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Performance of soybean as influenced by foliar application of macro and micro nutrients

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Abstract
A field experiment was conducted during *Kharif* season from July 2021 to October 2021 to study the effect of foliar application of potassium, boron and zinc on growth, yield and economics of soybean at the agriculture research farm of Lovely Professional University, Punjab. The experiment was laid out in randomized block design with three replications comprising of seven treatments. The treatments consisted of control no foliar application), foliar application of potassium nitrate @ 2%, boric acid @ 50ppm, foliar application of zinc sulphate @ 1%, foliar application of potassium nitrate @ 2% + boric acid @ 50ppm, foliar application of potassium nitrate @ 2% + zinc sulphate @ 1% and foliar application of boric acid @ 50ppm + zinc sulphate @ 1%. The growth parameter of soybean such as plant height (48.5cm), number of trifoliate leaf (28.0 plant^{-1}), leaf area (12.73 dm^{2}plant^{-1}), leaf areas index (4.2 dm^{2}plant^{-1}) and dry matter (34.1 g plant^{-1}), yield parameters such as higher number of pods (46.7 plant^{-1}), number of seeds per pod (3.2) and seed weight (2.4 plant^{-1}), seed yield (32.3q ha^{-1}), haulm yield (59.7q ha^{-1}), harvest index (35.1%) and net return (₹83,327 ha^{-1}) were observed with foliar application of potassium nitrate @ 2% + boric acid @ 50ppm when compared to rest of the treatments. However, foliar application of boric acid @ 50ppm + zinc sulphate @ 1% and foliar application potassium nitrate @ 2% + zinc sulphate @ 1% were on par. Contrarily, control treatment has recorded significantly the lowest growth and yield parameters, yield and economics as compared to foliar application treatments.

Keywords: Foliar nutrition, zinc, boron, yield, growth, economics

Introduction
Soybean (*Glycine max* L.) is considered as the most important oilseed crop that produces about 2 percent of world edible oil production. Soybean is the only oilseed crop that produces half of the edible oil in the whole world. Soybean is a good source of iron, minerals, phosphorus, etc. The soybean crop also contains a high number of macronutrients and micronutrients and is a very good source of food for humans and animals (Awan *et al.*, 2020) [8]. India is the fourth-largest producer of soybean in the world (11.5mt). Soybean is a cold season crop and the productivity of soybean in India is very less when compared to global average productivity (data). The cultivation of soybean in India is limited because it is a rainfed crop.
Indian agriculture has achieved a fourfold growth in food production by adopting modern agricultural practices like application of fertilizer and growing high yielding varieties. Initially, this became possible by using nitrogenous fertilizers alone, as the soil could provide all other essential nutrients needed by plants. However, within a few years, the nutrient reserves in soil were gradually exhausted and it was no longer possible to sustain higher yields even by applying both N and phosphorus (Singh, 2008) [22]. Thus, in this north western parts (Haryana and Punjab) where high cropping intensity is observed, deficiencies of secondary nutrients and micronutrients were frequently observed in cereal, oilseed, pulse and vegetable crops. This has become critical in obtaining and sustaining higher crop production over the years (Singh, 2008) [22]. Further, In race towards high production and profit from agriculture, the farmers are adopting abnormal production technologies like heavy and injudicious use of chemical fertilizers that have not only reduced the factor productivity, but also eroding biodiversity and enhancing environmental pollution (Shivran *et al.*, 2014) [21]. Further, heavy fertilizer application to soil has showed inefficient use nutrients due to huge loss of nutrients through, DE nitrification, volatilization and leaching. Hence need of the hour is to increase nutrient use efficiency and to reduce micro nutrient deficiencies in the soybean crop.
The foliar application of nutrients is more beneficial than soil application because the foliar application has direct contact with the foliage of the plants so that the nutrients get easily available to the plants. It is a very efficient and proven means of fertilizer application.

It has direct contact with the foliage of the crop so that the nutrient gets easily and directly available to the plants. Foliar application makes the plant to use nutrients more efficiently. It can stimulate root development and can control the growth rate of the crop. The application of potassium, boron, and zinc through the foliar application is more beneficial and easier to absorb by the plants (Abd EL-Kader, 2013 [1] and Shwetha Kumari & Prakash, 2018). Hence, foliar nutrition is an important crop management strategy for maximizing the crop yields. By keeping all those above-mentioned points in view, this research work was conducted with an objective to the effect of foliar application of potassium, boron, and zinc on the nodulation, yield, and seed quality of soybean.

