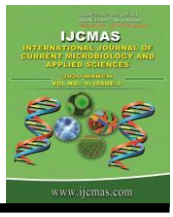
Int.J.Curr.Microbiol.App.Sci (2020) *9*(3): 890-897

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 9 Number 3 (2020)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2020.903.104

Effect of Nutrient Levels and Plant Growth Regulators on Harvest Index and Economics of Soybean (*Glycine max*)

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Keywords

Chlormequat chloride, Ethrel, Harvest index, Net return, BC ratio

Article Info

Accepted:
05 February 2020
Available Online:
10 March 2020

A B S T R A C T

A field experiment was conducted to study the influence nutrient levels and plant growth regulators on harvest index and economics of soybean [*Glycine max* (L.) Merrill] during *kharif* 2017. The experiment was laid out using randomized complete block design (factorial concept) with 14 treatments including control and replicated thrice. The treatments consisted of two nutrient levels 125 % RDF and 100 % RDF, six plant growth regulator (PGR) dosages: salicylic acid @ 50 and 100 ppm, ethrel @ 100 and 200 ppm, chlormequat chloride (CCC) @ 250 and 500 ppm; independent control: RPP, without PGR spray and RPP + KNO_3 @ 1 %. PGRs were sprayed at 25 and 40 DAS. Results shows that application of 125 % RDF + chlormequat chloride @ 500 ppm at 25 and 40 days after sowing (DAS) as foliar spray. The results revealed that application of 125 % RDF + chlormequat chloride @ 500 ppm was optimum to get higher yield (26.31 q ha^{-1}), harvest index (46.6 %) and net return (₹ 64,714 ha^{-1}) with B:C (3.15), *followed by* 125 % RDF + ethrel @ 200 ppm (23.70 q ha^{-1}, 46.03 %, ₹ 56,146 and 2.92, respectively).

Introduction

The soybean [*Glycine max* (L.) Merrill] is also called as "Miracle crop" is a source of protein for human beings, animal feeds and many prepackaged meals. It is excellent in its nutritive value with enhanced protein (40-42 %) and oil (20 %) content and is also rich in vitamins, minerals, salts and other essential amino acids (Dass *et al*., 2018). Globally it occupies an area of 120.30 million hectares with production of 351.32 million tonnes and

productivity of 2.92 t ha^{-1} (Anon., 2017). In India it is grown over an area of 11.25 million hectare with production of 11.73 million tonnes and productivity of 1042 kg ha^{-1} (Anon., 2018). Soybean is characterized by prolific flower production with an extremely low proportion of pod set. The extent of flower shedding is said to be 60-92 % in soybean (Nahar and Ikeda, 2002), which causes low yield. Plant growth regulators are well known to improve the source-sink connection and encourage the translocation of photo-assimilates thereby helping in effective flower formation, fruit, and seed development and ultimately increase the yield of crops. Some of the growth regulators like salicylic acid, ethrel and chlormequat chloride (cycocel) may play a greater role to increase the growth and yield attributing characters of soybean. Salicylic acid is an endogenous growth regulator of phenol nature, which participates in regulation of physiological processes in plant, stomata closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan *et al*., 2003). And also its application increase carbon dioxide (CO_2) and assimilation and photosynthetic rate, thus increasing dry matter. Ethylene released from ethrel (2-Chloro ethyl phosphonic acid) could possibly be utilized for promoting pod growth and early pod development in chickpea and tomato are related to higher ethylene levels, thus decreasing flower and pod shedding and thereby reducing abscission and improving better pod set. Ethrel induced increase in cell division, resulting in increased fruit size and yield have been reported in tomato fruits. Chlormequat chloride (CCC) or Cycocel is a plant growth regulator and known as antagonist of the plant hormone gibberellin. It acts by inhibiting gibberellin biosynthesis, reducing intermodal growth to give stouter stems, enhanced root growth, causing early fruit set and increasing seed set in plants, which leads to improve in the harvest index of the crop (Manu *et al*., 2020). Sanjay (2017) also reported that foliar spray of chlormequat chloride 50 % SL @ 500 g ha^{-1} at flowering and pod formation stage resulted in maximum net income and BC ratio.

