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Adsul PB
Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Patil VD
Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Shinde SE
Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Corresponding Author:
Adsul PB
Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on growth and yield of soybean (*Glycine max* L. Merrill)

Adsul PB, Patil VD and Shinde SE

Abstract
Initial and final plant population of soybean recorded non-significant effect due to various fertility levels administered during both the experimental years. The effect of soil and foliar application of nutrients and growth regulators recorded significant impact on height of plant in both the years of experiments. The maximum numbers of leaves were found at flowering stage of soybean in both the years. Application of each additional nutrient through soil and foliar application increased number of leaves per plant significantly. Thereafter leaf count reduced due to physiological shedding of older leaves to maturity of soybean leaf count becomes less. In both the years of experimentation, leaf area & leaf area index were increased progressively up to flowering stage of soybean there after there was decrease in leaf area index due to falling of leaves towards maturity of soybean. There was periodical increase in dry weight of soybean. It was found to be increased with the advancement of crop growth stages up to maturity of soybean. There was significant increase in number of pods per plant with all the treatments (Fertility levels) over control. Application of RD + Zn + foliar K, B and GR significantly recorded highest growth parameters, seed yield, straw yield and total biological yield and The influence of different treatments by the order; $F_6 > F_5 > F_7 > F_4 > F_3 > F_2 > F_1$.

Keywords: soil, sulphur, zinc, foliar, KNO_3, borax, NAA, GA, soybean

Introduction
Soybean (*Glycine max* L.) is important oil and protein crop belongs to family Fabaceae, it contains high quality protein (40-42%), oil (18-20%) and other nutrients like calcium and iron. (Devi *et al.*, 2012) [3]. Soybean is preferable for human nutrition due to its high protein content. It is a good source of is flavones and therefore, it helps in preventing heart disease, cancer and HIV's. Soybean oil is leading vegetable oil in the world and is used in many industrial applications including biodiesel. Because of its high nutritional value and myriad form of uses, it is recognized as "Golden Bean" in India. The annual soybean production in India was 12.21 million tons (2011-12) with its area under cultivation was 10.1 million hectares. Zinc was assumed to be greater significance due to wide occurrence of its deficiency. The magnitude of sulphur removal is much higher due to intensive cropping. (Jaga, 2013) [6]. In Maharashtra, soybean occupied an area of 5 lakh ha. with production of 6 lakh tones. Sulphur is an essential macronutrient in plant growth and development. It is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. Among the fertilizer elements, sulphur requirement of oilseed crops s quite high as compared to other crops. (Das and Das, 1994) [2].
The soils of Marathwada region, which are largely deficient in nutrients like N, P, K, S, Zn and B are mainly responsible for the greenness of the crops. Among all these nutrients S, Zn and B deficient in pulses growing regions of Marathwada. Therefore for the efficient exploitation of high yielding potential and oil content of soybean and monitoring growth attributes by spectral reflectance, with this background the present investigation was undertaken.

Material and Methods
The research experiment were carried out for two consecutive years 2016-17 and 2017-18 on experimental farm of Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The material used and methods adopted for planning and conduct of field experiments for soil and plants chemical analysis, stastical analysis was done. Geographically, Parbhani district is situated in the Godavari drainage basin

in the central part of India between $76^{0}46^{'}$, east longitude and $19^{0}16^{'}$ North latitude, having elevation of 423.46 m above the mean sea level in Marathwada division of Maharashtra State. The region has a semi-arid climate. It is under assured monsoon rainfall agro climatic zone with an average annual precipitation between 800 to 850 mm. The major portion of precipitation (75 per cent) being received through south-west monsoon from June to September. The mean maximum temperature varies from 26.9 ^{0}C in winter to 42.4 ^{0}C in summer and means minimum temperature varies from 5.8 ^{0}C to 25.6 ^{0}C. The climate is suitable for *Kharif* crops like Soybean, Cotton, Sorghum, Green gram, Black gram and Red gram. The soils of the region are medium to deep black (Inceptisol/Vertisol).

The meteorological data on rainfall, maximum and minimum temperature and relative humidity recorded during the experimental period at meteorological observatory. In order to determine the soil properties of experimental soil before sowing, the representative surface (20 cm depth) soil sample was collected from randomly selected spots covering experimental area. A composite soil sample was prepared and analyzed for its various soil properties. After completion of preparatory tillage operations, the experiment was laidout in Randomized Block Design comprising seven (07) treatments replicated thrice. The land of the experimental site was prepared by one ploughing and two harrowing and layout was done after the onset of monsoon. The certified seed of soybean MAUS 162 were sown in *kharif* by dibbling one seed per hill at 45 x 5 cm^2 distances; gap filling was done 12 days after sowing to maintain plant population. Schedule of cultural operation was carried out as per recommendations. The soybean crop was harvested and plot wise seed and straw yield per plot was recorded.

