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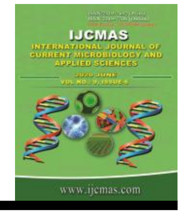

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Influence of Plant Growth Regulators and Micronutrients on Seed Yield of Black Gram (*Vigna mungo* L.) and Benefit Cost Ratio for Economic Analysis

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The pulses are prima facia to alleviate malnutrition from the un-developed and developing countries. The study was conducted during 2015-16 in India to know the effect of plant growth regulators and micronutrients on growth and seed yield of black gram cv. LBG-625 (Rashmi). The results revealed that foliar application of gibberellic acid (GA_3) @ 30 ppm at pre-flowering stage recorded significantly higher plant height (56.44 cm), number of leaves plant^{-1} (24.46), number of branches plant^{-1} (7.71), days to 50 per cent flowering (40.44 DAS), days to maturity (73.27 DAS), number of cluster plant^{-1} (8.71), pods plant^{-1} (33.28), pod weight plant^{-1} (10.71 g), number of seeds plant^{-1} (6.57) and seed yield ha^{-1} (19.52 q/ha) compared to control. GA_3 application also showed significant positive impact on the income of farmers. Thus, foliar application of GA_3 at pre-flowering stage is essential for high crop yield in black gram.

Introduction

Black gram [*Vigna mungo* (L.) Hepper.] is the third most important pulse crop covering an area of about 4.49 million hectares with production of 2.92 million tonnes in India after red gram and chickpea. The average productivity of pulses (699 kg ha^{-1}) in India is far below to worlds' average productivity (909 kg ha^{-1}) (Jadhav *et al.*, 2019). The major constrains in achieving higher yield is lack of genetic variability, early senescence of leaves, pod shattering, low dry matter accumulation and harvest index, cultivation on poor and marginal lands, erratic rainfall, absence of suitable ideotypes for different cropping system and susceptibility to insects and diseases (Sujatha, 2001). Black gram is commendatory short duration pulse crop as it thrives better in all seasons either as sole, mixed, intercrop or fallow crop. Black gram (2n= 2x= 24) is one of the important grain legumes and is an excellent source of easily digestible good quality protein. The primary centre of origin of black gram is India.

The productivity of black gram is not sufficient enough to meet the domestic demand of the fast growing Indian population. Hence, there is an urgent need for augmentation of the productivity of black gram. Several strategies have been initiated to boost the productivity of black gram. The promising one is foliar application of organic and inorganic sources of nutrients for exploiting genetic potential of the crop and crop quality (Jadhav *et al.*, 2019). This is considered to be an efficient method of supplementing part of the nutrient requirements during critical growth stages. Diversion of food from sink to source, alteration of plant architecture, promotion of photosynthesis, uptake of nutrients (mineral ions), assimilate partitioning, enhancing nitrogen metabolism, promotion of flowering, uniform pod formation and arresting of vegetative growth in black gram is an essential criterion to obtain higher seed yield and quality (Chandrasekhar and Bangarusamy, 2003).

With this background, the present study was conducted to identify the constraints for increasing the productivity in black gram and to generate appropriate technology using growth regulators and micronutrients to achieve higher productivity.

Materials and Methods

Plant material and experimental design

The field experiment was conducted during Rabi season of 2015-16 at zonal agricultural research station ($11^{\circ}30^{\prime}$ N, 76° $05^{\prime}$ E; 695 m above mean sea level), Mandya in University of Agricultural Sciences, Bengaluru, India. The soil descriptor of experimental site was sandy loam with pH 5.30, organic carbon 0.51%, available N, P, K, (226, P_2O_5 33 and K_2O_5 156 kg/ha, respectively). The treatments comprised of foliar application of different plant growth regulators and micronutrients i.e. IAA @ 600 ppm, ethrel @ 250 ppm, GA_3 @ 30 ppm, thiourea @ 500 ppm, salicylic acid @ 100 ppm, NAA @ 40 ppm, boron (0.5%) and $FeSO_4$ (0.5%) at pre flowering growth stage in black gram cv. LBG-625. The observations pertaining to crop growth stages and seed yield were recorded at 30 days after sowing (DAS), 45 DAS, coincides with pre-flowering and flowering stages; and at harvest stage. The experiment was laid out in a randomized complete block design with three replications.

Experimental observation:

Growth parameters (plant height, number of leaves and branches, DAF-days to 50 per cent flowering and days to maturity) and yield and yield contributing traits (number of clusters per plant, pods per cluster and pods per plant, pod length (cm), pod weight per plant (g), number of seeds per pod, seed yield (g/plant), seed yield (kg/plot), seed yield (q/ha), seed recovery (%) and shelling (%) were studied as per standard procedure.

To assess the impact of economic feasibility on farmers' income, benefit cost ratio was calculated. All the data were subjected to statistical analysis and results were discussed below.