Therefore, the present investigation was aimed to evaluate effect nutrient levels and plant growth regulators on harvest index and economics of soybean [*Glycine max* (L.) Merrill].

Materials and Methods

A field study was conducted at University of Agricultural Sciences, Dharwad, Karnataka (India) on medium deep black soil during *kharif* 2017. The experiment was laid out using randomized complete block design (factorial concept) with nutrient levels (N_1): 100 % RDF (40:80:25 N:P_2O_5:K2O kg ha^{-1}) and (N_2): 125 % RDF (50:100:31.2 N:P_2O_5:K_2O kg ha^{-1}); Plant growth regulators (G_1): Salicylic acid @ 50 ppm, (G_2): Salicylic acid @ 100 ppm, (G_3): Ethrel @ 100 ppm, (G_4): Ethrel @ 200 ppm, (G_5): Chlormequat chloride @ 250 ppm and (G_6): Chlormequat chloride @ 500 ppm; Controls (C_1): Independent control RPP-without plant growth regulator spray and (C_2): RPP + KNO_3 @ 1 % foliar spray. The experiment consisted of twelve treatment combinations with two control treatments (Table 1) and replicated thrice. The N, P_2O_5 and K_2O were applied as per the treatments to each plot in the form of Urea, SSP and MOP at the time of sowing along with gypsum at the rate of 100 kg ha^{-1}. Plant growth regulators were sprayed in different concentration as per the treatment at 25 and 40 DAS on 1st Aug 2017 and 16th Sept 2017, respectively. During the crop growth period, a total rainfall of 582.8 mm was received which was optimum for good growth and higher yield. The soil of the experimental site was clay with pH of 7.02 and electrical conductivity of 0.29 dS m^{-1}. The soil was

medium in organic carbon (0.51 %) and low in available nitrogen (258.5 kg ha^{-1}) and medium in available P (32.5 kg ha^{-1}) and available K (285.5 kg ha^{-1}). The land was ploughed by tractor once after the harvest of previous crop followed by harrowing twice. At the time of sowing, the land was prepared to a fine seed bed, FYM was added at the rate of 5 tonnes per hectare and the plots were laid out as per the plan of layout of the experiment. Gross plot size and net plot size were 4.0 × 3.6 m and 3.8 × 3.0 m, respectively. Soybean variety *DSb-21* seeds were treated using 1250 g each *Rhizobium* and *PSB* per hectare seeds. Two seeds per hill were dibbled 5 cm deep in furrows at a spacing of 30 × 10 cm on 06th July 2017. The seed rate used was 62.5 kg ha^{-1}. Two protective irrigations were given to the crop at 2^{nd} and 4^{th} week of August 2017 as rainfall received was less. Agronomic parameters were recorded from randomly selected five plants in net plot area at 30 and 60 DAS and at harvest. Seeds harvested from net plot were dried and weighed. On the basis of seed weight per net plot, the seed yield per ha was computed and expressed in kg per ha and converted to q per ha. The total biological portion from above ground portion from net plot at harvest was weighed after complete sun drying and haulm yield per ha was worked out by deducting the seed yield and expressed as kg per ha and converted to q per ha. Harvest index is defined as the ratio of economic yield to biological yield and expressed in percentage. Harvest index was estimated as per the formula suggested by (Donald, 1962).

$$HI\ (\%) = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Pod yield+ Haulm yield (kg ha}^{-1})} \times 100$$

The income from main product (seed) and by-product (haulm) of soybean was considered for accounting gross return. The market price prevailed at the time of selling seed (₹ 3,600 q^{-1}) and haulm (₹ 75 q^{-1}) was considered to calculate the gross return (₹ ha^{-1}). Net return was calculated by subtracting the cost of cultivation (₹ ha^{-1}) from the gross return (₹ ha^{-1}). The ratio of net return and cost of cultivation (Table 2 and 3) was worked out for each treatment and was given as benefit cost ratio (B: C) to compare the performance of different treatments.

$$B:C = \frac{\text{Gross return (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

The experimental data was statistically analyzed based on mean values obtained by using a standard method of ANOVA (analysis of variance). The level of significance used in 'F' and 'T' test was P= 0.05 (Gomez and Gomez, 1984).

