micronutrients on seed quality and yield of soybean" was conducted during *kharif* 2022 at Post Graduate Institute, MPKV, Rahuri. The experiment was laid out in Randomized Block Design with eight treatments in three replications. The treatments comprise of different micronutrients such as Borax @200 ppm, $FeSO_4$ @200 ppm, $ZnSO_4$ @200 ppm, $CuSO_4$ @100 ppm, $MnSO_4$ @100 ppm, $(NH_4)_2MoO_4$ @100 ppm, Phule Grade 2 Micronutrient 100 ml/10 lit water including control. The micronutrients were applied as foliar spray at 25 and 40 days after sowing.

Results: The Phule Grade 2 Micronutrient was found to be better treatment for growth, seed quality and yield characters of soybean variety Phule Sangam *viz*., days to 50% flowering (42 days), plant height (74.80 cm), days to maturity (100 days), number of branches (7.26), moisture content (9.30 %), germination (92.66 %), speed of germination (22.40), root length (14.20 cm), shoot length (20.00 cm), shoot root ratio (1.43), seedling dry weight (1.89 g), seed vigour index I (3160), seed vigour index 2 (174), dead seed (1.66), electrical conductivity (0.42 dS/m), number of pods per plant (85.06), number of seeds per pod (3.00), 1000 seed weight (168 g), seed yield per plant (41.50 g).

Conclusion: Application of Phule grade 2 micronutrient treatment as two foliar sprayings at 25 and 40 DAS was found more beneficial in increasing growth, yield and seed quality characters of soybean variety Phule Sangam as compared to the untreated control treatment.

Keywords: *phule grade 2 micronutrient, phule sangam, soybean, spraying, quality and yield*

Introduction

Soybean is a unique crop, serving as a valuable source of food, animal feed and an essential industrial raw material. It provides an economical source of protein for both human consumption and animal feed. Increasing soybean crop productivity is a pressing need, achievable through the adoption of improved production methods and the use of high-quality seeds from improved varieties. The availability of top-quality seeds is the cornerstone for realizing the potential of high-yielding varieties. Indian scientists have been diligently working to develop new soybean varieties and standardize crop management practices to enhance crop productivity per unit area. Among the various management

practices, the application of micronutrients has proven crucial for boosting seed yield and quality. Several micronutrients are indispensable for sustaining crop productivity. In Maharashtra, various soybean varieties are cultivated for commercial and seed production purposes. It is essential to investigate the impact of micronutrients on seed yield and seed quality of these commercially grown soybean varieties. Besides essential nutrients, micronutrients play a pivotal role in the production of seed. The application of micronutrients to deficient soil has demonstrated a significant increase in the yield of various crops. These micronutrients actively participate in vital plant metabolic processes, ranging from cell wall development to the facilitation of respiration, photosynthesis, chlorophyll formation, enzyme activity and nitrogen fixation. Serving as co-factors for numerous enzymes, micronutrients are indispensable for improving both yield and quality, playing a pivotal role in enhancing overall plant growth and the yield of multiple crops (Alam et al., 2010; Hänsch & Mendel, 2009). The application of micronutrients through foliar spraying proves beneficial in scenarios where roots fail to supply the required nutrients. Certain soil characteristics such as high pH, presence of lime, or heavy texture can impede the absorption of vital micronutrients like zinc and boron by crop roots. The foliar application of these nutrients can facilitate better nutrient uptake compared to traditional soil-based methods. Among the various alternative methods for providing plant nutrients, employing foliar nutrition of micronutrients stands out as a potential approach to enhance productivity, elevate fertilizer utilization efficiency and minimize environmental risks. Micronutrient foliar sprays enable the direct and efficient utilization of nutrients by plants through their leaves, manifesting observable effects within a short period. Considering these advantages and their significance in augmenting seed yield and quality, the current study aimed to explore the impact of applying micronutrients *via* foliar application on growth, seed yield and quality of soybean.

