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Effect of different sources and levels of nitrogen, phosphorus and zinc on soil fertility, nutrient content, uptake and yield of soybean

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Abstract
A field experiment was conducted to study the effect of different sources and levels of nitrogen, phosphorus and zinc on soil fertility status, nutrient uptake, yield and quality of soybean. The results revealed that, with increasing levels of nitrogen (60, 90 and 120 kg ha^{-1}) and phosphorus (40, 60 and 80 kg P_2O_5 ha^{-1}) there was increase in soil available N and P_2O_5 with application of N:P_2O_5:K_2O:$ZnSO_4$ @ 120:80:40:25 kg ha^{-1} (T_5). The nutrient uptake by soybean was also significantly higher at T_5. The N, P, K and Zn uptake (seed + haulm) found to be 200.94, 27.89, 54.04 kg ha^{-1} and 195.45 g ha^{-1}, respectively. The soybean seed yield (2159 kg ha^{-1}) was also highest with T_5. However, the yield was on par with T_4 (2115 kg ha^{-1}). With regard to quality parameters the crude protein (41.94%), oil per cent (18.17%) and oil yield (392.18 kg ha^{-1}) also followed the same trend as that of seed yield.

Keywords: Soybean, Fertility status, Nutrient uptake, Yield, Quality.

Introduction
Soybean [*Glycine max* (L.)] is the second largest oilseed crop in India after groundnut. It is the cheapest and richest source of high-quality protein. It belongs to family Leguminosae and sub-family Papillionaceae. Soybean is also called "Gold of soil" as it builds up the soil fertility by fixing atmospheric nitrogen through nodules. Symbiotically soybean fixes nitrogen and leaves about 25 per cent for succeeding crop (Nutan Lal *et al.*, 2019) [11].
In India soybean is grown in 11.33 million hectares with a production of 13.79 million tonnes and productivity of 1217 kg ha^{-1} (Directorate of Economics and Statistics, 2020). The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Telangana and Gujarat. In Telangana the soybean crop is grown in an area of 0.15 million hectares with 0.23 million tonnes of production and a productivity of 1584 kg ha^{-1}. The cultivation of soybean crop is increasing at a faster rate and is extensively grown in Adilabad, Nizamabad, Medak and Karimnagar districts in Telangana state.
Soybean being a legume crop, is capable of fixing atmospheric nitrogen. However, this nitrogen alone is not sufficient to meet the crop demand for nitrogen. Phosphorus is essential for nodulation in legumes and zinc is an essential micronutrient and plays a key role in chlorophyll formation, growth hormone stimulation, enzymatic activity and reproductive processes (Thenua *et al.*, 2014) [15]. Though the consumption of chemical fertilizers in India increased over the years, the use efficiency of nutrients is very low for N (40-50%), P (10-15%) and Zn (2-5%).
To improve the use efficiency of phosphorus and minimize the P-fixation in soil, foliar application through different sources, especially nano P was found effective in groundnut (Swetha Kumari *et al.*, 2018) [14]. Studies related to use of nano Zn and nano P in rice & maize were carried out and found that the foliar application of these nutrients was effective (Apoorva *et al.*, 2019) [1]. However, studies need to be carried out on crops like soybean to know the nutrient use efficiency using nano fertilizers. Imbalanced and excess use of chemical fertilizers need to be discouraged to reduce the input cost and also to increase the nutrient use efficiency through proper methods of application. Hence, the present study was conducted, to know the effect of different sources and levels of N, P and Zn on soil nutrient status, nutrient uptake, yield and quality of soybean.