Results and Discussion

Harvest index

The data on harvest index (%) as influenced by nutrient levels and plant growth regulators are presented in Table 1. With respect to different levels of nutrient on harvest index, application of 125 % RDF recorded significantly recorded higher harvest index (45.25 %) compared to 100 % RDF (44.38). Among the different plant growth regulators, chlormequat chloride @ 500 ppm recorded significantly harvest index (46.42 %) followed by ethrel @ 200 ppm (45.49 %) as compared to rest of the treatments. Within the interactions, significantly higher harvest index (46.61 %) recorded with the combined application of 125 % RDF + chlormequat chloride @ 500 ppm, follwed by application of 125 % RDF + ethrel @ 200 ppm (46.52 %) as compared to other treatment combinations and control [C_1] (42.04 %).

Table.1 Effect of nutrient levels and plant growth regulators on seed yield, haulm yield, harvest index and net return and BC ratio of soybean

Treatments	Seed yield (q ha^{-1})	Haulm yield (q ha^{-1})	Harvest index (%)	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C
Nutrient levels							
N_1	20.46	25.61	44.38	27,781	73,677	45,896	2.65
N_2	22.34	26.66	45.25	29,203	80,436	51,233	2.75
S. Em. ±	0.14	0.23	0.27	-	489	489	0.02
C. D. at 5 %	0.40	0.68	0.80	-	1435	1435	0.05
Plant growth regulators							
G_1	19.81	25.09	44.14	28,092	71,341	43,249	2.54
G_2	20.43	25.45	44.53	28,631	73,585	44,954	2.57
G_3	19.61	25.15	43.79	27,994	70,603	42,609	2.52
G_4	22.67	27.15	45.49	28,436	81,627	53,191	2.87
G_5	21.12	26.34	44.51	28,451	76,058	47,607	2.67
G_6	24.75	28.55	46.42	29,351	89,128	59,777	3.03
S. Em. ±	0.24	0.40	0.47	-	847	847	0.03
C. D. at 5 %	0.69	1.18	1.38	-	2485	2485	0.09
Interaction							
N_1 G_1	19.46	24.33	44.44	27,391	70,068	42,677	2.56
N_1 G_2	19.74	25.16	43.98	27,821	71,011	43,190	2.55
N_1 G_3	18.58	24.49	43.13	27,271	66,912	39,641	2.45
N_1 G_4	21.66	27.05	44.47	27,671	77,907	50,236	2.82
N_1 G_5	20.18	25.45	44.21	27,771	72,565	44,794	2.61
N_1 G_6	23.26	27.20	46.03	28,671	83,511	54,840	2.91
N_2 G_1	20.16	25.84	43.84	28,791	72,613	43,822	2.52
N_2 G_2	21.22	25.74	45.08	29,351	76,069	46,718	2.59
N_2 G_3	20.63	25.80	44.46	28,716	74,293	45,577	2.60
N_2 G_4	23.70	27.25	46.52	29,201	85,347	56,146	2.92
N_2 G_5	22.09	27.23	44.80	29,132	79,551	50,419	2.73
N_2 G_6	26.31	29.89	46.61	30,031	94,745	64,714	3.15
S. Em. ±	0.33	0.57	0.67	-	1198	1198	0.04
C. D. at 5 %	0.98	NS	0.80	-	3514	3515	NS
Control							
C_1	17.09	22.36	42.04	26,571	61,546	34,675	2.34
C_2	18.04	23.10	42.86	27,321	64,967	37,646	2.38
S. Em. ±	0.35	0.58	0.71	-	1244	1244	0.04
C. D. at 5 %	1.00	1.67	2.07	-	3616	3616	0.13

