Indian Journal of Agricultural Sciences **94** (12): 1317–1321, December 2024/Article
https://doi.org/10.56093/ijas.v94i12.141547

Effect of foliar nutrition on productivity and profitability of mungbean (*Vigna radiata*) in western Rajasthan

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Received: 28 August 2023; Accepted: 01 October 2024

ABSTRACT

The experiment was conducted during rainy (*kharif*) seasons of 2021 and 2022 at Agricultural Research Station (Agriculture University, Jodhpur, Rajasthan), Mandor, Rajasthan to evaluate the impact of foliar nutrient application on mungbean [*Vigna radiata* (L.) Wilczek] growth, yield, and economic returns. The mungbean variety GM4 was used for the study. The treatment was laid out in a randomized block design (RBD) comprised of 8 treatments, viz. T_1, Water spray; T_2, 2% urea; T_3, 2% DAP (diammonium phosphate); T_4, NPK (18:18:18) @2%; T_5, 0.5% $ZnSO_4$; T_6, 2% urea + 0.5% $ZnSO_4$; T_7, 2% DAP + 0.5% $ZnSO_4$; and T_8, NPK (18:18:18) @2% + 0.5% $ZnSO_4$, replicated thrice. All foliar nutrient applications were performed at pre-flowering and pod initiation stages. The treatment involving foliar spray of NPK (18:18:18) @2% + 0.5% $ZnSO_4$ during these stages exhibited superior performance in terms of growth parameters and yield, including number of nodules/plant, plant height (cm), number of branches/plant, number of pods/plant, number of seeds/pod, test weight (g), and overall yield compared to the control. This treatment showed comparable efficacy to the application of 2% NPK (18:18:18). Additionally, foliar application of NPK (18:18:18) @2% + 0.5% $ZnSO_4$ resulted in significantly higher gross monetary returns (₹107,096/ha) and net monetary returns (₹80,156/ha). However, the treatment combining 2% urea + 0.5% $ZnSO_4$ exhibited the highest benefit to cost ratio.

Keywords: Foliar spray, Mungbean, Nutrients, Net return, Yield

Mungbean [*Vigna radiata* (L.) Wilczek] holds a significant position as a versatile leguminous pulse crop, cultivated worldwide for its nutritional and economic value (Kebede 2021). It has been successfully adapted to diverse agro-climatic zones in India, serving various purposes such as vegetable, pulse, fodder, and green manure (Kumar *et al.* 2021, Banotra *et al.* 2021, Kumawat *et al.* 2022), while also contributing to soil fertility restoration through its inherent biological nitrogen fixation mechanism (Meena and Kumhar 2017, Bahadari *et al.* 2020). Despite its adaptability, low productivity of mungbean due to suboptimal management practices, inherent factors, and physiological intricacies is associated with the crop (Athnere *et al.* 2021).

Zinc deficiency, particularly prevalent in soils with low organic carbon content and alkaline *p*H, is a key factor limiting mungbean productivity (Meena *et al.* 2020, Danga *et al.* 2020). Common fertilizer practices involve applying nitrogen and phosphorus. Moreover, micronutrient deficiencies, especially zinc, have emerged as significant barriers to achieve high crop yields. In certain soil conditions, such as salinity or extreme *p*H, root-based nutrient uptake is impeded, making foliar nutrition an effective strategy to overcome fixation and immobilization challenges, enhancing nutrient efficiency, particularly for short-duration crops (Pochampally *et al.* 2021). Securing a balanced supply of macro- and micronutrients is pivotal for optimizing mungbean crop yield, quality, and economic returns. Previous research, exemplified by Das *et al.* (2016), underscores the efficacy of basal application of these nutrients in bolstering seed yields in pulse crops. However, it's important to recognize that the intricate interactions among these nutrients within the soil and plants can manifest as both antagonistic and synergistic effects (Alloway 2004). Thus, the implementation of efficient mineral nutrient management through foliar applications emerges as a fundamental requirement to unlock the full yield potential of major crops, including mungbean.

The arid region of western Rajasthan presents a unique challenge for mungbean cultivation due to nutrient deficiencies exacerbated by limited water availability and high temperatures. Addressing these challenges, foliar nutrition emerges as a potential solution to enhance nutrient uptake efficiency and mitigate the impact of abiotic stress

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factors. Therefore, the objective of this study was to assess the effect of foliar nutrition on productivity and profitability of mungbean.