In the statistical analysis these data obtained from field experiment and the ground truth of the crop soybean available soil nutrients, plant nutrient concentrations should be computed and correlation regression technique to be followed (Panse and Sukhatme, 1985) [11]. The biomass and economic yield data should also be derived and exposed for design analysis and critical difference is to be calculated for the treatment comparison.

Result and Discussion

Growth Parameters

The results emerged out of the experimentation were statistically analyzed, organized, appropriately tabulated, interpreted and discussed. Initial and final plant population of soybean (Table 1) recorded non significant effect due to various fertility levels administered during both the experimental years. The average initial and final plant stand was 1667 (99.22%) and 1657 (98.63%) during the year 2016-17 and 2017-18, respectively. This explains good conduct of experimentation and no baisness in plant population that is going to affect treatment behavior.

The height of soybean was monitored at critical growth stages of crop during both the experimental years. The critical growth stages of soybean *viz.*, vegetative, grand growth, flowering, pod formation stages falls at nearly 30,60,75 and 90 days after sowing of soybean MAUS-162 late variety specially developed for high yielding and mechanical harvesting purpose. It was observed that height of soybean crop increased from 24.55 to 74.77 cm and 29.47 to 70.17 cm during year 2016-17 and 2017-18, respectively. The average heights recorded were 53.89 and 54.73 cm during the year 2016-17 and 2017-18, respectively. There was significant increase in height in both the years of experiments. There was significant increase in height of plant with every addition of nutrients through soil and foliar applications.

Numbers of leaves of soybean were recorded at critical growth stages of soybean during both the years of experiment. The average numbers of leaves recorded were 43.53 and 44.06 ion 2016-17 and 2017-18, respectively. Further, it was also observed that during 2016-17 and 2017-18 application of each additional nutrient through soil and foliar application increased number of leaves per plant significantly. Treatments F_6 significantly showed more number of leaves per plant at all growth stages over control and other treatments. The mean number of leaves during 2016-17 and 2017-18 were 25.67, 36.85, 64.61 and 47.00 and 25.14, 45.25, 59.28 and 46.57 at 30, 60, 75 and 90 DAS. The numbers of leaves were maximum at 75 days after sowing *i.e*. at flowering stage.

Leaf area was increased from 537.03 to 974.18 cm with a mean of 722.56 cm during 2016-17 and during 2017-18 leaf area increased from 749.86 to 1108.20 cm with mean value of 808.24 cm whereas, leaf area index per plant increased front 2.37 to 4.32 with a mean value of 3.30 during year 2016-17 and during year 2017-18, it was increased from 2.41 to 4.91 with mean value of 3.57. In both the years of experimentation, leaf area & leaf area index were increased progressively up to flowering stage of soybean there after there was decrease in leaf area index due to falling of leaves towards maturity of soybean. Similar beneficial effect of micronutrients on plant height was reported by Krishnaveni *et al.*, (2004) [9] in green gram and (Upadhyay, 1994) [16] in cotton and Jadhav *et al*.., 2019 [5] on soybean crop.

It was found to be increased with the advancement of crop growth stages up to maturity of soybean. The average increase in dry weight of plant recovery was from 14.67 to 30.78 g $plant^{-1}$ in 216-17 and 16.39 to 35.89 g $plant^{-1}$ in 2017-18. The average mean of individual year was 24.72 and 28.62 g $plant^{-1}$. At all growth observations, application of RDF + Zn + foliar applications of potash, borax, NAA and GA produced maximum dry weight of soybean. The said treatment is followed by F_5 (RDF+Zn+K).

The data on nodules per plant, fresh weight of nodules and dry weight of nodules per plant are presented in Table 2. The number of nodules varied from 24.47 to 30.18 and 25.33 to 32.00 during year 2016-17 and 2017-18, respectively. There were no significant differences observed in both the years of experimentation due to various and treatments.

The data on yield attributing characters of soybean as affected by various fertility levels presented in Table 3. The number pods per plant varied from 42.2 to 74.94 and 41.00 to 80.00 during 2016-17 and 2017-18, respectively. There was significant increase in number of pods per plant with all the treatments (Fertility levels) over control. In pooled analysis, the maximum number of pods (77.47) recorded with treatment F_6 *i.e*. soybean crop fertilized with RD+ Zn+ K, B and GR followed by treatment (F_5) soybean crop with RDF + Zn+ foliar K, B. In general numbers of pods were found maximum in year 2017-18 as compared to 2016-17. The pooled data indicated superiority of F_6 over all other treatments. The influence of different treatments on numbers of pods by the order; $F_6 > F_5 > F_7 > F_4 > F_3 > F_2 > F_1$.