N_1 = 100 % RDF (40:80:25 N:P_2O_5:K_2O kg ha^{-1})	**G_3 = Ethrel @ 100 ppm**	**C_1 = RPP, without plant growth regulator**
N_2 = 125 % RDF(50:100:31.25 N:P_2O_5:K_2O kg ha^{-1})	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	B:C = Benefit cost ratio

Table.2 Treatment-wise details of cost of cultivation (₹ ha^{-1}) of soybean per hectare basis during *kharif*-2017

Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}
Land preparation														
Ploughing (tractor)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Harrowing (bullock)	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Seeds and sowing														
Sowing	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
Seed cost	4,100	4,100	4,100	4,100	4,100	4,100	4,100	4,100	4,100	4,100	4,100	4,100	4,100	4,100
Seed treatment (*Rhizobium* and *PSB)*	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Fertilizer cost														
FYM (5 t ha^{-1})	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Urea	540	540	540	540	540	540	675	675	675	675	675	675	540	540
SSP	4,150	4,150	4,150	4,150	4,150	4,150	5,187	5,187	5,187	5,187.5	5,187	5,187	4,150	4,150
MOP	751	751	751	751	751	751	938	938	938	938	938	938	751	751
Application cost	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Intercultivation	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Hand wedding	900	900	900	900	900	900	900	900	900	900	900	900	900	900
Treatment cost														
Plant growth regulators	420	850	300	600	800	1,700	460	1020	385	870	800	1,700	-	250
Application cost	600	600	600	600	600	600	600	600	600	600	600	600	-	700
Chemical cost														
Pendimetheline 30% EC	800	800	800	800	800	800	800	800	800	800	800	800	800	800
Chlorpyriphos	280	280	280	280	280	280	280	280	280	280	280	280	280	280
Coragine	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
Harvesting and Threshing	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150
Tansport	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Total	**27,391**	**27,821**	**27,271**	**27,671**	**27,771**	**28,671**	**28,791**	**29,351**	**28,716**	**29,201**	**29,131**	**30,031**	**26,571**	**27,321**

T_1: 100 % RDF + Salicylic acid @ 50 ppm	**T_3:** 100 % RDF + Ethrel @ 100 ppm	**T_5:** 100 % RDF + Chlormequat chloride @ 250 ppm	**T_7:** 125 % RDF + Salicylic acid @ 50 ppm	**T_9:** 125 % RDF + Ethrel @ 100 ppm	**T_{11}:**125 % RDF + Chlormequat chloride @ 250 ppm	**T_{13}: Control** (C_1): RPP, without spray of plant growth regulator
T_2: 100 % RDF + Salicylic acid @ 100 ppm	**T_4:** 100 % RDF + Ethrel @ 200 ppm	**T_6:** 100 % RDF + Chlormequat chloride @ 500 ppm	**T_8:** 125 % RDF + Salicylic acid @ 100 ppm	**T_{10}:** 125 % RDF + Ethrel @ 200 ppm	**T_{12}:** 125 % RDF + Chlormequat chloride @ 500 ppm	**T_{14}: Control** (C_2): RPP + KNO_3 @ 1.0 %

Table.3 Prices of inputs and outputs

Sl. No.	Particulars	Unit	Price (₹)
A)	**Inputs**		
1	Land ploughing		
	Tractor cultivation	Per hr	500
	Harrowing (bullock pair)	Per day	1,200
2	Seed	Per kg	66
3	FYM	Per t	500
4	Fertilizer		
	Urea	Per kg	6
	SSP	Per kg	8.6
	MOP	Per kg	17.3
5	Plant growth regulators		
	Salicylic acid	Per kg	1152
	Ethrel	100 ml	187
	Chlormequate chloride (cycocel)	25 g	900
6	Plant protection		
	Chlorpyriphos	500 ml	180
	Chlorantraniliprole	50 ml	600
	Pendimethalin 30 % EC	700 ml	450
7	Labour Wages		
	Men	Per day	318
	Women	Per day	318
B)	**Outputs**		
1	Seed yield	Per q	3600
2	Haulm yield	Per q	75

