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Research Communication

Effect of plant-growth regulators and nutrient levels on productivity and nutrient uptake of soybean (*Glycine max*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2017 at Dharwad, Karnataka, to study the influence of plant-growth regulators and nutrient levels on yield and nutrient uptake of soybean [*Glycine max* (L.) Merrill]. The experiment was laid out using randomized complete-block design with 14 factorial combinations of treatments including control treatments and replicated thrice. The treatments consisted of 2 nutrient levels, *viz.* 125% recommended dose of fertilizer (RDF) [50-45-25 NPK kg/ha] and 100% RDF (40-35-20 NPK kg/ha), with 6 levels of plant-growth regulators (PGR), *viz.* salicylic acid @ 50 and 100 ppm, ethrel @ 100 and 200 ppm, chlormequat chloride (CCC) @ 250 and 500 ppm and the control. Recommended package of practice (RPP)-without PGR spray and RPP + KNO_3 @ 1%. Results indicated that, foliar application of 125 % RDF + CCC @ 500 ppm at 25 and 40 days after sowing (DAS) resulted in significantly higher seed yield (2.63 t/ha) over the other treatments but it was at par with 125% RDF + ethrel @ 200 ppm (2.37 t/ha). The increment in seed yield owing to these treatments over the control was to the tune of 35.3% and 27.8% respectively. Number of pods/plant, seed weight/ plant, total uptake of nitrogen, phosphorus and potassium, protein content and oil content were found higher in soybean when combined application of 125% RDF + CCC @ 500 ppm was done.

Key words: Chlormequat chloride, Ethrel, Nitrogen uptake, Oil content, Protein content, Soybean, Yield

Soybean having higher nutritive value with 40–42% protein and 20% oil content, is one of the major oilseed crops of India which is cultivated on an area of 11.33 million ha with a production of 13.79 million tonnes and productivity of 1.22 t/ha (GoI, 2019). Large-scale cultivation of soybean under rainfed with low input conditions and improper nutrient management resulted in lower productivity at national level (Rana *et al*., 2018; Dass *et al*., 2019). Concurrently, the major physiological constraints in pulses and oilseed crops which limit the productivity are lack of seedling vigour, slow development of leaf area during the first eight weeks after planting, profuse flowering but poor seed set, limitation of source at the time of seed development due to early leaf senescence, inefficient mobilization of carbon and nitrogen etc. (Rajanna *et al*., 2016; Rana *et al*., 2016, 2018). Plant-growth regulators (PGRs) are well known to improve the source-sink relationship in plants and encourage the translocation of photo-assimilates thereby helping in effective flower formation, fruit, and seed development and ultimately increase the yield of crops (Solaimalai *et al.,* 2001). Some of the growth regulators like salicylic acid, ethrel and chlormequat chloride (cycocel) play a significant role in enhancing soybean yield and quality parameters of soybean. Considering the importance of soybean production in the country, the present investigation was conducted to analyse the effect of the PGRs on soybean growth and productivity.

A field experiment was conducted during the rainy (*kharif*) season of 2017 at the University of Agricultural Sciences, Dharwad, Karnataka, having clay-textured soils with *p*H of 7.02 and electrical conductivity of 0.29 dS/m. The soil was medium in organic carbon (0.51%) and low in available nitrogen (258.5 kg/ha) and medium in available P (14.2 kg/ha) and available K (236.9 kg/ha). The highest mean monthly maximum temperature of 37.7°C, lowest mean monthly minimum temperature of 13.9 °C was observed during the months of April and January 2017. Mean monthly maximum relative humidity (93.4%) was ob-

