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Effect of seed fortification with Mo and foliar application of micronutrients on nutrient uptake by soybean crop

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Abstract
A field experiment was conducted during the year 2017-18 at college of Agriculture, Badnapur with aim to study the effect of seed fortification with Molybdenum (Mo) and foliar application of Zinc (Zn) and Iron (Fe) on uptake of nutrient at critical growth stages of soybean crop. The treatments comprised of RDF along with seed fortification of Mo and foliar application Zn and Fe alone and in different combination. The foliar application Zn and Fe @ of 0.5% was undertaken at 30, 50 and 70 days after sowing.
The results emerged out from this study indicated that the significant and maximum nutrient uptake i.e. 174.18, 181.55 and 186.39 kg N ha^{-1}, 16.84, 17.81 and 19.23 kg Pha^{-1}, 128.17, 134.35 and 141.13 kg K ha^{-1} and 18.96, 21.12 and 24.34 kg S ha^{-1} were recorded at flowering, pod formation and harvesting stages of soybean crop with application of treatment T_9 which received RDF along with seed fortification of Mo and foliar application Zn and Fe. Similarly micronutrient uptake was also noticed significant and maximum i.e. 162.91, 166.91 and 177.41 g. Zn ha^{-1}, 398.85, 401.24 and 402.39 g. Fe $ha^{-1}$and 189.57, 198.18 and 203.15 g. Mo ha $^{-1}$ at flowering pod formation and harvesting stage of soybean plot with use of treatment T_9, except the Fe content was found maximum with the use of treatment T_6 which comprised of RDF along with foliar application of Fe and Zn. The grain and strw yield was found to be significantly highest i.e.2666.30Kg and 2247.60 Kg $ha^{-1}$with addition of treatment T_9.

Keywords: Soybean, seed fortification**,** molybdenum (Mo), foliar application, zinc (Zn) and Iron (Fe)

Introduction
The increasing cost of fertilizer nutrients have led to search for alternative practices of managing the fertilizer nutrients more judiciously, efficiently and in balance proportions. Such approach would reduce the depletion of macro and micronutrients from soil. Among the nutrients, macro-nutrients have been given the priority and little attention has been given the priority and little attention has been paid towards micronutrients. In the absence of micronutrients, plant shows physiological disorder which eventually lead to low crop yield and fair quality.
Foliar spraying is a new method for crop feeding in which micronutrients in the form of liquid are used into leaves (Nasiri *et al.*, 2010) [8]. Foliar application of micronutrient is more beneficial than soil application. Since application rates are lesser as compared to soil application, same quantity of nutrient application could be supplied easily and crop reacts to nutrients application immediately. Foliar spraying of micronutrient is very helpful when the roots cannot provide necessary nutrients. Crop roots are unable to absorb some important nutrients such as Zn, because of soil properties, such as high pH, lime or heavy texture, and in this situation, foliar spraying is better as compared to soil application (Kinaci and Gulmezoglu, 2007) [4]. It has been found that micronutrient foliar application is in the same level and even more influential as compared to soil application. Resistance to different stresses will be increased by foliar application of micronutrients. Since in field situation, soil features and environmental factors which affect nutrients absorption are extremely changeable, foliar application could be an advantage for crop growth and yield.

Material and Methods
The experiment was conducted in 2017-18at College of Agriculture, Badnapur. Experiment was conducted to study the effect of foliar application of micronutrients (Zn, Fe) and seed treatment with Mo on growth, yield, uptake of nutrients and quality of Soybean. The experiment was laid out in Randomized Block design with nine treatments replicated thrice; each treatment consisted of 10 rows with row to row spacing of 45 cm. The soil had pH 7.6 and EC 0.28 dSm^{-1} and clayey texture.