MATERIALS AND METHODS

Soil characterization: The soil's composition of the three primary elements nitrogen (N), phosphorus (P), and potassium (K) was determined using established methods-alkali potassium permanganate method (Subbiah and Asija 1956), Olsen method (Olsen 1954), and flame photometer method (Stanfield and English 1949), respectively. Additionally, standard protocols were followed to assess *p*H (Singh *et al.* 1999), electrical conductivity (EC) (Singh *et al.* 1999), and organic carbon content (Walkley and Black 1934) of the soil samples. The soil was identified as loamy sand in texture with a bulk density of 1.77 Mg/m³. It exhibited a slightly alkaline *p*H of 8.1 and an electrical conductivity of 0.12 dS/m. The organic carbon content measured 0.13%. Regarding nutrient availability, the soil contained 174 kg/ha of nitrogen, 24.2 kg/ha of phosphorus, and 325 kg/ha of potassium.

Field experiment: The experiment was conducted during rainy (*kharif*) seasons of 2021 and 2022 at Agricultural Research Station (Agriculture University, Jodhpur, Rajasthan), Mandor (26°15' N and 26°45' N latitude and 73°00' E and 73°29' E longitude, with an altitude of 231 m amsl), Rajasthan. Fig. 1 illustrates the weather parameters recorded during the crop season. The experiment was laid out in a randomized block design (RBD) encompassed eight distinct treatments, viz. T_1, Water spray; T_2, 2% urea; T_3, 2% DAP (diammonium phosphate); T_4, NPK (18:18:18) @2%; T_5, 0.5% $ZnSO_4$; T_6, 2% urea + 0.5% $ZnSO_4$; T_7, 2% DAP + 0.5% $ZnSO_4$; and T_8, NPK (18:18:18) @2% + 0.5% $ZnSO_4$, replicated thrice. Foliar sprays were applied at both pre-flowering and pod initiation stages. Sowing dates were 17th July 2021 and 4th July 2022. The mungbean variety GM4 was manually sown with two lines per plot spaced 30 cm apart, and a plant to plant distance of 10 cm. The seed rate ranged from 12–15 kg/ha. Each plot was 4.0 m in length and 3.0 m in width i.e. 12 m². A standard dose of nitrogen (15 kg N/ha) and phosphorus (35 kg P_2O_5/ha) was applied using urea and Diammonium phosphate (DAP) as basal fertilizers at sowing. Cultural practices appropriate for the agro-climatic zone were applied throughout the mungbean growth cycle, except for the experimental foliar nutrient management technique. Activities such as gap filling, thinning, irrigation, weeding, mulching, and pest control were performed as needed to ensure optimal plant growth and development.

Analyses of plant growth, yield attributes and yield: Observations on the number of nodules/plant, plant height (cm), number of branches/plant, number of pods/plant, and number of seeds/pod were conducted by randomly selecting five representative plants from each plot within each replication. Additionally, test weight (g) and overall yield were documented. Harvesting occurred on 1st October 2021 and 5th October 2022. Grain and straw yield were recorded from the net plot area of each treatment. Harvest index (HI) was calculated as:

$$\text{HI (\%)} = [\frac{\text{Seed yield}}{\text{Biological yield}}] \times 100$$

Calculation of benefit-cost ratio: Benefit-cost (B:C) ratio was computed to assess the economic viability of different treatment combinations. Economic analyses were conducted to compare and select the most effective treatment.

Statistical analysis: Statistical analysis involved pooling the mean values of experimental data from each year's three replications. These pooled mean values were subjected to statistical analysis using SAS software through one-way analysis of variance (ANOVA).