Results and Discussion

Growth parameters

The present investigation in black gram cv. LBG-625 revealed that foliar application of GA_3 30 ppm was noted significantly higher plant height by registering 35.33, 46.73 and 56.44 cm in comparison to control (27.97, 34.17 and 48.43 cm) at 40, 60 DAS and at the time of harvesting, respectively. The increase in plant height was possibly ascribed due to GA_3 effect on cell elongation, internode extension, efficient photosynthate mobilization, enlarged photosynthetic activity and change in the cell membrane permeability. This result is in the conformity with Krishnamoorthy (1981), Deotal *et al.,* (1995) and Shukla *et al.,* (1997) in soybean. Number of branches per plant also showed same trend by registering 3.86, 6.42 and 7.71 as compared to control (2.18, 3.71 and 5.65) at 40, 60 DAS and at the time of harvesting, respectively) in GA_3 treated plants (Table 1). Higher number of branches might be attributed to the impact of GA_3, which enhanced growth, cell division and other metabolic processes. Similar results were also reported by Borkar *et al.,* (1991) in cowpea and Deotale *et al.,* (1995) in soybean.

GA_3 application was also recorded higher number of leaves per plant by registering 20.23 and 24.46 as compared to control (16.06 and 20.05) at 40, 60 DAS, respectively. Interestingly, Control showed higher number of leaves per plant by registering 19.80 in compared to other treatments at the time of harvesting. The possible reason for higher number of leaves at 40 and 60 DAS is that due to increase of chlorophyll content by foliar application of GA_3 and act as stimulant for chlorophyll synthesis. At the time of harvest, lower numbers of leaves were observed due to natural shedding of leaves in black gram crop.

These results are in conformity with the research findings of Bora and Sharma (2006) in pea. Foliar application of GA_3 also manifested early days to 50% flowering by registering 40.44 days in comparison to control (43.71 days). Induction of early flowering might be due to attainment of phenological stages early in the ontogeny of the crop and leading to acceleration in growth. The results are in agreement with findings of Paliwal *et al.,* (1999). GA_3 also showed minimum days to maturity by registering 73.27 days as compared to other treatments (Ethrel 250 ppm, NAA 40 ppm and control, viz., 73.60, 74 and 76.27 days, respectively).

Yield parameters

Yield is a complex and quantitative trait. Foliar application of GA_3 was resulted higher number of clusters per plant, number of pods per cluster and number of pods per plant by registering 8.71, 4.48 and 33.28 as compared to control recorded as 5.48, 3.00 and 21.97, respectively (Table 2). GA_3 application was also recorded increased pod length (cm) and number of seeds per pod by registering 5.90 cm and 6.57 as compared to control (4.60 cm and 4.41). Increased pod length and number of seed per pod might be attributed due to influence of GA_3 on various morpho-physiological characters. The results are in agreement with findings of Nawalagatti *et al.,* (2009) in French bean. Significantly higher pod weight per plant (gm), seed yield per plant (gm), seed yield per plot (kg) and seed yield per hector (q/ha) were recorded by registering 10.71, 7.90, 1.76 and 19.52 in comparison to control recorded as 7.69, 5.37, 1.27 and 14.15, respectively. Similarly, GA_3 was manifested higher seed recovery and shelling percentage by registering 97.25 and 78.16% in comparison to control recorded as 90.70 and 60.67%, respectively.

Table.1 Influence of plant growth regulators and micronutrients on growth parameters in black gram cv. LBG-625 (Rashmi)

Treatments	Plant height (cm)			Number of branches			Number of leaves			DFF (days)	Maturity (days)
	40 DAS	60 DAS	H	40 DAS	60 DAS	H	40 DAS	60 DAS	H		
T1: RDF + Boron @ (0.5%)	31.53	36.09	50.70	2.78	4.85	5.72	16.80	20.67	17.84	43.00	75.25
T2: RDF + IAA @ 600 ppm	33.28	40.38	52.32	3.62	5.21	6.79	19.46	21.89	17.43	42.33	73.60
T3: RDF + Ethrel @ 250 ppm	32.13	37.43	51.07	3.03	4.46	5.76	18.38	21.19	17.44	41.70	74.61
T4: RDF + GA_3 @ 30 ppm	35.33	46.73	56.44	3.86	6.42	7.71	20.32	24.46	17.67	40.44	73.27
T5: RDF + Thiourea @ 500 ppm	31.00	34.93	50.05	2.37	4.10	6.06	16.55	20.13	17.66	42.53	74.38
T6: RDF + Salicylic acid @ 100 ppm	32.00	37.43	50.75	3.20	5.15	6.18	18.23	21.07	17.04	42.70	74.14
T7: RDF + NAA @ 40 ppm	32.77	43.41	53.02	3.67	5.56	6.94	19.63	23.29	16.84	41.26	74.00
T8: RDF + $FeSO_4$ @ (0.5%)	30.90	36.78	49.87	2.33	4.43	5.74	17.63	20.80	17.54	42.50	75.45
T9: RDF (Control)	27.97	34.17	48.43	2.18	3.71	5.65	16.06	20.05	18.24	43.71	76.27
Mean	31.8	38.60	51.41	3.00	4.88	6.29	18.12	21.50	17.52	42.24	74.55
S.Em±	0.924	0.682	0.961	0.148	0.202	0.231	0.907	0.674	0.321	0.443	0.546
C.D. (p=0.05)	2.769	2.043	2.881	0.443	0.605	0.694	2.718	2.020	0.962	1.327	1.637
CV (%)	5.0	3.1	3.2	8.5	7.2	6.4	8.7	5.4	3.2	1.8	1.3