Materials and Methods

A field experiment was conducted during *kharif*, 2017 at College Farm, Agricultural College, Polasa, Jagtial, Professor Jayashankar Telangana State Agricultural University. The experiment was laid out in Randomized Block Design (RBD) with 14 treatments replicated thrice. Among the different treatments, three levels of nitrogen (60, 90 and 120 kg ha^{-1}), phosphorus (40, 60 and 80 kg ha^{-1}) along with $ZnSO_4$ @ 25 kg ha^{-1} were applied to soil. Soybean variety JS-335 was used for the study. Nitrogen and phosphorus were supplied as per the treatments. Entire dose of phosphorus was applied as basal while nitrogen and potassium were applied in split doses *viz.*, half as basal and the rest in two splits at vegetative and pod formation stages. Recommended dose of K (40 kg ha^{-1}) was applied to all treatments (T_2 to T_{14}) except control. The N, P and K were applied through urea, diammonium phosphate and muriate of potash, respectively. $ZnSO_4$ was applied @ 25 kg ha^{-1} as basal in T_2 to T_5 treatments. Foliar spraying of nano Zn (1.5 ml/L), biophos (3 ml/L) and nano P (2 ml/L) were done at flowering and pod formation stages of soybean in T_6 to T_{14} treatments.

Treatment Details

The experimental site is sandy clay loam in texture, neutral (7.60) in pH, non-saline (0.18 dSm^{-1}) and have low organic carbon content (0.19%). With regard to available nutrient status, it is low in nitrogen (226 kg ha^{-1}), high in phosphorus (45.20 kg ha^{-1}) and potassium (328 kg ha^{-1}), sufficient in sulphur (11.28 mg kg^{-1}) and deficient in zinc (0.52 mg kg^{-1}). The soil samples collected at harvest were analysed for available nutrients *viz.*, N, P_2O_5, K_2O and Zn and the plant samples were analysed for nutrient contents (N, P, K and Zn) following standard procedures and the nutrient uptake was calculated. The soybean yield (kg ha^{-1}) and quality parameters *viz.*, crude protein, oil per cent and oil yield were recorded at harvest. The crude protein content in seed was estimated by multiplying per cent N content in seed with the factor 6.25. Oil content was determined by Nuclear Magnetic Resonance (NMR) spectrophotometer and expressed as per centage (Sambunatham *et al.*, 1985) [12]. Oil yield was calculated by multiplying the oil content (%) in each treatment with corresponding seed yield as given below:

$$\text{Oil yield (kg/ha)} = \frac{\text{Oil per cent (\%) x Seed yield (kg/ha)}}{100}$$

Treatments	Treatment Details
T_1	Absolute control
T_2	Soil application of $ZnSO_4$ @ 25 kg/ha
T_3	60 kg N + 40 kg P_2O_5/ha + $ZnSO_4$ soil application @ 25 kg/ha
T_4	90 kg N + 60 kg P_2O_5/ha + $ZnSO_4$ soil application @ 25 kg/ha
T_5	120 kg N + 80 kg P_2O_5 /ha+ $ZnSO_4$ soil application @ 25 kg/ha
T_6	60 kg N + 40 kg P_2O_5/ha + Foliar application of nano Zn @ 1.5 ml/L
T_7	90 kg N + 60 kg P_2O_5/ha + Foliar application of nano Zn @ 1.5 ml/L
T_8	120 kg N + 80 kg P_2O_5/ha + Foliar application of nano Zn @ 1.5 ml/L
T_9	60 kg N/ha + Foliar application of biophos @ 3 ml/L
T_{10}	90 kg N/ha + Foliar application of biophos @ 3 ml/L
T_{11}	120 kg N/ha + Foliar application of biophos @ 3 ml/L
T_{12}	60 kg N/ha + Foliar application of nano P @ 2ml/L
T_{13}	90 kg N/ha + Foliar application of nano P @ 2ml/L
T_{14}	120 kg N/ha + Foliar application of nano P @ 2ml/L

Results and Discussion

Available Nutrient Status

The data pertaining to available nutrient status at harvesting stage of soybean was presented in table 1.