Note: Prices of the inputs as per University of Agricultural Sciences, Dharwad, Karnataka (India) norms used during the experimentation considered (November-2017)

Harvest index (42.04 and 42.86 %, respectively) recorded in control treatments C_1 (RPP, without plant growth regulators) and C_2 (RPP + KNO_3@ 1 %) were on par to each other. Increase in the harvest index because of increase in economic and biological yield of the crop in general. It is mainly due 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 improved source-sink relationship. Which lead to the increased productivity of soybean. Similarly these results are in agreement with the results of Devi *et al.*, (2011), Vaiyapuri *et al*., (2012) and Shweta *et al*., (2014).

Economic analysis

The data on economic analysis of soybean as influenced by nutrient levels and plant growth regulators are presented in Table 1. Application of 125 % RDF (50:100:31.25 kg ha^{-1}) recorded significantly higher gross returns (₹ 80,436 ha^{-1}), net returns (₹ 51,233

ha^{-1}) and B:C ratio (2.75) as compared to 100 % **(**40:80:25 kg ha^{-1}**)** RDF (₹ 73,677 ha^{-1}, ₹ 45,896 ha^{-1} and 2.65, respectively), control C_1 (₹ 61,546, ₹ 34,675 and 2.34, respectively) and C_2 (₹ 64,967, ₹ 37,646 and 2.38, respectively). This was due to higher seed yield (22.34 q ha^{-1}) and haulm yield (26.66 q ha^{-1}) recorded with this treatment. These results are in conformity with the findings of Chaplot *et al.*, (2013), Geeta and Radder (2015) and Yadravi (2015). Application of chlormequat choloride @ 500 ppm recorded significantly higher gross returns (₹ 89,128 ha^{-1}), net returns (₹ 59,777 ha^{-1}) and B:C ratio (3.03), followed by ethrel @ 200 ppm (₹ 81,627 ha^{-1}, ₹ 53,191 ha^{-1} and 2.87) as compared to other treatments (Table 1). These results are in agreement with the findings of Devi *et al.*, (2011), and (Sanjay, 2017). Among the interaction, application of 125 % RDF + chormequat choloride @ 500 ppm recorded significantly higher gross returns (₹ 94,745 ha^{-1}) and net returns (₹ 64,714 ha^{-1}), followed by 125 RDF + ethrel @ 200 ppm (₹ 85,347 ha^{-1}, ₹ 56,146 ha^{-1}) as compared to other treatment combinations, C_1 and C_2 (Table. 1). But, B:C ratio was statistically non-significant within the interaction. However, when compared to control, higher B:C ratio (3.15) obtained with the application of 125 % RDF + chlormequat chloride @ 500 ppm followed by 125 RDF + ethrel @ 200 ppm (2.92). This was mainly due to higher seed yield of soybean. Similar results have been reported by Kalyankar (2008), Vaiyapuri *et al.*, (2012) and Manpreet (2016).

In conclusion, the above results clearly indicates that application of 125 % RDF + chlormequat chloride @ 500 ppm at 25 and 40 DAS as foliar spray was found to improve the harvest index, net returns and BC ratio of soybean; *followed by* 125 % RDF + ethrel @ 200 ppm. Thus, these treatments could be recommended for increasing the productivity of soybean.

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How to cite this article:

Manu, S. M., S. P. Halagalimath, H. T. Chandranath and Biradar, B. D. 2020. Effect of Nutrient Levels and Plant Growth Regulators on Harvest Index and Economics of Soybean (*Glycine max*). *Int.J.Curr.Microbiol.App.Sci.* 9(03): 890-897.
doi: https://doi.org/10.20546/ijcmas.2020.903.104