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Research Article

EFFECT OF FOLIAR APPLICATION OF POTASSIUM, BORON AND ZINC ON GROWTH ANALYSIS AND SEED YIELD IN SOYBEAN

Gowthami P. and *Rama Rao G.
Department Of Crop Physiology, Agricultural College, Bapatla (ANGRAU)-522101-Andhra Pradesh
**Author for Correspondence*

ABSTRACT
A field experiment was conducted at Agricultural College Farm, Bapatla during *Kharif* 2013-14 to study the effect of foliar application of potassium, boron and zinc on growth analysis and seed yield in soybean. The results revealed that foliar application of potassium nitrate @ 2 % + boric acid @ 50 ppm + zinc sulphate @ 1 % (T_7) at 30 and 60 DAS was found to be superior in increasing the CGR, RGR, NAR, LAI, SLW, LAR and seed yield followed by potassium nitrate @ 2 % + boric acid @ 50 ppm at 30 and 60 DAS (T_4), boric acid @ 50 ppm + zinc sulphate @ 1 % at 30 and 60 DAS (T_6) and potassium nitrate @ 2 % + zinc sulphate @ 1 % at 30 and 60 DAS (T_5) where as lower values were recorded in control.

Keywords: *Foliar Application, Growth Analysis, Seed Yield, Soybean*

INTRODUCTION
In India, soybean has emerged as an important oil seed crop and was grown in an area of 9.3 million ha with a production of 10.13 million tons and productivity of 1089 kg ha^{-1} during 2012-13. Foliar application of micro nutrients was more beneficial than soil application, since application rates are lesser as compared to soil application, same results could be obtained easily and the crop reacts to nutrient application immediately (Zayed *et al.*, 2011). Increased leaf area index and crop growth rate were reported in groundnut with post flowering foliar spray of potassium nitrate @ 0.5 per cent (Patra *et al.*, 1995). Higher values of crop growth rate and net assimilation rate were recorded in soybean with foliar application of zinc @ 116 ppm along with iron @ 116 ppm (Heidarian *et al.*, 2011). Ali and Adel (2013) reported that high pod number per plant, seeds per pod, 1000 seed weight and seed yield were obtained in mungbean plants sprayed with 500 ppm zinc. Less research work was done on foliar application of potassium, boron and zinc on soybean. Hence, this study was conducted to know the effect of foliar application of potassium, boron and zinc on growth analysis and seed yield in soybean.

MATERIALS AND METHODS
A field experiment was conducted at College Farm, Agricultural College, Bapatla during *Kharif* 2013-14. The experiment was laid out in clay loam soil in a Randomized Block Design with eight treatments and three replications. Treatments consists of T_1- Foliar application of potassium nitrate @ 2 per cent at 30 and 60 DAS, T_2- Foliar application of boric acid @ 50 ppm at 30 and 60 DAS, T_3- Foliar application of zinc sulphate @ 1 per cent at 30 and 60 DAS, T_4- Foliar application of potassium nitrate @ 2 per cent + boric acid @ 50 ppm at 30 and 60 DAS, T_5- Foliar application of potassium nitrate @ 2 per cent + zinc sulphate @ 1 per cent at 30 and 60 DAS, T_6- Foliar application of boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 and 60 DAS, T_7- Foliar application of potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 and 60 DAS, T_8- Control.
The plot size was 4m x 3m with spacing of 30 cm x 10 cm. The total drymatter accumulation and its partitioning was estimated from three adjacent plants sampled from each treatment in three replications and then separated into roots, stem, leaves and pods recorded from 15 to 90 DAS. The plant parts were dried to a constant weight in hot air oven at 80°C for two days and the dry weights were recorded and expressed in g plant^{-1}. Leaf area was measured by using leaf area meter from 15 to 90 DAS and expressed as leaf area plant^{-1} in cm^2. The growth analysis parameter was calculated by using leaf area and total dry matter from formulas.