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served during September-October 2017. The mean annual rainfall of experimental location was 787.2 mm. The experiment was laid out in randomized complete-block design with 14 factorial combinations of treatments including the control and replicated thrice. The treatments consisted of 2 nutrient levels 125% RDF and 100% RDF with 6 levels of plant-growth regulator (PGR), *viz.* salicylic acid @ 50 and 100 ppm, ethrel @ 100 and 200 ppm, chlormequat chloride (CCC) @ 250 and 500 ppm; control: RPP, without PGR spray and RPP + KNO_3 @ 1%. Seeds were treated with *Rhizobium* and phosphate-solublizing bacteria (1,250 g each per hectare seeds). Two seeds of 'DSB 21' variety were dibbled at 5 cm deep in furrows at a spacing of 30 cm × 10 cm and sown on 6 July 2017. Recommended dose of nitrogen (40 kg/ha), phosphorus (35 kg/ha) and potash (20 kg/ha) were applied as per the treatments to each plot (4.0 , × 3.6 m) through urea, single superphosphate and muriate of potash at the time of sowing along with gypsum at the rate of 100 kg/ha. The PGRs were sprayed as per the treatments at 25 and 40 days after sowing (DAS). Two irrigations were given at 2nd and 4th week of August 2017 due to deficit rainfall. The crop was harvested on 16th October 2017. The soil samples collected before sowing and at harvesting were analyzed for available nutrients and plant samples for nutrient concentrations at harvesting. The standard analytical methods were followed for estimation of nutrients from soil and plants (Subbiah and Asija, 1956). The nitrogen percentage in soybean seeds was estimated by modified Kjeldahl's method (Jakson, 1967) and protein content (%) was calculated by multiplying the nitrogen percentage with factor 6.25 (Tai and Young, 1974). Oil content (%) was estimated by using Nuclear Magnetic Resonance (NMR) spectrometer.

Results showed that significantly higher soybean seed yield was recorded with application of 125% RDF compared to 100% RDF and control: RPP-without PGRs and RPP + KNO_3 @ 1% (Table 1). Increase in seed and haulm yield could be owing to increase in yield parameters like number of pods/plant and seed weight/plant. It was owing to the beneficial effect of nitrogen, phosphorus and potassium nutrition on exploiting inherent potential of the crop for vegetative and reproductive growth and plant growth regulators resulted in improved souce-sink relationship. The yield increase was attributed to application of higher nutrient levels that has accelerated the photosynthetic rate leading to production of carbohydrates (Dass *et al*., 2018; Omran *et al*., 2020). Application of chlormequat chloride @ 500 ppm recorded significantly higher soybean seed yield than other plant-growth regulators and the control treatments. The increased seed yield was owing to higher dry-matter production and its accumulation in reproductive parts. Among the combined effects, significantly higher number of pods/plant, seed weight/plant and seed yield were obtained with 125% RDF + chlormequat chloride @ 500 ppm. The next best treatment was 125% RDF + ethrel @ 200 ppm which was on a par with 100% RDF + chlormequat chloride @ 500 ppm. The increment in seed yield over the control was to the tune of 35.3% and 27.8% respectively. Significantly lower seed yield, were recorded in the control treatments C_1 (RPP, without plant-growth regulators) and C_2 (RPP + KNO_3 @ 1%). Significantly higher seed yield with the application of higher doses of nutrient and PGR was also reported by Devi *et al.* (2011) and Vaiyapuri *et al*. (2012).

The maximum protein content (35.93%), protein yield (0.68 t/ha), oil content (18.94%), oil yield (0.45 t/ha) were enhanced with the application of chlormequat chloride @ 500 ppm and followed by application of ethrel @ 200 ppm (35.30%, 0.64 t/ha, 18.15% and 0.43 t/ha, respectively) (Table 1). Grewal *et al.* (1993) reported that, cycocel improved the translocation of photosynthates, thus helping in accumulation of more dry-matter. More protein content stored in the seeds could be attributed to improvement of translocation of photosynthates to the seeds (Devi *et al.,* 2011).

Total uptake of nitrogen, phosphorus and potassium were influenced by foliar application of PGRs and nutrient levels (Table 1). With respect to nutrient levels, application of 125% RDF recorded significantly higher nitrogen, phosphorus and potassium uptake by soybean at harvesting over 100% RDF. The higher uptake may be due to increased availability of nutrients in the soil, which in turn led to higher production of dry matter and yield components. Among the different plant-growth regulators, application of chlormequate chloride @ 500 ppm recorded significantly higher nitrogen, phosphorus and potassium uptake by soybean at harvesting compared to the other PGRs (Table 1). Combined effect revealed that, higher uptake of nitrogen, phosphorus and potassium was observed in combined application of 125% RDF + chlormequat chloride @ 500 ppm followed by 125% RDF + ethrel @ 200 ppm as compared to the other treatment combinations and contol plots of C_1 (RPP, without plant growth regulators) and C_2 (RPP + KNO_3@ 1%). The PGRs improved the protein synthesis, photosynthesis by translocating the photosynthate from source to sink resulted in significantly higher nutrient uptake by the soybean crop. It was reflected in enhancing the growth and yield attributes.