Materials and Methods

A field experiment was conducted during *kharif* season of 2022 at Botany Farm, Post Graduate Institute and Laboratory studies was conducted in Seed Technology Research Unit, MPKV, Rahuri. The sowing of soybean variety Phule Sangam was done on 15th July 2022 at the distance of 30 x 7.5 cm. The recommended fertilizer dose (50 kg N, 75 kg P_2O_5 and 45 kg K_2O ha^{-1}) was applied at the time of sowing. The experiment was conducted in randomized block design (RBD) with three replications and eight treatments including control. The treatments comprise of different micronutrients such as Borax @200 ppm, $FeSO_4$ @200 ppm, $ZnSO_4$ @200 ppm, $CuSO_4$ @100 ppm $MnSO_4$ @100 ppm, $(NH_4)_2MoO_4$ @100 ppm, Phule Micronutrient Grade 2 (Micronutrients Fe-250 ppm, Zn- 300 ppm, Bo- 30 ppm, Cu-100 ppm, Mo- 0.1% - A multi-micronutrient combination mixture) @ 100 ml/10 lit water including control (No spray). The Breeder Seed of Soybean variety Phule Sangam (KDS-726) was obtained from Agricultural Research Station, Kasbe Digraj, Dist. Sangali, under Mahatma Phule Krishi Vidyapeeth, Rahuri. Two foliar sprays of each micronutrient treatment were applied at 25 days and 40 days after sowing. Five plants from each plot were randomly selected for recording morphological and yield attributing observations at harvest. The data collected for all the yield attributing characters were subjected to the statistical analysis as described by Panse & Sukhatme (1985).

Results

Morphological characters

The data recorded on the number of days taken to 50% flowering, maturity, plant height, number of branches per plant as influenced by various micronutrients is presented in Table 1.

Table 1. Effect of foliar application of micronutrients on morphological characters

Sr. No.	Treatments	Days to 50% Flowering	Plant Height (cm)	Days to Maturity	No. of Branches / Pl.
1	Borax @ 200 ppm	42.00	67.40	100.00	6.40
2	$FeSO_4$ @200 ppm	42.33	65.10	100.66	6.26
3	$ZnSO_4$ @200 ppm	42.33	70.40	100.33	6.80
4	$CuSO_4$ @ 100 ppm	43.33	64.00	101.33	5.80
5	$MnSO_4$ @ 100 ppm	43.66	64.20	101.66	6.06
6	$(NH_4)_2MoO_4$ @ 100 ppm	43.00	67.60	101.66	6.45
7	Phule Micronutrient Grade 2 @ 100ml/ 10 lit water	42.00	74.80	100.00	7.26
8	Control (No Spray)	43.66	63.50	101.66	6.00
	SE +	**1.42**	**2.32**	**3.26**	**0.23**
	C. D. at 5%	**N.S.**	**7.05**	**N.S.**	**0.71**
	C.V. %	**5.76**	**6.24**	**5.59**	**5.96**

From the data, non-significant results were recorded for days to 50 % flowering and maturity. The minimum days taken to 50% flowering (42) was recorded in Phule Grade 2 and in Boron (42) whereas, the maximum days taken for 50% flowering were recorded in Control (43.66) and by $MnSO_4$ (43.66) in soybean. The minimum days taken to maturity (100) was recorded in Phule Grade 2 and Boron whereas, maximum days (101.66) taken for maturity was recorded in Control, $MnSO_4$ and $(NH_4)_2MoO_4$ treatments. The Phule Grade 2 recorded the maximum height (74.80 cm), number of branches per plant (7.26) and the Control treatment recorded the minimum height (63.50 cm), fewer branches per plant (6.00).

Yield characters

The results for yield characters are reported in Table 2. The highest number of pods per plant (85.06), number of seeds per pod (3.00), 1000 seeds weight (168 g) and seed yield per plant (41.50 g) were recorded in plants sprayed with Phule Grade 2. Whereas, the least number of pods per plant (69.40), number of seeds per pod (2.46), weight of 1000 seeds (151.00 g) and seed yield per plant (29.80 g) were recorded in untreated control treatment.

Table 2. Effect of foliar application of micronutrients on yield characters

Sr. No.	Treatments	Number of Pods per Plant	Number of Seeds per Pod	1000 Seed Weight (g)	Seed Yield per Plant (g)
1	Borax @ 200 ppm	78.80	2.80	164.10	36.80
2	$FeSO_4$ @200 ppm	76.60	2.66	156.30	33.33
3	$ZnSO_4$ @200 ppm	81.60	2.86	165.60	37.40
4	$CuSO_4$ @ 100 ppm	71.33	2.53	152.50	31.10
5	$MnSO_4$ @ 100 ppm	71.60	2.53	152.80	32.20
6	$(NH_4)_2MoO_4$ @ 100 ppm	74.20	2.66	157.80	32.50
7	Phule Micronutrient Grade 2 @ 100ml/ 10 lit water	85.06	3.00	168.00	41.50
8	Control (No Spray)	69.40	2.46	151.00	29.80
	SE +	**3.05**	**0.09**	**2.25**	**1.17**
	C. D. at 5%	**9.25**	**0.27**	**6.84**	**3.11**
	C.V. %	**6.94**	**5.80**	**2.46**	**5.91**