Materials and methods

The experiment was conducted at agriculture research farm of Lovely Professional University, Punjab during *Kharif* season from July 2021 to October 2021. The total rainfall during the crop growth season (July 16 to October 23) was 240 mm with 22 rainy days. The soil type of experimental site was loamy sandy soil. At 30 cm depth, randomly the soil sample was taken from the experimental field and the sample was analyzed to determine the chemical properties of the soil. The soil was slightly alkaline in reaction (8.25 pH) with normal in electrical conductivity (0.122 DS m^{-1}), low in organic carbon (0.18%) and medium in available nitrogen (188.16kg ha^{-1}) and available phosphorus (18.27kg ha^{-1}) and available potassium (170.24kg ha^{-1}). The experiment was laid out in randomized complete block design involving 7 treatments and replicated thrice. The treatments included were control (T_1-no foliar application), foliar application of potassium nitrate @ 2% (T_2), boric acid @ 50ppm (T_3), zinc sulphate @ 1% (T_4), potassium nitrate @ 2% + boric acid @ 50ppm (T_5), potassium nitrate @ 2% + zinc sulphate @ 1% (T_6) and boric acid @ 50ppm + zinc sulphate @ 1% (T_7).

The selected bold and healthy seeds of JS-9560 were sown manually in *Kharif* season @ 50 kg ha^{-1} at a spacing of 30 cm x 10cm. The recommended dose of fertilizer (31.25:80:0 kg $N:P_2O_5:K_2O$ ha^{-1}) was applied as per the package of practices to all the treatments. Further, seeds were inoculated with *Rhizobium* culture. Two foliar applications were done according to the treatments at 25 and 50 days after sowing (DAS). Five plants were selected randomly from net plot and tagged with label for taking various observations on growth and yield components like plant height, number of trifoliate leaf, leaf area, leaf areas index and dry matter and yield parameters like number of pods per plant, number of seeds per pod, seed weight per plant and test weight, the seed yield, haulm yield, harvest index, net return and benefit cost ratio. The experimental data obtained was compiled and subjected to statistical analysis by adopting Fischer's method of analysis of variance (Gomez and Gomez, 1984) [13]. The critical difference (CD) values given in the table at 5 percent level of significance were used.

Results

The data revealed that growth parameters, yield parameters and yield of soybean differed significantly due to foliar nutrient application of soybean.

Growth performance

Foliar nutrient application significantly influenced growth parameters of soybean (Table 1) such as higher plant height (48.5 cm), number of trifoliate leaf (28.0 per plant), leaf area (12.73$dm^2 plant^{-1}$), leaf areas index (4.2) and dry matter (34.1g $plant^{-1}$) were observed with foliar application of potassium nitrate @ 2% + boric acid @ 50ppm when compared to rest of the treatments. However, foliar application of boric acid @ 50ppm + zinc sulphate @ 1% and foliar application potassium nitrate @ 2% + zinc sulphate @ 1% were on par. Similarly, higher number of nodules (68.5$plant^{-1}$), dry weight of nodules (0.08$plant^{-1}$) and higher number of effective nodules (59.3$plant^{-1}$) was recorded with foliar application of potassium nitrate @ 2% + boric acid @ 50ppm when compared to all other treatments (Fig 1). However, it was on par with foliar application of boric acid @ 50ppm + zinc sulphate @ 1% (72.0 $plant^{-1}$) and foliar application of potassium nitrate @ 2% + zinc sulphate @ 1% (62.7 $plant^{-1}$).

Table 1: Growth parameters of soybean as influenced by foliar nutrient application

Tr. No	Treatments	Plant height (cm)	No. of trifoliate leaf	Leaf area ($dm^2 plant^{-1}$)	Leaf area index ($dm^2 plant^{-1}$)	Dry matter of soybean (g $plant^{-1}$)
T_1	Control	42.3	22.1	9.56	3.2	30.2
T_2	Potassium nitrate @ 2%	49.4	23.5	10.78	3.6	30.6
T_3	Boric acid @ 50ppm	48.5	23.9	10.67	3.6	31.5
T_4	Zinc sulphate @ 1%	44.5	24.1	9.49	3.2	30.1
T_5	Potassium nitrate @ 2% + Boric acid @ 50ppm	54.7	28.0	12.73	4.2	34.1
T_6	Potassium nitrate @ 2% + Zinc sulphate @ 1%	52.2	26.4	11.68	3.9	32.8
T_7	Boric acid @ 50ppm + Zinc sulphate @ 1%	53.2	26.9	11.97	4.0	33.3
	S.E m.±	1.5	0.8	0.40	0.1	0.9
	C.D. @ 5%	4.6	2.4	1.23	0.4	2.9