Pod weight varied from 9.42 to 14.82 g/ plant in year 2016-17 with mean of 12.53 g / plant in year 2016-17. Similarly in year 2017-18 seed weight varied from 7.72 to 14.50 g/ plant with mean of 12.44 g/ plant in year 2017-2018. The pooled mean data also indicated the superiority of treatment F_6 over

all other treatments with respect to pod weight g/ plant of soybean.

Table 1: Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on initial and final plant population of soybean

Treatments	Initial Plant Stand			Final Plant Stand		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean
F1: Ctrl	1665	1657	1661	1648	1652	1650
F2: NPK	1664	1660	1662	1650	1647	1648
F3: RDWS	1666	1662	1664	1656	1658	1657
F4: RDZn	1670	1665	1667	1662	1660	1661
F5: RDZnKB	1674	1670	1672	1652	1662	1657
F6: RDZnKBGR	1676	1675	1675	1662	1668	1665
F7: RDZnGR	1674	1664	1669	1665	1660	1662
Mean	1670	1665	1667	1656	1658	1657
SE+	5.06	6.37	--	6.49	5.74	--
CD at 5%	NS	NS	--	NS	NS	--

Table 2: Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on plant height of soybean

Treatments	Plant height										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	17.46	25.63	29.55	33.45	26.52	18.21	23.62	27.62	30.26	24.67	25.59
F2: NPK	22.22	42.60	56.38	70.40	47.90	26.80	48.80	61.28	65.30	50.54	49.22
F3: RDWS	24.52	47.26	67.63	74.70	53.52	30.76	55.46	68.61	72.44	56.81	55.16
F4: RDZn	25.59	50.49	73.49	80.54	57.52	31.26	59.47	72.67	77.21	60.15	58.83
F5: RDZnKB	28.37	58.41	81.35	87.45	63.89	33.12	62.26	75.22	80.47	62.76	63.32
F6: RDZnKBGR	30.59	62.57	84.47	92.32	67.48	34.71	65.28	78.78	84.30	65.76	66.62
F7: RDZnGR	23.10	55.56	78.56	84.58	60.45	31.46	60.81	76.26	81.22	62.43	61.44
Mean	24.55	48.93	67.34	74.77	53.89	29.47	53.67	65.77	70.17	54.73	54.31
SE+	1.62	0.40	0.77	0.66	--	0.56	0.81	0.70	0.84	--	--
CD at 5%	5.00	1.25	2.37	1.31	--	1.75	2.52	2.16	2.59	--	--

Table 3 Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on number of leaves of soybean

Treatments	Number of leaves										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	12.12	18.00	22.00	16.00	17.03	12.00	21.00	24.00	12.00	17.25	17.14
F2: NPK	22.32	32.00	62.00	45.00	40.33	19.00	35.00	45.00	33.00	33.00	36.66
F3: RDWS	26.00	37.00	65.00	48.00	44.00	24.00	38.00	48.00	40.00	37.50	40.75
F4: RDZn	27.20	40.00	68.00	50.00	46.30	26.00	42.00	64.00	48.00	45.00	45.65
F5: RDZnKB	30.00	43.00	78.00	54.00	51.25	31.00	60.00	78.00	64.00	58.25	54.75
F6: RDZnKBGR	32.70	46.00	82.33	60.00	55.25	34.00	64.00	81.00	67.00	61.50	58.37
F7: RDZnGR	29.40	42.00	75.00	56.00	50.60	30.00	57.00	75.00	62.00	56.00	53.30
Mean	25.67	36.85	64.61	47.00	43.53	25.14	45.28	59.28	46.57	44.06	43.79
SE+	0.45	1.52	0.63	0.73	--	0.65	0.90	1.38	1.10	--	--
CD at 5%	1.39	4.68	1.95	2.26	--	2.01	2.79	4.26	3.40	--	--

Table 4 Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on leaf area (cm^2/plant) of soybean