Among the treatments, it was found that with increasing levels of nitrogen and phosphorus there was significant increase in available nitrogen and phosphorus at harvesting stage of soybean. The highest available nitrogen and phosphorus were found with the treatments T_5 (262 kg N and 52 kg P_2O_5 ha^{-1}) and T_8 (252 kg N and 58 kg P_2O_5 ha^{-1}), respectively. There was no significant variation in soil available phosphorus with foliar application of biophos @ 3 ml/L and nano P @ 2 ml/L in the treatments T_9 to T_{14}. The results also revealed that, there was no significant variation among the treatments with regard to available potassium as uniform recommended dose of 40 kg K_2O ha^{-1} was applied to soybean for all the treatments except T_1 (control). Further, higher values of available zinc were recorded with T_2 (0.60 mg kg^{-1}), T_3 (0.55 mg kg^{-1}) and T_4 (0.52 mg kg^{-1}) as compared to other treatments (T_6 to T_8) where foliar application of nano zinc @ 1.5 ml/L was done.

The increase in N availability at harvesting stage (compared to initial) might be due to direct addition of nitrogen through fertilizer. Further, zinc increase the nodulation in legumes and atmospheric N fixation by increasing nitrogenase enzyme activity thereby the availability of N is increased. Similar results were also reported by Gajghane *et al.* (2015) [5]. The antagonistic effect of soil applied zinc with higher levels of phosphorus (80 kg P_2O_5 ha^{-1}), due to formation of insoluble precipitate of zinc phosphates could be the reason for decrease in available phosphorus at T_5 as compared to the treatments where foliar application of zinc @ 1.5 ml/L (T_6 to T_8) was done. Similar results were also reported by Das *et al.* (2005) [2]. With increase in levels of nitrogen, there was an increase in K availability due to release of exchangeable K from the surface of clay colloidal complex through its substitution by ammonium ions and vice versa (Simonson *et al.*, 2009) [13]. However, there was no significant variation in available potassium.

Table 1: Available nutrient status after harvest of soybean as influenced by different sources and levels of N, P and Zn

Treatments	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})	Available Zinc (mg kg^{-1})
T_1	175	28	220	0.32
T_2	191	33	331	0.60
T_3	235	49	342	0.55
T_4	240	51	355	0.52
T_5	262	52	360	0.50
T_6	231	53	334	0.33
T_7	245	57	341	0.35
T_8	252	58	345	0.38
T_9	238	33	333	0.31
T_{10}	231	34	335	0.34
T_{11}	256	35	339	0.32
T_{12}	240	31	333	0.36
T_{13}	246	30	339	0.39
T_{14}	259	32	348	0.40
SEm (±)	3.70	0.72	4.09	0.01
CD (0.05)	10.57	2.06	NS	NS

Nutrient Content and Uptake

The data pertaining to nutrient content and uptake at harvesting stage of soybean were presented in tables 2 and 3.

The results revealed that, in soybean seeds with increasing levels of N and P there was an increase in per cent N (6.71%), P (0.80%), K (0.92%) and Zn (58.10 mg kg^{-1}) in T_5 treatment with soil application of $N:P_2O_5:K_2O:ZnSO_4$ @ 120:80:40:25 kg ha^{-1}. With regard to foliar application of nano zinc @ 1.5 ml/L (T_6 to T_8), T_8 recorded significantly higher zinc content (56.6 mg kg^{-1}) and was on par with soil application of zinc sulphate (T_5), with zinc content of 58.10 mg kg^{-1}. Foliar application with two sources of phosphorus (T_9 to T_{14}) revealed that, there was no significant variation in per cent P in soybean seed with biophos @ 3 ml/L and nano P @ 2 ml/L. However, from the foliar application it was found that these sources *viz.*, nano zinc, biophos and nano P can also be used as alternate sources to $ZnSO_4$, DAP and SSP wherever P and Zn deficiencies are noticed at critical growth stages of soybean, so that the yields will not be affected.

The total nutrient uptake was computed using nutrient content, seed yield and haulm yield of soybean obtained at harvest and given in table 3.

With regard to total uptake (seed + haulm) of nutrients, the highest nitrogen, phosphorus and potassium uptake was recorded with T_5 (200.94, 27.89 and 54.04 kg ha^{-1}) followed by T_4 (180.66, 25.73 and 52.49 kg ha^{-1}) treatments. The highest zinc uptake was noticed with T_5 followed by T_8 with the values of 195.45 and 177.26 g ha^{-1}, respectively.