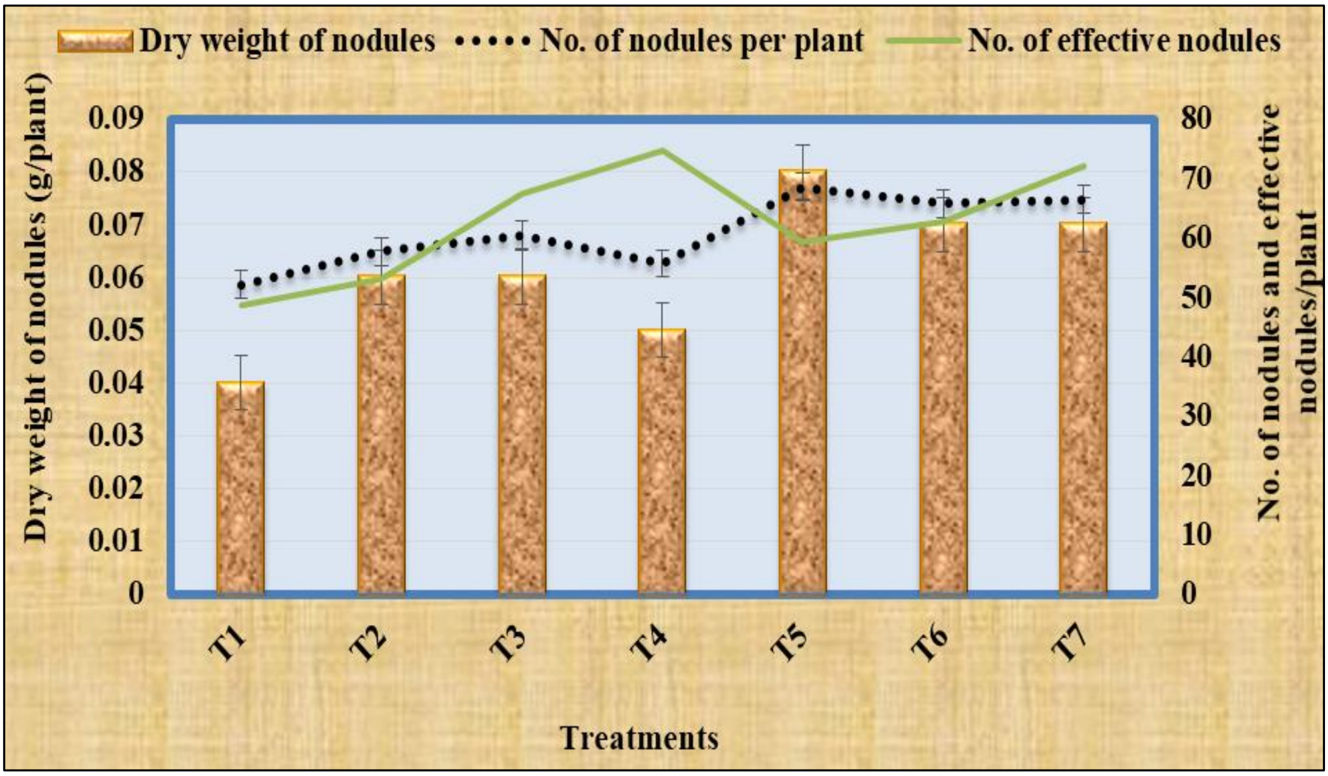


Fig 1: Nodulation of soybean as influenced by foliar nutrition

Yield performance

Foliar nutrient application significantly influenced yield parameters of soybean (Table 2) such as number of pods per plant, number of seeds per pod and seed weight per plant differed significantly with foliar application except test weight. Significantly superior and on par yield parameters such as higher number of pods (46.7 plant^{-1}), number of seeds per pod (3.2) and seed weight (2.4 plant^{-1}) were observed with foliar application of potassium nitrate @ 2% + boric acid @ 50ppm when compared to all other treatments. However, it was on par with foliar application of boric acid @ 50ppm + Zinc sulphate @ 1% and foliar application of potassium nitrate @ 2% + Zinc sulphate @ 1%. Further, significantly the higher seed yield (32.3q ha^{-1}), haulm yield (59.7q ha^{-1}) and harvest index (35.1q %) were observed with foliar application of potassium