RESULTS AND DISCUSSION

Significant differences were observed among the treatments with regard to CGR at all stages of plant growth except at 15-30 DAS as the foliar application was done at 30 and 60 DAS (Table 1).

Among the treatments, foliar application of potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 and 60 DAS(T_7) showed higher crop growth rate (36.44 g m^{-2} d^{-1}) at 45-60 DAS, followed by potassium nitrate @ 2 per cent + boric acid @ 50 ppm (33.93 g m^{-2} d^{-1}).

The treatments boric acid @ 50 ppm (26.82 g m^{-2} d^{-1}), potassium nitrate @ 2 per cent (25.56 g m^{-2} d^{-1}) and zinc sulphate @ 1 per cent (24.29 g m^{-2} d^{-1}) were on par with each other.

The treatments boric acid @ 50 ppm + zinc sulphate @ 1 per cent (32.30 g m^{-2} d^{-1}) and potassium nitrate @ 2 per cent + zinc sulphate @ 1 per cent (29.82 g m^{-2} d^{-1}) recorded the intermediate values where as the control plants recorded low (22.07 g m^{-2} d^{-1}) crop growth rate at 45-60 DAS.

Higher CGR in T_7 might be due to the fact that those plants were supplied with the three nutrients at the required stages which enable them to have higher leaf area, net assimilation rate thus enhancing the crop growth.

The decline in crop growth rate after 60 DAS might be due to loss in drymatter on account of senescence (Kalyani *et al.,* 1993). Similar results were reported by Vekaria *et al.,* (2013) in greengram.

Irrespective of the treatments, the relative growth rate decreases in all the treatments from 15-30 DAS to 75-90 DAS (Table 1). Significant differences were observed among the treatments after treatment imposition.

The maximum relative growth rate (0.0430 g g^{-1} d^{-1}) was observed in potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 and 60 DAS (T_7)followed by potassium nitrate @ 2 per cent + boric acid @ 50 ppm (0.0417 g g^{-1} d^{-1}),

boric acid @ 50 ppm + zinc sulphate @ 1 per cent (0.0412 g g^{-1} d^{-1}) and in potassium nitrate @ 2 per cent + zinc sulphate @ 1 per cent (0.0396 g g^{-1} d^{-1}) at 45-60 DAS where as control plants recorded lower value of 0.0356 g g^{-1} d^{-1}.

High RGR in T_7 might be due to having high leaf area, crop growth rate reflected through total drymatter. Similar results were reported by Kalyani *et al.,* (1993) in pigeon pea.

Irrespective of the treatments, higher net assimilation rate values were recorded at 15-30 DAS and thereafter it declines gradually (Table 1). The gradual decline in NAR might be due to the senescence and abscission of leaves. But significant differences were observed among treatments after imposition of treatments at 30 and 60 DAS.

At 45-60 DAS the treatment, potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 DAS and 60 DAS recorded higher net assimilation rate (0.75 mg cm^{-2} d^{-1}) followed by potassium nitrate @ 2 per cent + boric acid @ 50 ppm (0.73 mg cm^{-2} d^{-1}), boric acid @ 50 ppm + zinc sulphate @ 1 per cent (0.72 mg cm^{-2} d^{-1}) and potassium nitrate @ 2 per cent + zinc sulphate @ 1 per cent (0.69 mg cm^{-2} d^{-1}) where as lower NAR (0.63 mg cm^{-2} d^{-1}) was recorded in control plants. The higher NAR in T_7 might be due to maintenance of higher leaf area, leaf area index and leaf area duration (Zayed *et al.,* 2011).