The trends were similar to that of the drymatter production and nutrient contents. It was observed that with increasing levels of N and P and application of recommended doses of K and $ZnSO_4$ @ 25 kg ha^{-1}, there was an increase in crop growth, root proliferation and absorption of nutrients reflecting in an increase in nutrient contents of N, P, K and Zn (Mali *et al.*, 2017) [9].

Table 2. Nutrient content of soybean at harvest as influenced by different sources and levels of N, P and Zn

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Zinc (mg kg^{-1})	
	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm
T_1	2.92	0.53	0.58	0.16	0.74	0.80	24.15	12.50
T_2	5.53	1.00	0.61	0.18	0.78	0.82	42.16	15.52
T_3	5.90	1.26	0.70	0.26	0.82	0.89	44.62	18.16
T_4	6.27	1.46	0.75	0.30	0.91	1.01	52.00	19.00
T_5	6.71	1.69	0.80	0.32	0.92	1.03	58.10	21.10
T_6	5.66	1.01	0.71	0.28	0.81	0.87	51.10	18.10
T_7	6.20	1.38	0.72	0.29	0.88	0.96	49.00	18.78
T_8	6.50	1.60	0.78	0.31	0.90	0.98	56.60	20.16
T_9	5.80	1.19	0.64	0.20	0.79	0.84	26.18	14.10
T_{10}	6.17	1.31	0.67	0.22	0.86	0.93	27.20	13.60
T_{11}	6.59	1.66	0.69	0.24	0.87	0.95	28.10	13.00
T_{12}	5.68	1.15	0.63	0.19	0.80	0.85	25.68	13.72
T_{13}	6.00	1.27	0.66	0.21	0.83	0.90	25.00	15.10
T_{14}	6.40	1.52	0.68	0.23	0.84	0.91	26.10	14.00
SEm (±)	0.10	0.02	0.01	0.00	0.01	0.01	0.70	0.05
CD (0.05)	0.29	0.07	0.03	0.01	0.04	0.04	2.00	0.13

Table 3: Nutrient uptake by soybean at harvest as influenced by different sources and levels of N, P and Zn

Treatments	Nitrogen Uptake (kg ha^{-1})			Phosphorus Uptake (kg ha^{-1})			Potassium Uptake (kg ha^{-1})			Zinc Uptake (g ha^{-1})		
	Seed	Haulm	Total	Seed	Haulm	Total	Seed	Haulm	Total	Seed	Haulm	Total
T_1	34.31	9.34	43.65	6.82	2.82	9.64	8.70	14.10	22.80	28.38	22.04	50.42
T_2	75.71	19.28	94.99	8.35	3.47	11.82	10.68	15.81	26.49	57.72	29.92	87.64
T_3	111.63	37.70	149.33	13.24	7.78	21.02	15.51	26.63	42.14	84.42	54.33	138.75
T_4	132.61	48.05	180.66	15.86	9.87	25.73	19.25	33.24	52.49	109.98	62.53	172.51
T_5	144.87	56.07	200.94	17.27	10.62	27.89	19.86	34.18	54.04	125.44	70.01	195.45
T_6	102.22	28.04	130.26	12.82	7.77	20.59	14.63	24.15	38.78	92.29	50.25	142.54
T_7	121.27	42.72	163.99	14.08	8.98	23.06	17.21	29.72	46.93	95.84	58.14	153.98
T_8	129.48	51.20	180.68	15.54	9.92	25.46	17.93	31.36	49.29	112.75	64.51	177.26
T_9	80.74	25.06	105.8	8.91	4.21	13.12	11.00	17.69	28.69	36.44	29.69	66.13
T_{10}	107.11	32.72	139.83	11.63	5.50	17.13	14.93	23.23	38.16	47.22	33.97	81.19
T_{11}	118.09	43.03	161.12	12.36	6.22	18.58	15.59	24.62	40.21	50.36	33.70	84.06
T_{12}	78.67	23.01	101.68	8.73	3.80	12.53	11.08	17.01	28.09	35.57	27.45	63.02
T_{13}	84.60	28.16	112.76	9.31	4.66	13.97	11.70	19.95	31.65	35.25	33.48	68.73
T_{14}	109.89	35.14	145.03	11.68	5.32	17.00	14.42	21.04	35.46	44.81	32.37	77.18
SEm (±)	1.81	0.37		0.19	0.11		0.19	0.33		1.00	0.63	
CD (0.05)	5.16	1.06		0.54	0.31		0.54	0.94		2.85	1.81	