Treatments	Leaf area										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	248.43	512.54	532.42	232.26	381.41	312.71	536.28	556.59	334.59	435.04	408.22
F2: NPK	487.00	721.66	866.38	487.36	640.60	534.25	780.32	982.31	604.60	725.37	682.98
F3: RDWS	524.63	812.55	900.95	542.46	695.14	560.33	852.55	1115.60	681.34	802.45	748.79
F4: RDZn	582.44	860.47	956.45	581.33	745.17	617.77	961.23	1182.40	720.32	870.43	807.80
F5: RDZnKB	634.50	940.50	1182.30	670.67	857.00	602.49	1049.00	1300.00	822.70	943.54	900.27
F6: RDZnKBGR	661.46	1020.50	1238.30	710.34	907.65	639.31	1090.30	1360.12	868.31	989.51	948.58
F7: RDZnGR	620.78	904.39	1142.50	656.48	831.03	582.19	957.43	1260.40	765.72	891.43	861.23
Mean	537.03	824.65	974.18	554.41	722.56	749.86	889.55	1108.20	685.36	808.24	765.40
SE+	12.85	28.50	26.04	20.31	--	24.32	14.35	26.90	21.37	--	--
CD at 5%	39.55	87.69	80.12	62.49	--	74.83	44.17	82.79	65.77	--	--

Table 5 Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on LAI/plant of soybean

Treatments	LAI										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	1.10	2.27	2.36	1.47	1.80	1.38	2.37	2.46	1.48	1.92	1.86
F2: NPK	2.16	3.20	3.84	2.60	2.95	2.37	3.46	4.36	2.68	3.21	3.08
F3: RDWS	2.32	3.60	3.99	2.77	3.17	2.48	3.78	4.95	3.02	3.55	3.36
F4: RDZn	2.58	3.81	4.24	3.02	3.41	2.59	4.27	5.25	3.19	3.82	3.61
F5: RDZnKB	2.81	4.17	5.25	3.42	3.91	2.67	4.65	5.77	3.65	4.18	4.04
F6: RDZnKBGR	2.93	4.52	5.49	3.60	4.13	2.83	4.84	6.04	3.85	4.39	4.26
F7: RDZnGR	2.75	4.01	5.07	3.36	3.79	2.58	4.24	5.59	3.39	3.95	3.87
Mean	2.37	3.65	4.32	2.89	3.30	2.41	3.94	4.91	3.03	3.57	3.43
SE+	0.05	0.12	0.11	0.09	--	0.095	0.06	0.11	0.09	--	--
CD at 5%	0.17	0.38	0.35	0.28	--	0.290	0.19	0.36	0.29	--	--

Table 6 Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on dry weight (g/plant) of soybean

Treatments	Dry weight										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	10.48	18.31	19.40	15.48	15.91	11.23	18.55	23.32	20.58	18.42	17.16
F2: NPK	12.39	22.34	23.51	18.38	19.15	14.47	24.62	28.59	25.61	23.32	21.23
F3: RDWS	14.47	23.47	26.48	22.69	21.77	15.52	26.73	34.40	31.30	26.98	24.28
F4: RDZn	14.70	24.71	28.52	24.39	23.08	16.21	27.38	35.46	32.31	27.84	25.46
F5: RDZnKB	16.54	26.57	35.23	29.47	26.95	18.82	32.69	38.46	35.58	31.38	29.16
F6: RDZnKBGR	18.65	28.74	36.50	31.47	28.84	20.86	34.61	41.69	38.35	33.87	31.35
F7: RDZnGR	15.46	25.78	34.57	28.62	26.10	17.67	31.63	37.40	34.53	30.30	28.20
Mean	14.67	24.27	29.17	24.35	23.11	16.39	28.03	34.18	31.18	27.44	25.27
SE+	0.31	0.59	0.78	0.73	--	0.42	0.74	0.72	0.67	--	--
CD at 5%	0.95	1.82	2.42	2.26	--	1.31	2.29	2.24	2.07	--	--

Table 7 Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on number of nodules, dry and fresh weight of nodules of soybean

Treatments	Nodules/plant			Fresh weight of nodules (g/plant)			Dry weight of nodules (g/plant)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
F1: Ctrl	30.18	32.00	31.09	1.34	1.30	1.32	0.78	0.71	0.74
F2: NPK	23.31	25.00	24.15	1.22	1.12	1.17	0.47	0.62	0.54
F3: RDWS	24.47	25.33	24.90	1.24	1.20	1.22	0.58	0.68	0.63
F4: RDZn	25.22	30.00	27.61	1.27	1.25	1.26	0.65	0.74	0.69
F5: RDZnKB	27.30	28.00	27.65	1.30	1.22	1.26	0.72	0.71	0.71
F6: RDZnKBGR	28.28	31.00	29.64	1.32	1.28	1.30	0.76	0.74	0.75
F7: RDZnGR	26.17	27.00	26.58	1.28	1.20	1.24	0.68	0.68	0.68
Mean	26.41	28.33	27.37	1.28	1.22	1.25	0.66	0.69	0.67
SE+	2.28	2.51	--	0.043	0.023	--	0.022	0.012	--
CD at 5%	NS	NS	--	0.132	0.070	--	0.070	0.037	--