NPK fertilizer application (30:60:30) and other agronomic practices were carried out uniformly according to the recommendations in all the treatments. Seed treatment of Mo @ 4 g kg^{-1} (Source: Ammonium molybdate) at the time of sowing and foliar application of $ZnSO_4$ (0.5%) and Fe SO_4 (0.5%) at 30, 50, 70 DAS was given.

Plant sample was collected at flowering, pod formation and at harvest stages of soybean from each plot and uptake of nutrients were estimated. The nutrient (N, P, K and S) and micronutrient (Fe, Zn and Mo) uptake at flowering at pod formation and at harvest was calculated by multiplying its per cent concentration with total dry matter. Total nitrogen content in plant and grain was determined using the digestion method described by Parkinson and Allen (1975) [9].

Whereas, total Zn and Fe were determined by di-acid mixture extraction method (Lindsay and Norvell, 1978) [5] and total Mo was determined by spectrophotometric method as described by Purvis and Peterson (1956) [10]. The soil physico-chemical characteristics are presented in table 1.

Table 1: Physical and chemical properties of soil at experimental site

S. No.	Particulars	Value
A)	Physical properties	
1.	Soil texture	Clay
B)	Chemical properties	
1.	pH	7.6
2.	EC (d Sm^{-1})	0.28
3.	Organic carbon (g Kg^{-1})	7.0
4.	Calcium carbonate	6.5
5.	Available Nitrogen (Kg ha^{-1})	126.75
6.	Available Phosphorus (Kg ha^{-1})	16.22
7.	Available Potassium (Kg ha^{-1})	567.07
8.	Available Sulphur (Kg ha^{-1})	16.45
9.	Available Zinc (mg kg^{-1})	0.4
10.	Available Iron (mg kg^{-1})	1.2
11.	Available Molybdenum (μg g^{-1})	0.06

The findings of the present study as well as relevant discussion have been presented under following heads.

Nutrient uptake

Uptake of major nutrients

The data recorded on nutrient uptake by soybean as influenced by foliar application of Zn and Fe with or without seed treatment of Mo increased the uptake of N, P, K and S significantly.

Nitrogen uptake

Data presented in (Table 2) with respect to nitrogen uptake by soybean as influenced by foliar application of Zn and Fe with or without seed treatment of Mo indicated that at flowering, pod formation and harvest stages, the highest uptake of nitrogen was recorded i.e. 174.18, 181.55 and 186.39 kg N ha^{-1} respectively in treatment (T_9) which received N, P, K, S and foliar application of Zn and Fe with seed treatment of Mo. It was at par with T_7 and T_6found superior over rest of the treatments. The lowest uptake of N was recorded i.e.121.62, 127.74 and 131.53 kg N ha^{-1} respectively in control (T_1) which receives N, P, K, and S alone.

This result might be due to foliar feeding with micronutrients could partially counteract the negative effect of NaCl on nutrients uptake through improving root growth and prevented the nutritional disorders and caused an increase in the uptake of nutrients by the roots. The increased uptake of nitrogen might be resulted due to increased dry matter production. There results are in conformity to the finding of El-Foully *et al.* (2002) in wheat and Vyas *et al.* (2003) in soybean.

Phosphorus uptake

Data with respect to Phosphorus uptake by soybean as influenced by foliar application of Zn and Fe with or without seed treatment of molybdenum presented in Table 2, revealed that, at flowering, pod formation and at harvest the highest uptake of phosphorus was recorded (16.84, 17.81 and 19.23 kg P ha^{-1} respectively) in treatment (T_9) which received N, P, K, S and foliar application of iron and zinc with seed treatment of molybdenum. Treatment T_9 was at par with T_7 and found superior over rest of the treatments. The lowest uptake of phosphorus was recorded i.e.12.13, 12.56 and 12.87 kg Pha^{-1} respectively in control (T_1) which receives N, P, K and S alone. This result might be due to synergistic effect of iron with phosphorus increased nutrient uptake will result in higher dry matter production and yield. These findings are in conformity with the result reported by Ravi *et al.* (2007) in safflower and Mahatma. N (2007) [6] in cotton.