Seed quality parameters

The data on moisture content, germination percent, speed of germination, seedling dry weight and number of dead seeds of soybean are given in Table 3. Non-significant differences between the treatments for moisture content & speed of germination of seed were recorded. The maximum moisture content (9.30%) and speed of germination (22.40) recorded in treatment Phule grade 2 while minimum moisture content (8.60%) and slower germination speed (21.90) were recorded in Control treatment. Among the treatments, Phule grade 2 showed significantly the highest seed germination percentage (92.66%) and seedling dry weight (1.89 g). In contrast, the control treatment showed the lowest seed germination percentage (89.33%) and seedling dry weight (1.60 g). The lowest number of dead seeds (1.66) were observed in plants treated with Phule grade 2, while the control, $CuSO_4$ @ 100 ppm and $(NH_4)_2MoO_4$ @ 100 ppm were exhibited the highest number of dead seeds (3.33).

Table 3. Effect of foliar application of micronutrients on seed quality characters

Sr. No.	Treatments	Moisture Content (%)	Germination (%)	Speed of Germination	Seedling Dry Weight (g)	No. of Dead Seeds
1	Borax @ 200 ppm	8.80 (17.26)	92.33 (73.92)	22.35	1.68	2.00
2	$FeSO_4$ @200 ppm	8.85 (17.31)	91.66 (73.21)	22.15	1.65	2.66
3	$ZnSO_4$ @200 ppm	9.10 (17.56)	92.00 (73.57)	22.36	1.78	2.00
4	$CuSO_4$ @ 100 ppm	8.55 (17.00)	90.00 (71.57)	21.85	1.62	3.33

5	$MnSO_4$ @ 100 ppm	8.66 (17.11)	90.66 (72.20)	21.90	1.64	3.00
6	$(NH_4)_2MoO_4$ @ 100 ppm	8.76 (17.22)	91.00 (72.54)	22.18	1.67	3.33
7	Phule Micronutrient Grade 2 @ 100ml/ 10 lit water	9.30 (17.76)	92.66 (74.28)	22.40	1.89	1.66
8	Control (No Spray)	8.60 (17.05)	89.33 (70.82)	21.90	1.60	3.33
	SE +	**0.07**	**0.73**	**0.17**	**0.014**	**0.02**
	C. D. at 5%	**N.S.**	**2.21**	**N.S.**	**0.043**	**0.08**
	C.V. %	**1.41**	**1.44**	**1.40**	**1.47**	**1.85**

** The bracket values denotes arcsin transfer values*

The data on root length, shoot length, root shoot ratio, vigour index and electrical conductivity of soybean seeds are given in Table 4. The maximum root length (14.20 cm), shoot length (20.00 cm), shoot root ratio (1.43), seed vigour index I (3160) and vigour index II (174) were observed in plants treated with Phule grade 2, while in control treatment the minimum root length of 12.90 cm, shoot length (17.90 cm), shoot root ratio (1.34), seed vigour index I (2738) and vigour index II (142) were recorded.

Table 4. Effect of foliar application of micronutrients on seed quality characters

Sr. No.	Treatments	Root Length (cm)	Shoot Length (cm)	Shoot Root Ratio	Vigour Index I	Vigour Index II	Electrical Conductivity (dS/m)
1	Borax @ 200 ppm	13.62	19.00	1.38	3013	155	0.45
2	$FeSO_4$ @200 ppm	13.28	18.40	1.36	2884	150	0.47
3	$ZnSO_4$ @200 ppm	13.75	19.40	1.40	3030	163	0.45
4	$CuSO_4$ @ 100 ppm	12.90	17.96	1.34	2779	145	0.49
5	$MnSO_4$ @ 100 ppm	13.00	18.00	1.35	2791	147	0.48
6	$(NH_4)_2MoO_4$ @ 100 ppm	13.16	18.20	1.36	2865	152	0.47
7	Phule Micronutrient Grade 2 @ 100ml/ 10 lit water	14.20	20.00	1.43	3160	174	0.42
8	Control (No Spray)	12.90	17.90	1.34	2738	142	0.49
	SE +	**0.11**	**0.15**	**0.01**	**41.91**	**2.20**	**0.003**
	C. D. at 5%	**0.33**	**0.46**	**0.03**	**127.12**	**6.68**	**0.01**
	C.V. %	**1.42**	**1.43**	**1.42**	**2.49**	**2.47**	**1.42**

The minimum electrical conductivity value measuring 0.42 dS/m was observed in seeds treated with Phule grade 2 and the control treatment exhibited the maximum electrical conductivity value of 0.49 dS/m

Discussion

Morphological characters

The earliness in flowering observed due to micronutrient spraying. This might be due to efficient translocation of photosynthates in the various plant parts and also the production of growth regulating substances, carbohydrates and synthesis of nucleic acids and accumulation of accelerated photosynthates in the plant helps in growth and development in enhancing early flowering. The same results are reported by Trivedi et al. (2011). The increase in height might be due to the role of zinc in chlorophyll synthesis that favours cell division and expansion, meristematic activity and formation of new cell wall. Similar beneficial effects of micronutrients were noticed by Krishnaveni et al. (2004) in green gram, Hugar & Kurdikeri (2000), Nagaraja & Mohankumar (2010) and Chavan et al. (2022) in soybean.