Table 8: Effect of soil application of sulphur and zinc and foliar application of KNO_3, Borax, NAA and GA on grain, straw, biological yield (q/ha.) and HI of soybean

Treatments	Seed yield			Straw yield			Biological yield		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
F1: Ctrl	12.42	10.26	11.34	25.03	19.20	18.61	37.45	29.46	29.95
F2: NPK	20.57	17.30	18.57	37.63	31.44	34.53	58.20	48.00	53.10
F3: RDWS	21.72	18.62	19.84	39.48	32.24	35.86	61.20	50.86	56.03
F4: RDZn	23.60	20.47	22.04	42.56	33.90	38.23	66.16	54.37	60.26
F5: RDZnKB	26.82	24.00	25.41	47.44	39.40	43.42	74.26	63.40	68.83
F6: RDZnKBGR	27.90	25.42	26.66	48.25	41.51	44.88	76.15	66.93	71.54
F7: RDZnGR	25.70	23.81	24.71	46.71	39.33	43.02	72.41	64.04	67.72
Mean	22.67	19.98	21.22	41.01	33.88	36.93	63.69	53.43	58.20
SE+	1.00	0.90	0.67	2.20	1.88	1.45	2.14	2.46	1.63
CD at 5%	3.08	2.78	1.97	6.78	5.80	4.23	6.62	7.59	4.77
CV	7.87	8.05	7.96	8.24	9.22	8.45	5.85	7.90	6.83

Seed yield, straw yield and biological yield

The seed yield of *kharif* soybean significantly affected due to soil and foliar applications of nutrients and growth regulators (Table-4). In pooled analysis, application of RD + Zn + foliar K, B and GR significantly recorded highest seed yield 26.66 qha^{-1}, which was found at par with treatment F_5 and F_7 and significantly superior over rest of treatments. Treatment F_1 recorded lowest seed yield 11.34 qha^{-1}. During year 2016-17 application of RD + Zn+ foliar K, B & GR recorded highest seed yield 27.90 qha^{-1}, which were found at par with F_5 and

F_7. During year 2017-18 significantly highest seed yield (25.42 qha^{-1}) recorded with treatment F_6 which was found at par with F_5 and F_7.

During year 2016-17 seed yield varied from 12.42 to 27.90 qha^{-1} with a mean of 22.67qha^{-1}. During year 2017-18 seed yield of soybean varied from 10.26 to 25.42 qha^{-1} with a mean of 19.98 qha^{-1}. The treatments F_6, F_5, and F_7 were found on par with each other in pooled analysis as well as in both the years of experimentation.

Comparably highest seed yield was recorded in year 2016-17 compared to 2017-18. The seed yield was highest (27.90 and 25.42) with treatment F_6 during 2016-17 and 2017-18, respectively.

As regards the straw yield of soybean more over similar trend was observed as that of seed yield. Soil and foliar application of nutrients and growth regulators significantly influenced on biological yield of soybean. Biological yield varied from 37.45 to 76.15 qha^{-1} during year 2016-17 and 29.46 to 71.54 qha^{-1} during year 2017-18. The biological yield was highest (76.15 and 66.93 qha^{-1}) with treatment F_6 during year 2016-17 and 2017-18, respectively. The treatment F_5 and F_7 was found at par with each other. Lowest biological yield (37.45 and 29.46 qha^{-1}) recorded in control treatment.

The pooled mean data on biological yield was in the range of 29.95 to 71.54 qha^{-1} and further indicated the superiority of F_6 over all other treatments. The effect of different treatments followed the sequence; $F_6 > F_5 > F_7 > F_4 > F_3 > F_2 > F_1$. Similar results were reported by Tiwari and Yadava (1990) [14] in Siratro plant, Sarkar and Mukhopadhyay (1990) [12] in rice and Sudarshan and Ramaswami, (1993) [13] in groundnut and blackgram cropping system. The marked rise inseed yield parameters recorded by application of micronutrients may be ascribed to higher translocation of metabolites from source to sink (seed) and carbohydrate metabolism and synthesis of nucleic acids. These results are in agreement with the findings of Gopalgowda *et al.,* (1994) [4] and Kiss, (1997) [7] in groundnut and Balusumani *et al.,* (1996) [1] in soybean. The application of nutrients like zinc sulphate, Boron and Potassium nitrate brings about profound changes in various metabolic processes within the plant system and thereby, influence the seed yield potential (Tripathy *et al..,* 1999) [15].

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