Yield and Quality Parameters

The results pertaining to seed yield, crude protein, oil per cent and oil yield were given in table 4. The seed yield recorded with T_5 (2159 kg ha^{-1}) was higher than other treatments. However, the yield was on par with that recorded at T_4 (2115 kg ha^{-1}). Hence, among the treatments T_3 to T_5, T_4 ($N:P_2O_5:K_2O:ZnSO_4$ @ 90:60:40:25 kg ha^{-1}) found to be the best.

Seed and haulm yield of soybean were significantly influenced by the application of nitrogen and phosphorus. Nitrogen plays an important role in the synthesis of chlorophyll and amino acids and increased cell division and cell enlargement and better root growth which finally reflected into higher dry matter production, haulm and seed yield (Morshed *et al.*, 2008) [10]. The supply of phosphorus to soil might have accelerated cell division and enlargement, carbohydrate, fat metabolism and respiration in plant favouring increased growth and yield. The similar results were also reported by Dhage *et al.* (2014) [4]. Also, zinc might have played an important role in synthesis of carbohydrates and their transport to the site of seed production (Keram *et al.*, 2012) [7].

The results also revealed that, highest crude protein (%), oil per cent (%) and oil yield (kg ha^{-1}) were recorded with soil application of $N:P_2O_5:K_2O:ZnSO_4$ @ 120:80:40:25 kg ha^{-1} with the values of 41.94, 18.17 and 392.18, respectively. Nitrogen plays an important role in improving the protein content and oil content in soybean seeds via higher production of carbohydrates in plants and transferring to seeds (Jahangir *et al.*, 2009) [6]. Zinc is associated with activation of enzymes like cystine desulphydrase, dihydropeptidase and glycine dipeptidase responsible for producing oil content in seed and led to more oil yield (Maharnor *et al.*, 2018) [8].

Table 4: Effect of different sources and levels of N, P and Zn on seed yield and quality of soybean

Treatments	Seed yield (kg ha^{-1})	Crude protein (%)	Oil per cent (%)	Oil yield (kg ha^{-1})
T_1	1175	18.27	15.38	180.92
T_2	1369	34.58	16.72	228.93
T_3	1892	36.88	17.83	337.39
T_4	2115	39.19	18.04	381.57
T_5	2159	41.94	18.17	392.18
T_6	1806	35.38	17.82	322.05
T_7	1956	38.79	17.85	349.27
T_8	1992	40.63	17.93	357.57
T_9	1392	36.27	17.36	241.72
T_{10}	1736	38.60	17.53	304.27
T_{11}	1792	41.23	17.68	316.88
T_{12}	1385	35.54	17.22	238.55
T_{13}	1410	37.52	17.40	245.44
T_{14}	1717	40.00	17.51	300.95
SEm (±)	30.23	0.63	0.22	7.07
CD (0.05)	86.34	1.80	0.64	20.20

Conclusion

From the results it can be concluded that, soil application of $N:P_2O_5:K_2O:ZnSO_4$ @ 90:60:40:25 kg ha^{-1} found to be optimum in terms of fertility status, nutrient content, uptake and yield of soybean. Among the foliar treatments of phosphorus, it was found that application of biophos @ 3 ml/L found to be more effective than nano P @ 2 ml/L. Foliar application of phosphorus alone was not effective compared to soil application of P. However, the different sources of P and Zn can be used for spraying under critical conditions where deficiency symptoms are seen on the crop at critical growth stages. So that the final yield can be protected.

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