Potassium uptake

Data with respect to potassium uptake by soybean as influenced by foliar application of Zn, Fe with or without seed treatment of Mo presented in Table 2 indicated that, at flowering, pod formation and at harvest stages, the highest uptake of potassium was recorded i. 128.17, 134.35 and 141.13 kg K ha^{-1} respectively with application of treatment (T_9) which received N, P, K, S and foliar application of Fe and Zn with seed treatment of Mo. This treatment T_9 was found to be was at par with T_7 and T_6 and superior over rest of the treatments. The lowest uptake of potassium was recorded 94.49, 97.58 and 102.61 kg ha^{-1} respectively with control (T_1) which receives N, P, K and S alone.

Sulphur uptake

Data presented in Table 2 on uptake of the sulphur recorded at flowering, pod formation and at harvest were showed that, the uptake of S were significantly affected due to foliar application of micronutrients. At flowering stage, at pod formation and at harvest significantly highest uptake of Sulphur was recorded (18.96, 21.12 and 24.34 kg ha-1 respectively) with treatment T_9 which received NPKS + FeSO4 (0.5%) + ZnSO4 (0.5%) + Mo. It was at par with T_7 and $T_6$and found superior over rest of the treatments. The lowest uptake of S was recorded (10.84, 11.23 and 11.84 kg ha^{-1} respectively) in control (T_1). Similar results were reported by Ravi *et al*., (2008) [11] on Sulphur.

Uptake of micronutrient

Zinc uptake

Data presented in (Table 3) with respect to Zn uptake by soybean as influenced by foliar application of Zn, Fe with or without seed treatment of Mo showed that at flowering, pod formation and at harvest stage of soybean the highest uptake of Zn was noticed i.e.172.51, 178.59 and 184.01 g Zn kg^{-1} respectively in treatment (T_6) which received N, P, K, S and foliar application of Zn and Fe. It was at par with T_9 and found superior over rest of the treatments. The lowest uptake of zinc was recorded 141.10, 148.57 and 151.32 g Zn kg^{-1} respectively in control (T1). This might be due to Zn spray improved the root growth and prevented nutritional disorders and consequently caused increase the uptake of Zn and also due to interaction effect of Zn and Fe. The available soil Zn status (0.4 mg Zn kg^{-1}) was below critical level hence, there is significant response in terms of zinc uptake observed in the treatment receiving Zn. This result was supported by the findings of El-Foully *et al*. (2010) [1] in wheat, Ravi *et al*. (2008) [11] in safflower.

Iron uptake

Data in (Table 3) with respect to Iron uptake by soybean as influenced by foliar application of zinc, iron with or without seed treatment of molybdenum revealed that at flowering, pod formation and at harvest stages the highest uptake of Fe was recorded (401.30, 408.31 and 419.66 g kg-1 respectively) with allocation of treatment (T_6) which received N, P, K, S and foliar application of Zn and Fe. It was at par with T_9 and T_7 while found superior over rest of the treatments. The lowest uptake of Fe was recorded 340.09, 346.24 and 349.29 g kg-1 respectively in control (T_1) which receives N, P, K and S alone. Increase in iron uptake due to improve the performance of root growth and prevented nutritional disorders and consequently caused increased the uptake of iron. These result was supported by the findings of El-Fouly *et al*. (2010) [1] in wheat and Ravi *et al*. (2008) [11] in safflower.