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Table 1: Effect of foliar application of potassium, boron and zinc on CGR, RGR and NAR in soybean

Treatments at 30 and 60 DAS	CGR (g m^{-2} day^{-1})					RGR (g g^{-1} day^{-1})					NAR (mg cm^{-2} day^{-1})				
	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS
T_1: Potassium nitrate @ 2%	10.97	21.21	25.56	5.87	2.47	0.1567	0.0674	0.0379	0.0063	0.0025	1.15	0.80	0.66	0.15	0.08
T_2: Boric acid @ 50 ppm	11.04	21.76	26.82	7.15	4.00	0.1577	0.0683	0.0388	0.0074	0.0038	1.14	0.81	0.68	0.18	0.12
T_3: Zinc sulphate @ 1%	10.96	20.38	24.29	4.80	1.93	0.1590	0.0659	0.0373	0.0054	0.0021	1.17	0.78	0.64	0.13	0.07
T_4: Potassium nitrate @ 2% + Boric acid @ 50 ppm	11.23	26.67	33.93	11.96	6.84	0.1570	0.0765	0.0417	0.0101	0.0052	1.12	0.89	0.73	0.26	0.17
T_5: Potassium nitrate @ 2% + Zinc sulphate @ 1%	11.04	24.62	29.82	8.16	3.78	0.1583	0.0737	0.0396	0.0077	0.0033	1.14	0.87	0.69	0.19	0.10
T_6: Boric acid @ 50 ppm + Zinc sulphate @ 1%	11.22	25.47	32.30	10.13	5.67	0.1589	0.0746	0.0412	0.0090	0.0045	1.13	0.87	0.72	0.23	0.15
T_7: Potassium nitrate @ 2% + Boric acid @ 50 ppm + Zinc sulphate @ 1%	11.71	27.38	36.44	14.96	7.71	0.1595	0.0759	0.0430	0.0119	0.0054	1.14	0.89	0.75	0.30	0.17
T_8: Control	10.91	19.22	22.07	3.51	1.44	0.1576	0.0636	0.0356	0.0043	0.0017	1.16	0.77	0.63	0.11	0.05
CD (P = 0.05)	NS	3.28	4.00	1.22	0.62	NS	NS	0.0036	0.0016	0.0006	NS	0.06	0.06	0.03	0.03

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Table 2: Effect of foliar application of potassium, boron and zinc on LAI ,SLA and SLW in soybean

Treatments at 30 and 60 DAS	**LAI**					**SLA ($cm^2 g^{-1}$)**					**SLW ($mg\ cm^{-2}$)**				
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T_1: Potassium nitrate @ 2%	1.89	3.59	4.22	3.40	2.86	257	192	154	136	132	3.88	5.20	6.48	7.35	7.55
$T_{2\,:}$ Boric acid @ 50 ppm	1.92	3.65	4.29	3.51	2.98	259	193	155	138	134	3.85	5.18	6.45	7.21	7.42
T_3: Zinc sulphate @ 1%	1.87	3.50	4.09	3.25	2.71	256	189	153	131	127	3.90	5.28	6.53	7.62	7.83
T_4: Potassium nitrate @ 2% + Boric acid @ 50 ppm	1.97	4.33	5.01	4.36	3.92	267	202	168	163	155	3.74	4.94	5.93	6.11	6.45
T_5: Potassium nitrate @ 2% + Zinc sulphate @ 1%	1.93	3.98	4.65	3.90	3.43	263	193	161	150	142	3.79	5.17	6.21	6.63	7.03
T_6: Boric acid @ 50 ppm + Zinc sulphate @ 1%	1.96	4.15	4.83	4.10	3.65	266	196	164	155	148	3.75	5.10	6.07	6.43	6.73
T_7: Potassium nitrate @ 2% + Boric acid @ 50 ppm + Zinc sulphate @ 1%	1.99	4.50	5.18	4.65	4.18	268	203	169	164	159	3.73	4.93	5.92	6.07	6.25
T_8: Control	1.86	3.27	3.78	2.92	2.39	259	186	152	125	116	3.85	5.35	6.57	8.00	8.56
CD (P = 0.05)	NS	0.51	0.57	0.70	0.51	NS	15	14	13	15	NS	0.36	0.51	0.78	0.75

Table 3: Effect of foliar application of potassium, boron and zinc on LAR , LAD and seed yield in soybean