nitrate @ 2% + boric acid @ 50ppm when compared to rest of the treatments (Table 3). However, foliar application of boric acid @ 50ppm + zinc sulphate @ 1% and foliar application potassium nitrate @ 2% + zinc sulphate @ 1% were on par when compare to rest of the treatment.

Table 2: Yield parameters of soybean as influenced by foliar nutrient application

Tr. No	Treatments	Number of pods per plant	Number of seeds per pod	Seed weight per plant	Test weight (g)
T_1	Control	45.2	2.2	1.5	13.7
T_2	Potassium nitrate @ 2%	40.8	2.4	1.8	14.2
T_3	Boric acid @ 50ppm	40.4	2.4	2.0	13.7
T_4	Zinc sulphate @ 1%	40.5	2.6	1.7	14.2
T_5	Potassium nitrate @ 2% + Boric acid @ 50ppm	46.7	3.2	2.4	14.5
T_6	Potassium nitrate @ 2% + Zinc sulphate @ 1%	45.2	2.6	2.2	14.3
T_7	Boric acid @ 50ppm + Zinc sulphate @ 1%	46.1	2.8	2.3	14.4
	S.E m.±	1.4	0.2	0.1	0.2
	C.D. @ 5%	4.4	NS	0.2	NS

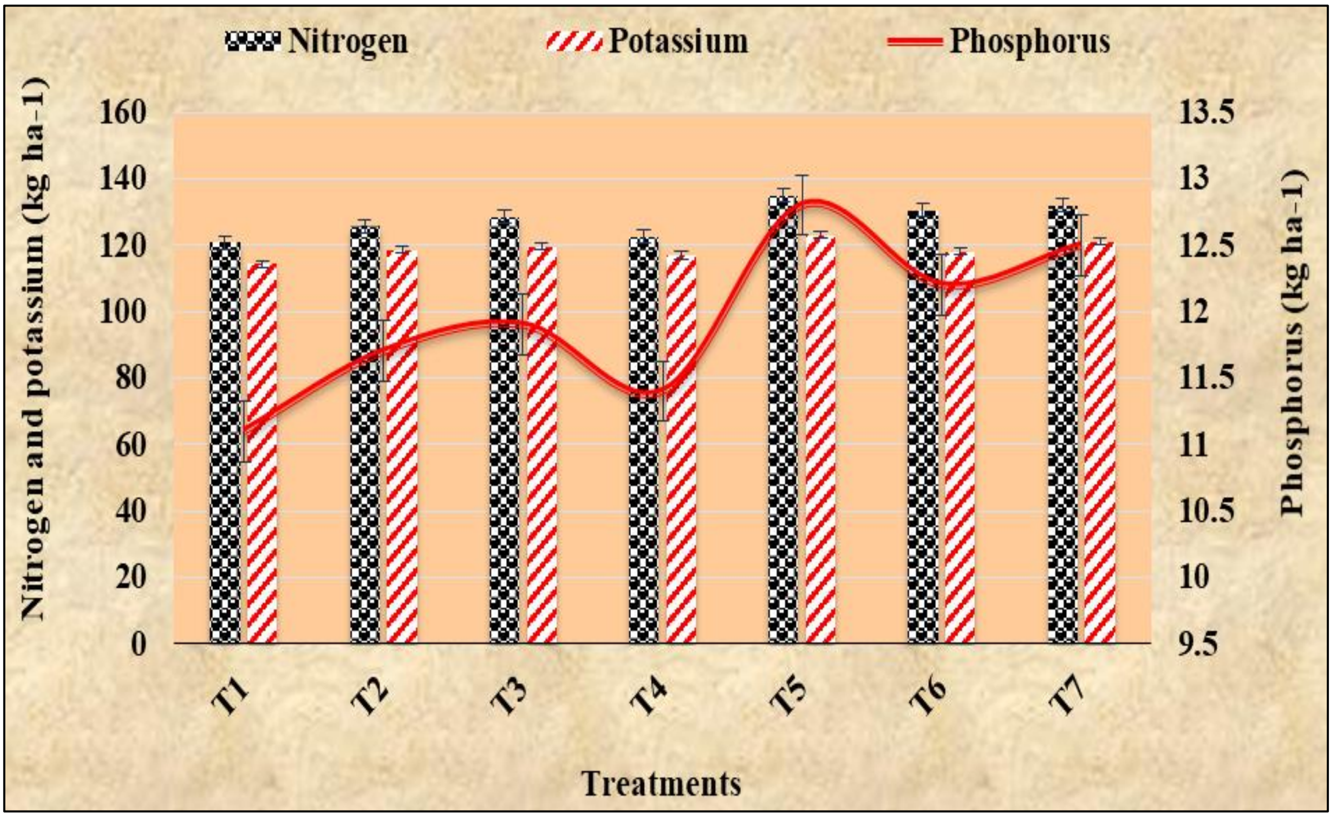
Table 3: Yield and Economics of soybean as influenced by foliar nutrient application