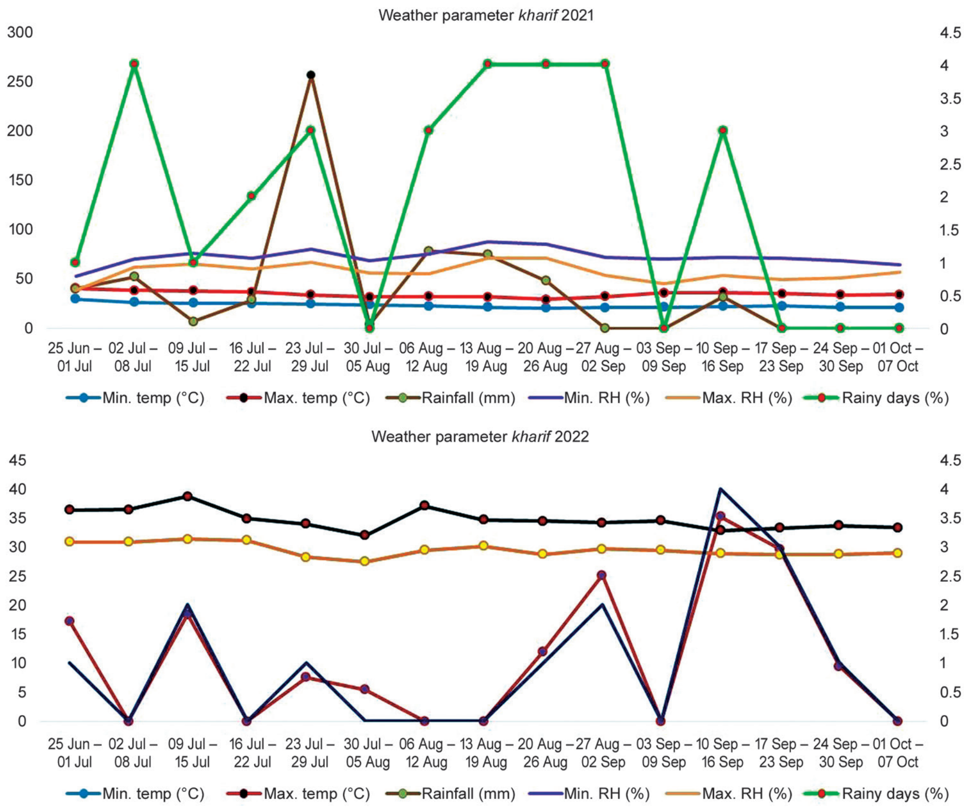

Fig. 1 Meteorological parameters during crop season.

RESULTS AND DISCUSSION

Effect of foliar spray of nutrients on growth, yield attributes and yield of mungbean: Foliar applications of various types of nutrients significantly influenced the growth parameters, yield and yield attributes of mungbean. Among the treatments, the application of NPK (18:18:18) at 2% concentration along with 0.5% $ZnSO_4$ at pre-flowering and pod initiation stages resulted in significant enhancement in plant height, with a remarkable growth enhancement of 25.81% as compared to control. Number of nodules/plant significantly increased by 33.82% over the control with foliar application of NPK (18:18:18) @2% + 0.5% $ZnSO_4$ at pre flowering and pod initiation stage. Foliar application of NPK (18:18:18) @2% + 0.5% $ZnSO_4$; 2% urea + 0.5% $ZnSO_4$ and 2% DAP + 0.5% $ZnSO_4$ at pre-flowering and pod initiation stage increased number of branches/plant by 24.53%, 20.75% and 20.75%, respectively over control. 1000-grains weight of mungbean also exhibited a significant increase with foliar application of NPK (18:18:18) @2% + 0.5% $ZnSO_4$ at pre- flowering and pod initiation stage, with a notable 10.70% improvement over control. The overall yield of mungbean was significantly enhanced with foliar application of NPK (18:18:18) at 2% + 0.5% $ZnSO_4$ during pre-flowering and pod initiation stages, as well as other nutrient applications (Table 1). Significantly highest grain yield was recorded with foliar application of NPK (18:18:18) @2% + 0.5% $ZnSO_4$ at pre-flowering and pod initiation stage which was at par with 2% urea + 0.5% $ZnSO_4$ and 2% DAP + 0.5% $ZnSO_4$ at pre-flowering and pod initiation stage over control. This phenomenon can be attributed to the improved availability of both macro and micronutrients to the plants through foliar nutrient application. This enhanced nutrient availability facilitated early root growth, cell multiplication, and nutrient absorption from deeper soil layers. Consequently, these factors contributed to increased plant height, enhanced food synthesis and better partitioning of resources.