Based on the results, it can be concluded that the application of 125% RDF + chlormequat chloride @ 500 ppm at 30 and 40 DAS to soybean was found to be beneficial in enhancing the seed yield, protein content, oil content and nutrient uptake. Chlomequat chloride can be effectively sprayed under drought-stress condition in soybean and

Table 1. Yield, quality parameters and nutrient uptake of soybean as influenced by plant-growth regulators and nutrient levels

Treatment	Seed yield (t/ha)	Protein content (%)	Protein yield (t/ha)	Oil content (%)	Oil yield (t/ha)	Nutrient uptake(kg/ha)		
						Nitrogen	Phosphorus	Potassium
Nutrient levels								
N_1	2.05	34.82	0.62	17.76	0.36	144.0	20.6	88.9
N_2	2.23	35.07	0.63	17.93	0.40	159.9	23.1	96.5
SEm±	0.01	0.26	0.009	0.22	0.005	0.8	0.1	0.5
CD (P=0.05)	0.04	NS	NS	NS	0.015	2.3	0.3	1.4
Plant-growth regulators								
G_1	1.98	34.36	0.59	17.21	0.34	134.4	19.7	84.5
G_2	2.04	34.80	0.61	17.57	0.36	141.2	20.2	87.5
G_3	1.96	34.75	0.60	17.43	0.34	136.6	21.1	89.5
G_4	2.27	35.30	0.64	18.15	0.43	165.9	23.2	96.5
G_5	2.11	34.55	0.62	17.76	0.38	148.8	22.7	92.0
G_6	2.48	35.93	0.68	18.94	0.45	184.6	24.8	106.3
SEm±	0.02	0.44	0.016	0.38	0.009	1.3	0.2	0.8
CD (P=0.05)	0.07	NS	0.046	1.12	0.025	4.0	0.5	2.4
Interaction								
$N_1 G_1$	1.95	32.52	0.59	17.18	0.33	130.2	18.8	82.2
$N_1 G_2$	1.97	34.76	0.61	17.43	0.34	134.9	19.1	84.8
$N_1 G_3$	1.86	34.53	0.59	17.35	0.32	128.4	19.6	86.1
$N_1 G_4$	2.17	35.89	0.69	18.89	0.41	157.7	21.9	92.8
$N_1 G_5$	2.09	34.44	0.61	17.67	0.36	140.1	21.1	87.1
$N_1 G_6$	2.32	35.03	0.63	18.02	0.42	170.6	23.8	100.4
$N_2 G_1$	2.02	34.44	0.60	17.24	0.35	138.3	20.6	86.8
$N_2 G_2$	2.12	34.85	0.62	17.70	0.37	146.9	21.2	90.3
$N_2 G_3$	2.06	34.96	0.61	17.52	0.36	144.6	22.5	92.9
$N_2 G_4$	2.37	35.56	0.65	18.29	0.45	171.6	24.7	100.2
$N_2 G_5$	2.21	34.66	0.62	17.86	0.39	157.1	24.4	96.8
$N_2 G_6$	2.63	35.97	0.68	18.99	0.48	187.5	25.7	112.1
SEm±	0.03	0.63	0.022	0.54	0.012	1.9	0.3	1.2
CD (P=0.05)	0.10	NS	NS	NS	NS	5.7	0.7	3.4
Control								
C_1	1.71	33.82	0.56	16.69	0.29	119.9	17.7	79.0
C_2	1.80	34.15	0.58	17.01	0.031	124.1	18.3	80.8
SEm±	0.04	0.64	0.021	0.53	0.011	2.0	0.4	1.3
CD (P=0.05)	0.10	NS	NS	NS	0.036	5.8	1.3	3.8

N_1, 100% RDF (40-35-20 NPK kg/ha); G_3, Ethrel @ 100 ppm; C_1, RPP, without plant-growth regulator; N_2, 125% RDF (50-45-25 NPK kg/ha); G_4, Ethrel @ 200 ppm; C_2, RPP + KNO_3 @ 1% (foliar spray); G_1, salicylic acid @ 50 ppm; G_5, chlormequat chloride @ 250 ppm; RDF, recommended dose of fertilizer; G_2, Salicylic acid @ 100 ppm; G_6, chlormequat chloride @ 500 ppm; RPP, recommended package of practice [Note: Spray at 25 and 40 DAS]; NS, non-significant; KNO_3, potassium nitrate

similar growth habit crops in all the agro-ecological regions of India.

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