Tr. No	Treatments	Seed yield (q ha^{-1})	Haulm yield (q ha^{-1})	Harvest index (%)	Net return (₹ ha^{-1})	B:C Ratio
T_1	Control	24.4	49.3	33.1	56455	1.41
T_2	Potassium nitrate @ 2%	27.1	54.0	33.3	63477	1.46
T_3	Boric acid @ 50ppm	26.3	54.2	32.7	62263	1.49
T_4	Zinc sulphate @ 1%	27.1	53.3	33.7	63826	1.48
T_5	Potassium nitrate @ 2% + Boric acid @ 50ppm	32.3	59.7	35.1	83327	1.88
T_6	Potassium nitrate @ 2% + Zinc sulphate @ 1%	31.5	57.0	35.6	79406	1.76
T_7	Boric acid @ 50ppm + Zinc sulphate @ 1%	32.0	58.7	35.2	83016	1.91
	S.E m.±	1.62	5.06	1.33	6401	0.15
	C.D. @ 5%	4.99	4.97	NS	19724	0.46

Nutrient uptake, nutrient use efficiency and economics of soybean

Foliar nutrient application has significantly influenced nutrient uptake of soybean. The significantly higher uptake of nitrogen (135.0kg ha^{-1}), phosphorous (12.8kg ha^{-1}) and potassium (123.0kg ha^{-1}) was recorded with foliar application of potassium nitrate @ 2% + boric acid @ 50ppm when compared to all other treatments (Fig. 2). However, it was on par with foliar application of boric acid @ 50ppm + zinc sulphate @ 1% and foliar application of potassium nitrate @ 2% + zinc sulphate @ 1%. The data with respect to nutrient use efficiency of soybean did not show significant difference with foliar nutrient application. However, it ranged from 19.9 to 25.8kg seeds per kg nutrient. Similarly, the data on available nutrient content in soil such as nitrogen, phosphorus and potassium were found non-significant.

Similarly, foliar nutrient application significantly influenced economics of soybean (Table 3) such as net return and B:C ratio. The significantly higher net return (₹83327 ha^{-1}) and benefit cost ratio (1.88) were observed with foliar application of potassium nitrate @ 2% + boric acid @ 50ppm when compared to rest of the treatments. However, foliar application of boric acid @ 50ppm + zinc sulphate @ 1% and foliar application potassium nitrate @ 2% + zinc sulphate @ 1% were on par when compare to rest of the treatment. Contrarily, the lowest growth and yield parameters, yield, nutrient uptake and economics were recorded with control treatment.



Note: Initial status of available N was 188.16 kg/ha, available P_2O_5 was 18.37 kg/ha and available K_2O was 170.24kg/ha

Fig 2: NPK uptake and NUE of soybean as influenced by foliar nutrition

Discussion

The increased growth parameters under combined foliar application of macro and micro nutrients (T_5, T_7 and T_6) is mainly due to supply of nutrients directly and easily to the plants. This might have increased availability of nutrients in the plant which are required for cell multiplication and elongation. Besides, more potassium availability might have reduced stomata resistance, increased CO_2 fixation and increased transport of photosynthesis into phloem. Further, it has increased meristematic growth which resulted in increased plant height and number branches. Similar findings were also reported by Alidust *et al.* (2020) [4] and Channabasavanna *et al.* (2008) [9]. The increased number of leaves, leaf area and leaf area index were might be due to the higher plant height and more number of branches. Higher number of leaves and leaf area & leaf area index were progressively increased total dry matter of the crop. Similar beneficial effect of foliar nutrition of micronutrients reported by Kumari *et al.* (2019) [15] in green gram and Debnath *et al.* (2018) [12] in soybean crop.