These results are in accordance with Zafar *et al.* (2023) who investigated that number of branches, plant height, pods/plant, pod length, seeds/pod, 1000-grain weight and grain yield of mungbean were significantly enhanced with foliar application of Zn @0.3%. Dhaliwal *et al.* (2023) similarly reported that application of foliar $ZnSO_4$ at a concentration of 0.5% was found to be effective in enhancing both grain and straw yields in mungbean crops. Zinc (Zn) serves a multifaceted role in plant physiology, exerting regulatory control over water uptake and efficient utilization by plants (Bahadari *et al.* 2020). Beyond its structural role in enzymes, Zn functions as a vital activator of numerous enzymatic reactions within plants. Furthermore, direct involvement of Zn in the biosynthesis of growth-promoting substances underscores its significance in plant development. Particularly during the early stages of growth, Zn has been shown to enhance photosynthetic efficiency, thereby contributing to improved growth parameters in mungbean plants (Banotra *et al.* 2021). The application of foliar nutrition, including Zn, brought about significant enhancements across various growth attributes of crops. This study results align with this understanding, demonstrating significant improvements due to foliar nutrient application. These improvements can be attributed to Zn's diverse roles, ranging from activating enzymes that drive essential metabolic processes to influencing growth substance biosynthesis and photosynthetic enhancement. Our results are also corroborated with the study of Meena *et al.* (2020), who revealed that the application of 125% recommended dose of fertilizer (RDF) coupled with Zn and Fe led to the highest grain yield (1098 kg/ha) and straw yield (2458 kg/ha). This underscores the potential efficacy of incorporating Zn into fertilizer application strategies, demonstrating a positive impact on mungbean productivity by enhancing nutrient utilization and metabolic processes. The intricate role of Zn in facilitating water uptake, enzyme activation, growth substance biosynthesis, and photosynthesis directly influences mungbean growth and productivity. The application of Zn through foliar nutrition

Table 1 Effect of foliar spray of nutrients on growth, yield attributes and yield of mungbean (Pooled data of two years 2021 and 2022)

Treatment	*Nodules/ plant	*Plant height (cm)	*Branches/ plant	*Pods/ plant	*Seeds/ pod	*Test weight (g)	Grain yield (kg/ha)			*Harvest index (%)
							2021	2022	Pooled	
T_1, Water spray	6.8	39.9	5.3	20.2	8.4	43.0	863	1147	1005	38.2
T_2, 2% urea	8.2	46.7	6.3	23.9	9.1	45.0	1028	1351	1190	37.7
T_3, 2% DAP	7.6	45.6	6.2	23.3	9.0	44.2	1003	1340	1171	38.2
T_4, NPK (18:18:18) @2%	7.9	47.7	6.2	24.6	9.2	44.6	1047	1384	1216	38.0
T_5, 0.5% $ZnSO_4$	7.8	45.3	6.0	22.7	9.1	45.0	988	1347	1168	38.1
T_6, 2% urea + 0.5% $ZnSO_4$	8.3	48.5	6.4	25.7	9.6	47.0	1076	1419	1248	37.4
T_7, 2% DAP + 0.5% $ZnSO_4$	8.2	47.9	6.4	24.5	9.3	46.3	1049	1396	1222	37.3
T_8, NPK (18:18:18) @2% + 0.5% $ZnSO_4$	9.1	50.2	6.6	26.1	9.7	47.6	1142	1504	1323	37.3
SEm.±	0.3	1.5	0.20	0.9	0.3	0.88	53.3	66.9	42.8	1.41
CD (P=0.05)	0.8	4.3	0.59	2.7	0.8	2.5	162	203	124	4.1
CV (%)	8.6	7.8	8.1	9.4	7.0	4.7	9.0	8.5	8.8	9.1

aligns with previous studies, highlighting its potential to enhance various growth parameters and ultimately contribute to improved crop yield.

Several researchers, including Meena *et al.* (2013), Jat *et al.* (2016) and Meena *et al.* (2017) have also reported significant enhancement in the number of nodules through the implementation of foliar fertilization. The practice of foliar fertilization, involving urea, zinc, NPK, and DAP, had demonstrated a comprehensive enhancement in the overall growth of the crop. This improvement may be attributed to the significant impact of these foliar nutrients on the nutritional environment and their involvement in various physiological processes within the plant system, which are recognized as prerequisites for optimal plant development. The heightened growth and development of the crop plants in this particular investigation can be attributed to augmented metabolic activities and an increased rate of photosynthesis. This, in turn, has led to the improved assimilation of dry matter throughout the different growth stages, culminating in enhanced maturity. According to Bhavya *et al.* (2024), the foliar application of monopotassium phosphate and 19:19:19 each at a concentration of 1% at 30 and 45 DAS, in conjunction with a recommended package of agricultural practices, resulted in notably enhanced plant height, total dry matter production, number of pods, number of seeds/plant, pod length, and grain yield. This approach led to a significant yield increase of 25.07% compared to the standard package of agricultural practices and a remarkable 46.85% increase compared to traditional farmer practices. Incorporating present findings into agricultural practices could potentially enhance overall mungbean productivity and contribute to more sustainable and efficient farming methods.