Treatments at 30 and 60 DAS	LAR ($cm^2\ gm^{-1}$)					LAD ($cm^2\ d^{-1}$)					Seed yield ($Kg\ ha^{-1}$)
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	
T_1: Potassium nitrate @ 2%	103.88	71.49	46.71	32.75	25.80	17.10	41.08	58.53	57.13	46.96	2506
T_2: Boric acid @ 50 ppm	105.05	71.73	47.06	33.36	26.31	17.43	41.79	59.56	58.51	48.66	2600
T_3: Zinc sulphate @ 1%	103.13	70.65	45.61	31.62	24.68	16.88	40.26	56.90	55.03	44.68	2450
T_4: Potassium nitrate @ 2% + Boric acid @ 50 ppm	106.06	73.94	49.80	37.47	31.15	17.90	47.30	70.09	70.33	62.12	2817
T_5: Potassium nitrate @ 2% + Zinc sulphate @ 1%	105.47	72.15	48.69	35.52	29.11	17.45	44.32	64.78	64.18	55.00	2691
T_6: Boric acid @ 50 ppm + Zinc sulphate @ 1%	105.51	73.16	49.33	36.36	30.13	17.78	45.81	67.37	66.95	58.08	2723
T_7: Potassium nitrate @ 2% + Boric acid @ 50 ppm + Zinc sulphate @ 1%	106.40	74.50	50.67	37.61	31.35	18.22	48.67	72.63	73.73	66.23	2996
T_8: Control	103.11	69.71	45.67	30.44	23.34	16.86	38.49	52.87	50.23	39.81	2330
CD (P = 0.05)	NS	5.42	3.96	3.18	2.32	NS	4.94	6.35	9.38	7.86	293

The data on leaf area index of soybean as influenced by foliar application of potassium, boron and zinc at 30 and 60 DAS was presented in Table 2. A significant difference among treatments was observed from 45 to 60 DAS and it increases upto 60 DAS and then it declines up to 90 DAS. The decline in LAI after 60 DAS might be due the senescence and abscission of leaves. Among the treatments, the plants sprayed with potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 DAS and 60 DAS(T7) recorded higher leaf area index at 60 DAS (5.18) which was 37 per cent higher over control (3.78) followed by potassium nitrate @ 2 per cent + boric acid @ 50 ppm (5.01), boric acid @ 50 ppm + zinc sulphate @ 1 per cent (4.83) and potassium nitrate @ 2 per cent + zinc sulphate @ 1 per cent (4.65) . The higher LAI in T_7 might be due to maintenance of higher leaf area, leaf drymatter and crop growth rate by utilizing the foliar applied nutrients (Pradeep and Elamathi, 2007). The results are in well agreement with those reported by Patra *et al.,* (1995) in groundnut.

The specific leaf area showed a gradual decline from 30 DAS to 90 DAS. At 30 DAS the treatments were not differed significantly as the foliar application was done at 30 DAS and 60 DAS. There was a significant difference in specific leaf area among the treatments from 45 DAS to 90 DAS. Even though the specific leaf area decreases in all the treatments, the treatment potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 DAS and 60 DAS(T_7) recorded the higher specific leaf area (159 cm^2 g^{-1}) followed by potassium nitrate @ 2 per cent + boric acid @ 50 ppm (155 cm^2 g^{-1}) and boric acid @ 50 ppm + zinc sulphate @ 1 per cent (148 cm^2 g^{-1}) at 90 DAS where as control plants recorded lower SLA (116 cm^2 g^{-1}). Higher SLA in T_7 might be due to maintenance of higher leaf area, leaf drymatter and higher photosynthetic rate due to the supply of the nutrients at critical stages (Pradeep and Elamathi, 2007; Zayed *et al.,* 2011).