Further, increased nodulation under T_5, T_7 and T_6 treatments is mainly because of foliar application which supplied many nutrients easily and rapidly to plant which increased the total number of nodules, their effectiveness and dry weight of nodules. Further, foliar application of nutrient might have helped in spreading of root system and gave more site for rhizobia infection, and hence increase their proliferation in rhizosphere. Therefore, foliar application has helped in forming more effective nodules and their dry weight. Similar results were also suggested by Terakado *et al.* (2005) [27] and Tahir *et al.* (2009) [26].

Increase in yield parameters can be traced back to increased growth parameters and dry matter accumulation in foliar treatments. This was mainly due to enhanced fertilization through foliar application of nutrients. Further, rapid and direct availability of the nutrients along with balanced nutrient proportions increased vegetative and reproductive parts. Besides, maximum synergistic effect of nutrients like nitrogen with potassium, boran, zinc and sulphur might have encouraged the adequate growth of the plant during vegetative and reproductive stage with foliar fertilization. Similar results were reported by Chavan *et al.* (2011) and Pandey *et al.* (2013) [18]. Further, increased yield was higher due to superior yield parameters such as number of pods per plant, number of seeds per pod and seed weight per plant. Balanced and adequate supply of nutrients which involved optimum N dose, along with P_2O_5, K_2O, zinc and born doses which might have resulted in higher translocation of photosynthesis to economic parts and hence increased weight of seed. In addition, high potassium dose might have helped in translocation of starch efficiently from sites of production to storage with enhanced activity of enzymes. Besides, balanced fertilization with higher macro and micro nutrient doses might have resulted in early flowering and higher assimilation of photosynthesis in reproductive parts which reflected in higher number of pods per plant, number of seeds per pod and seed weight per plant. This observation is in agreement with the findings of Togay *et al.* (2015) [29], Ullah *et al.* (2017) [30], Longkumer *et al.* (2017) [16].

Uptake of nutrients was superior in T_5, T_7 and T_6 treatments as compared to rest of the treatments. It was mainly due to higher availability of nutrients due to foliar application. Further, it might have increased the diffusion of nutrients to the roots and increased nutrient content in plant system. Besides this, foliar application of nutrients might have reduced nutrient losses and hence all applied nutrients were absorbed and utilized by plant. Higher nutrient content indicates higher accumulation of dry matter in vegetative and reproductive parts at harvest, which further increased uptake of nutrients. Similar results were reported by Srikanth *et al.* (2000) [24], Yin and Vyn (2002) [31], Rajashree *et al.* (2005) [19] and Tagoe *et al.* (2008) [25]. Hence, increased, growth, yield parameters and yield along with lower cost of cultivation led to increased economic returns such as net return and benefit cost ratio. These results were in line with the results reported by Ali *et al.* (2011) [3], Paikra *et al.* (2018) [17], Sravya and George (2021) [23] and Kumar *et al.* (2022) [14].

Contrarily, the lowest growth and yield parameters, yield, nutrient uptake and economics were recorded with control treatment. This is mainly attributed to less availability of nutrients in the plants due to no foliar nutrient application. This might have decreased cell division and cell expansion leading to small statured plants with lesser yield parameters and yield. Besides this, poor nutrition of the plants might have led poor root growth leading to production of fewer nodules.

Conclusion

Foliar application of nutrients is an important crop management strategy in maximizing crop yields. It can supplement soil fertilization. When nutrients are applied to soils, they absorbed by plant roots and translocated to aerial parts, whereas in foliar application, nutrient gets easily and directly available to the plant foliage. In light of this, the experiment conducted clearly indicated that, foliar application of potassium nitrate @ 2% + boric acid @ 50ppm followed by foliar application of boric acid @ 50ppm + zinc sulphate @ 1% and foliar application potassium nitrate @ 2% + zinc sulphate @ 1% found superior with respect to growth, yield, nutrient uptake, nutrient use efficiency and economics of soybean as compared to control (no foliar application) treatment and other foliar treatments.

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