Molybdenum uptake

Data presented in (Table 3) with respect to molybdenum uptake by soybean as influenced by foliar application of zinc, iron with or without seed treatment of molybdenum showed that at flowering stage, at pod formation and at harvest stage the highest uptake of molybdenum was recorded 189.57, 198.18 and 203.15 g kg^{-1} respectively) with allocation of treatment T_9 which received N, P, K, S and foliar application of Zn and Fe with seed treatment of Mo. Treatment T_9 was at par with $T_{6,}$ $T_{8,}$ T_7 and T_5 found superior over rest of the treatments. The lowest uptake of molybdenum was recorded 159.35, 163.45 and 171.39 g kg-1 respectively in control (T1) which receives N, P, K and S alone. The increased in Mo was might be due to synergistic effect of zinc, iron and molybdenum in the metabolic activities in photosynthesis, nitrogen metabolism, essential for protein synthesis. Molybdenum and iron plays important role in activities of several enzymes. Similar result were quoted by Nadiya Gad. (2012) [7] in cowpea due to molybdenum seed treatment. Sale and Nazirkar (2013) [12] reported that micronutrient application had significant effect on nutrient uptake of soybean.

Table 2: Uptake of major nutrients in soil as influenced by foliar application of micronutrient at critical growth stages of soybean.

Treatments	Uptake of nitrogen (kg ha-1)			Uptake of Phosphorus (kg ha-1)			Uptake of Potassium (kg ha-1)			Uptake of Sulphur (kg ha-1)		
	At Flowering	At Pod Formation	At Harvest	At Flowering	At pod formation	At harvest	At flowering	At pod formation	At harvest	At flowering	At pod formation	At Harvest
T1:Control	121.62	127.74	131.53	12.13	12.56	12.87	94.49	97.58	102.61	10.84	11.23	11.84
T2: NPKS + Water	124.21	129.44	132.50	12.29	12.78	13.17	97.87	101.73	104.43	12.01	12.54	13.19
T3: NPKS + FeSO4 (0.5%)	126.97	131.76	136.46	12.46	12.93	13.71	105.49	109.4	112.55	12.45	12.89	13.77
T4: NPKS + ZnSO4 (0.5%)	137.11	143.58	146.80	12.57	13.19	14.03	108.52	113.26	119.36	13.76	13.85	14.61
T5: NPKS + Seed treatment with Mo	146.43	155.59	159.53	12.87	13.84	15	110.42	117.68	125.66	14.54	15.45	15.94
T6: NPKS + FeSO4 (0.5%) + ZnSO4 (0.5%)	168.79	173.58	174.58	15.51	16.26	17.35	119.74	121.5	129.99	16.32	17.54	19.69
T7: NPKS + FeSO4 (0.5%) + Mo	170.48	178.64	181.58	15.99	16.67	17.7	122.85	126.98	137.16	18.29	19.89	20.28
T8:NPKS + ZnSO4 (0.5%) + Mo	155.24	168.80	170.56	14.62	16.07	16.35	116.11	120.7	126.72	15.34	16.45	16.71
T9: NPKS + FeSO4 (0.5%) + ZnSO4 (0.5%) + Mo	174.18	181.55	186.39	16.84	17.81	19.23	128.17	134.35	141.13	18.96	21.12	24.34
S.E. ±	4.73	4.71	4.94	0.4321	0.46	0.48	3.33	3.46	4.41	1.19	0.51	0.54
C.D @ 5%	14.25	14.19	14.87	1.3	1.39	1.44	10.02	10.42	13.29	3.59	1.56	1.56

Table 3: Uptake of micronutrients in soil as influenced by foliar application of micronutrient at critical growth stages of soybean.