Irrespective of treatments, the specific leaf weight increased in all the treatments upto 60 DAS and thereafter the rate of increase was declining from 60 DAS (Table 2). Significant differences were observed among the treatments throughout the crop growth. The maximum specific leaf weight was observed in control plants at 90 DAS. Foliar application of nutrients significantly decreased the specific leaf weight at all stages of growth when compared to control plants. At 90 DAS the treatment potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 DAS and 60 DAS (T_7) showed lower specific leaf weight (6.25 mg cm^{-2}) whereas control plants showed higher specific leaf weight (8.56 mg cm^{-2}). The extent of decrease was 26.98 per cent and all the other treatments recorded an extent of decrease from 26.98 per cent to 8.52 per cent. This gradual decline in SLW might be due to maintaining higher leaf area, leaf drymatter and leaf area index in the foliar applied plants. Similar results were reported by Mahobia *et al.,* (2006) in Pigeonpea.

Leaf area ratio gradually decreases from 30 DAS to harvest (Table 3). At 30 DAS there were no significant differences among treatments regarding leaf area ratio. At 45,60 and 75 DAS, the treatment potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 DAS and 60 DAS(T_7) recorded higher leaf area ratio (74.50 cm^2 g^{-1}, 50.67 cm^2 g^{-1} and 37.61 cm^2 g^{-1} respectively) followed by potassium nitrate @ 2 per cent + boric acid @ 50 ppm at 30 DAS and 60 DAS (73.94 cm^2 g^{-1}, 49.80 cm^2 g^{-1} and 37.47 cm^2 g^{-1} respectively). Higher leaf area ratio in T_7 might be due to maintenance of higher leaf area, leaf area index and leaf drymatter (Pradeep and Elamathi, 2007). Similar results were reported by Nalini *et al.,* (2013) in blackgram.

Leaf area duration indicates the leafiness of crop till harvest. The leaf area duration gradually increases from 30 DAS to 60 DAS and thereafter it declines irrespective of the treatments (Table 3). The decline in leaf area duration after 60 DAS might be due to the senescence and abscission of the leaves resulting in decreased leaf area and leaf area index. There was no significant difference among the treatments at 15-30 DAS as the foliar application was done at 30 and 60 DAS. Hence after 30 DAS there were significant differences among treatments with regard to leaf area duration.

At 45-60 DAS, maximum leaf area duration was recorded in all treatments. Higher leaf area duration (72.63 cm^2 d^{-1}) was recorded with potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 DAS and 60 DAS (T_7) followed by potassium nitrate @ 2 per cent + boric acid @ 50 ppm (70.09 cm^2 d^{-1}) and boric acid @ 50 ppm + zinc sulphate @ 1 per cent (67.37 cm^2 d^{-1}) where as control recorded low value (52.87 cm^2 d^{-1}). Higher LAD in T_7 treatment might be due to maintenance of higher leaf area and leaf area index (Seifinadergholi *et al.*, 2011). Similar results were reported by Sunil *et al.*, (2010) in mungbean.

Foliar sprays of nutrients increased the seed yield considerably over control (Table 3). Significant differences were observed among different treatments with regards to seed yield. Among all the treatments, the treatment potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 DAS and 60 DAS (T_7) recorded significant increase in seed yield (2996 Kg ha^{-1}) which was 28.59 per cent higher over control (2330 Kg ha^{-1}). Higher yield in T_7 might be due to the significant effect of nutrient sprays enhancing number of pods per plant and the role of boron in increasing drymatter and efficiency of translocation of assimilates to developing sink leading to increased pods and higher seed yield (Pradeep and Elamathi 2007) and potassium might have improved pod filling and phytomass production due to increased photosynthetic activity and effective translocation of assimilates to reproductive parts resulting in higher yield (Menjel, 1976) and foliar application of zinc increased the leaf area, drymatter, length of flowering period, number of pods per plant and thereby yield (Khodadad Mostafavi, 2012). Similar results were reported by Beg *et al.*, (2013) in urdbean. From these results it can be concluded that foliar application of potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 DAS and 60 DAS increased growth parameters and seed yield in soybean.

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