The present findings underscored the positive impact of foliar fertilization on the crop's metabolic and photosynthetic processes, resulting in an overall improvement in growth and development. This aligned with previous research, which collectively highlighted the potential of foliar fertilization strategies to bolster crop performance. The results of present investigation are in conformity with the findings of Meena *et al.* (2013) who reported that foliar spray of 0.5% $FeSO_4$ + 0.1% citric acid treatment showed statistical superiority over 25 kg $FeSO_4$/ha as basal application in respect to dry matter accumulation, leaf area chlorophyll content, number of pods/plant, number of nodules per plant, test weight and harvest index. Similarly, Mehriya *et al.* (2020) observed that the application of 2% urea combined with 75 ppm salicylic acid at flowering initiation significantly increased the number of branches/plant (4.1), plant height (42.2 cm), pods/plant (29.9), and grain yield (989 kg/ha) of mungbean, outperforming other treatments including nitrobenzene at 500 ppm, 0.25% boron, 75 ppm salicylic acid, and 2% urea.

Net return and benefit: cost ratio in respect to foliar fertilization of nutrients: The study highlighted the economic impact of different nutrient application strategies on mungbean cultivation. The highest return (₹107096/ha) was observed with application of NPK (18:18:18) at 2% concentration along with 0.5% $ZnSO_4$ at pre-flowering and pod initiation stage (Table 2). Similarly, the treatment of 2% urea + 0.5% $ZnSO_4$ exhibited the highest benefit cost ratio of 4.02 for mungbean. Differences in net returns and benefit cost ratios could be attributed to the effects of yield of mungbean for each treatment. These findings are aligned with previous research conducted by Mehriya *et al.* (2020) and Saitheja *et al.* (2022), indicating a consensus in the agricultural community regarding the efficacy of these specific nutrient application methods. Similar results were also reported by Banotra *et al.* (2021) under recommended dose of fertilizer in mungbean (16 N: 40 P_2O_5 kg/ha). Additionally, Diwedi *et al.* (2024) reported that foliar spray of $ZnSO_4$, when combined with the recommended dose of fertilizer, contributed to enhanced net returns and benefit cost ratios.

Foliar application of NPK (18:18:18) @2% + 0.5% $ZnSO_4$ at pre flowering and pod initiation stage was observed to be more suitable for mungbean cultivation in western arid zone of Rajasthan, India. Similarly, the foliar spray of

Table 2 Effect of foliar spray of nutrients on economics of mungbean

Treatment	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit cost ratio
T_1, Water spray	24.55	81.24	56.74	3.31
T_2, 2% urea	24.68	96.24	71.62	3.90
T_3, 2% DAP	25.06	94.71	69.71	3.78
T_4, NPK (18:18:18) @2%	26.59	98.38	71.88	3.70
T_5, 0.5% $ZnSO_4$	25.05	94.42	69.48	3.77
T_6, 2% urea + 0.5% $ZnSO_4$	25.14	101.07	76.01	4.02
T_7, 2% DAP + 0.5% $ZnSO_4$	25.52	99.02	73.58	3.88
T_8, NPK (18:18:18) @2% + 0.5% $ZnSO_4$	27.04	107.09	80.15	3.96
SEm.±	-	3395	3395	-
CD (*P*=0.05)	-	9835	9835	-
CV (%)	-	8.62	11.7	-

#Values are pooled of two years (2021 and 2022).

2% urea + 0.5% $ZnSO_4$ and 2% DAP + 0.5% $ZnSO_4$ at pre flowering and pod initiation stage proved significant over the control in terms of seed yield. Both the NPK (18:18:18) at 2% + 0.5% $ZnSO_4$ and 2% urea + 0.5% $ZnSO_4$ treatments exhibited superior economic feasibility compared to other treatments.

ACKNOWLEDGEMENT

The authors are grateful to the Indian Council of Agricultural Research (ICAR), New Delhi, for their financial support through the All India Coordinated Research Project (AICRP) on *kharif* pulses.

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