Treatments	Uptake of Zinc (g ha-1)			Uptake of Iron (g ha-1)			Uptake of Molybdenum (g ha-1)		
	At Flowering	At pod formation	At Flowering	At Flowering	At Pod Formation	At Harvest	At Flowering	At Pod formation	At Harvest
T1:Control	141.1	148.57	151.32	340.09	346.24	349.29	159.35	163.45	171.39
T2: NPKS + Water	145.03	151.3	154.42	342.17	347.29	353.51	164.45	171.51	176.03
T3: NPKS + FeSO4 (0.5%)	158.22	162.38	168.13	353.42	357.65	363.62	168.29	174.71	178.16
T4: NPKS + ZnSO4 (0.5%)	159.92	164.50	174.70	343.04	348.06	352.74	164.79	172.63	174.51
T5: NPKS + Seed treatment with Mo	153.73	156.28	157.31	359.87	365.9	369.58	174.59	181.58	191.36
T6: NPKS + FeSO4 (0.5%) + ZnSO4 (0.5%)	172.51	178.59	184.01	401.3	408.31	419.66	187.22	193.56	196.53
T7: NPKS + FeSO4 (0.5%) + Mo	157.31	161.51	166.28	383.29	389.82	393.34	181.54	187.59	192.14
T8:NPKS + ZnSO4 (0.5%) +Mo	159.77	163.65	171.64	362.95	370.94	380.43	186.81	191.48	195.51
T9: NPKS + FeSO4 (0.5%) + ZnSO4 (0.5%) + Mo	162.91	166.58	177.41	398.85	401.24	402.39	189.57	198.18	203.15
S.E. ±	4.98	5.032	5.17	10.75	11.2	11.43	5.58	5.68	6.58
C.D @ 5%	14.99	15.14	15.57	32.37	33.74	34.41	16.8	17.09	19.82

Table 4: Grain and straw yield (Kg ha^{-1}) as influenced by foliar application Fe, Zn and seed treatment of Mo in soybean.

Treatments	Yield (kg ha^{-1})	
	Straw	Grain
T1:Control	1886.60	1605.00
T2: NPKS + Water	2063.30	1780.30
T3: NPKS + FeSO4 (0.5%)	2160.00	1856.00
T4: NPKS + ZnSO4 (0.5%)	2246.00	1966.30
T5: NPKS + Seed treatment with Mo	2360.30	2070.30
T6: NPKS + FeSO4 (0.5%) + ZnSO4 (0.5%)	2596.30	2147.60
T7: NPKS + FeSO4 (0.5%) + Mo	2569.00	2240.00
T8: NPKS + ZnSO4 (0.5%) + Mo	2427.30	2080.60
T9: NPKS + FeSO4 (0.5%) + ZnSO4 (0.5%) + Mo	2666.30	2247.60
S.E. ±	67.60	89.60
C.D @ 5%	203.60	269.80

Grain and Straw yield

The data presented in table 4 indicated that, the treatment significantly influenced the grain and straw yield of soybean. There was significant and maximum grain yield 2247.60 Kg ha^{-1} was recorded with application of treatment T_9which received N, P, K, S and foliar application of iron and zinc with seed treatment of molybdenum. It was found to be at par with T7, T6, T8 and T5 and superior over rest of the treatments. The lowest grain yield was observed in control (1605.00 kg ha^{-}1). The highest straw yield observed (2666.30 kg ha^{-1}) in T9 which receives N, P, K, S and foliar application of iron and zinc with seed treatment of molybdenum. It was at par with T6 and T7 these are superior over rest of the treatments including control (1886.60 kg ha^{-1}) which was lowest. This result might be due to enzymatic enhancement of micronutrient effectively increased photosynthesis and translocation of assimilates to the seed. The available soil zinc and iron status (0.4 mg Zn $kg^{-1}$and 1.2 mg Fe kg^{-1}) was below the critical level, hence there was significant response in terms of grain and straw yield observed in the treatment receiving zinc and iron. Similar results were quoted by Ravi *et al*. (2008) [11], Kobraee *et al*. (2011) in respect of zinc and iron application in soybean and Galavi *et al*. (2012) [7] in safflower.

Conclusion

From this study it was concluded that application of treatment T_9 which received RDF along with seed fortification of Mo and foliar application Zn and Fe significantly superior in order to have maximum macronutrient (N, P, K, S), micronutrient (Zn and Mo) uptake and grain and straw yield in soybean. However, treatment T_7 was the next best option.

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