Yield characters

The yield characters *viz.,* number of pods per plant, number of seeds per pod, 1000 seeds weight and seed yield per plant were recorded highest in plants sprayed with Phule Grade 2. The maximum seed yield recorded in Phule multi-micronutrient treatment might be due to the significant effect of all micronutrient combination spray increasing number of pods per plant as the role of boron in enhancing dry matter and translocation efficiency of photosynthates to developing sink leading to more pods and increase seed yield (Dixit & Elamathi, 2007). Additionally, Molybdenum is

responsible for enhancing nitrogen fixation process by nodule tissues formation. These factors might have contributed to a higher number of pods and seeds per pod, ultimately leading to an increased seed yield as reported by Adesoji et al. (2009). Similar conclusions regarding the impact of foliar micronutrients on soybean seed yield were reported by Shelge et al. (2000), Shinde et al. (2015) and Chavan et al. (2022).

Seed quality parameters

The increase in moisture content and speed of germination recorded in micronutrient sprayed treatments while minimum were recorded in Control treatment. A minor variation in moisture content and germination speed might be attributed to the larger-sized seeds obtained from plants treated with Phule grade 2. Among the treatments, Phule grade 2 showed significantly the highest and control reported lowest seed germination percentage and seedling dry weight. These results support the earlier findings that micronutrient treatments in soybean significantly increased seed germination compared to control due to deposition of higher qualities of protein and sugars (Jadhav et al., 2009). Hugar & Kurdikeri (2000) and Deosarkar et al. (2002) also found significant effect of micronutrients on seed germination in soybean. The control treatment exhibited the highest number of dead seeds. The more number of dead seeds might result from improper seed development during the ripening and maturation stages. The maximum root length, shoot length, shoot root ratio, seed vigour index I and vigour index II were observed in plants treated with Phule grade 2, while in control treatment the minimum values were recorded. The use of micronutrients appears to enhance the viability and vigor of seeds by fostering proper development of the embryo and endosperm, potentially contributing to the observed results. Zinc plays important role in the auxins and hormones production that helps in cell elongation, root branching and even the timing of flower initiation (Tripathi et al., 2022). Similar results were found in studies by Charjan & Tarar (1991), Yadav et al. (1991) and Kachare et al. (2022). The improvement in seed quality characters may be due to the fact that nutrition to mother plant that reflected seed quality by accumulation of higher qualities of carbohydrates and protein. These results are supported by the findings of Deosarkar et al. (2002) in soybean. The minimum electrical conductivity was observed in seeds with Phule grade 2 treatment and the control treatment exhibited the maximum. The seed with high germination percentage and vigor typically exhibit low leachates, resulting in low electrical conductivity. Conversely, seeds with higher conductivity measurements showed electrolyte leakage and lower quality. Lower quality seeds possess poor membrane structures that allow electrolytes and ions to leak through. Similar findings were reported by Parmar et al. (2023) in groundnut and Kachare et al. (2022) in green gram regarding the impact of micronutrients on seed electrical conductivity.

Conclusion

From the data it was concluded that the two foliar sprayings of different micronutrients such as Borax @200 ppm, $FeSO_4$ @200 ppm, $ZnSO_4$ @200 ppm, $CuSO_4$ @100 ppm $MnSO_4$ @100 ppm and $(NH_4)_2MoO_4$ @100 ppm showed positive results for morphological, yield attributing and seed quality characters than control unsprayed treatment in soybean. But the application of Phule grade 2 micronutrient treatment as two foliar sprayings at 25 and 40 days after sowing was found more beneficial in increasing growth and yield attributing characters as well as seed quality parameters of soybean variety Phule Sangam as compared to the untreated control treatment.

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Author contributions

Amar G. Meher conducted Research trial, collection, analysis of data, Thesis writing.
Hitendra J. Rajput has contribution as Research guide, guided to conduct trial, observations, analysis & thesis writing.
Ramesh S. Bhadane wrote the entire manuscript of research article in addition to help in collection of data, analysis and interpretation.
Vitthal R. Patil involved in collection of data, analysis, field and laboratory trial formulation.

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Conflict of interest

The author declares no conflict of interest. The manuscript has not been submitted for publication in any other journal.

Ethics approval

Not applicable.

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