RDF: Recommended dose of fertilizer (25:50:20 NPK kg/ha); IAA: Indole acetic acid; NAA: Naphthalene acetic acid; GA_3: Gibberellic acid, $FeSO_4$: Ferrous sulphate, DFF: Days to 50% flowering, DAS: Days after sowing and H: At the time of harvest. Foliar application once at 30 DAS and second at 45 DAS were given to all the treatments except T_9

Table.2 Effect of plant growth regulators and micronutrients on seed yield of black gram cultivar LBG-625 (Rashmi)

Treatments	No. of clusters/ plant	No. of pods/ cluster	No. of pods/ plant	Pod length (cm)	Pod weight/ plant (gm)	Seeds/ pod	Seed yield/ plant (gm)	Seed yield/ plot (kg)	Seed yield (kg/ha)	Seed recovery (%)	Shelling (%)
T1	6.46	3.31	23.75	5.24	8.98	5.85	6.27	1.57	17.41	92.08	69.83
T2	7.44	3.45	29.75	5.25	10.09	6.00	6.87	1.60	17.81	94.75	70.23
T3	7.33	3.50	26.72	4.81	9.30	5.77	5.72	1.43	15.89	93.33	65.20
T4	8.71	4.48	33.28	5.90	10.71	6.57	7.90	1.76	19.52	97.25	78.16
T5	5.76	3.04	20.57	4.77	8.02	4.93	6.18	1.55	17.18	92.45	65.69
T6	7.43	3.21	27.61	5.39	8.77	5.90	5.91	1.48	16.43	93.25	65.80
T7	7.57	3.83	30.18	5.33	10.08	6.00	6.86	1.62	17.98	94.10	70.00
T8	6.30	3.45	24.37	5.12	8.23	4.91	5.79	1.42	15.78	92.18	63.72
T9	5.48	3.00	21.97	4.60	7.69	4.41	5.37	1.27	14.15	90.70	60.67
Mean	6.94	3.47	26.47	5.16	9.10	5.59	6.32	1.52	16.90	93.34	67.70
S.Em	0.408	0.182	1.184	0.234	0.568	0.399	0.242	0.061	0.649	1.168	2.339
CD (P=0.05%)	1.223	0.545	3.550	0.702	1.702	1.197	0.726	0.182	1.944	3.503	7.013
CV (%)	10.2	9.1	7.7	7.9	10.8	12.4	6.6	6.9	6.6	2.2	6.0

Table.3 Influence of plant growth regulators and micronutrients on gross returns, net returns and benefit cost ratio in black gram cv. LBG 625 (Rashmi)

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C Ratio
T1: RDF + Boron @ (0.5%)	25357.87	64120	38762.13	2.52
T2: RDF + IAA @ 600 ppm	34167.87	67480	33312.13	1.97
T3: RDF + Ethrel @ 250 ppm	25492.87	59320	33827.13	2.32
T4: RDF + GA_3 @ 30 ppm	25967.87	75720	49752.13	2.91*
T5: RDF + Thiourea @ 500 ppm	24425.87	63520	39094.13	2.6
T6: RDF + Salicylic acid @ 100 ppm	24217.87	61280	37062.13	2.5
T7: RDF + NAA @ 40 ppm	24333.87	67640	43306.13	2.77
T8: RDF + $FeSO_4$ @ (0.5%)	24917.87	58160	33242.13	2.33
T9: RDF (Control)	24167.87	51200	27032.13	2.11
Mean	25894.4	63160	37265.6	2.44

*Indicates highest B C ratio in presence of foliar application of GA_3. Supporting files are also attached for calculation of B C ratio

Supporting files

Supporting file 1: details of cost of cultivation in different treatments (₹ ha^{-1})

Sl. No.	Particulars	T1	T2	T3	T4	T5	T6	T7	T8	T9
1	**Land preparation**									
a)	Deep ploughing	4000	4000	4000	4000	4000	4000	4000	4000	4000
b)	Harrowing (bullock pair)	2000	2000	2000	2000	2000	2000	2000	2000	2000
2	**Sowing and fertilizer application**	2000	2000	2000	2000	2000	2000	2000	2000	2000
	Seed cost	1050	1050	1050	1050	1050	1050	1050	1050	1050
3	**Farm yard manure**	2500	2500	2500	2500	2500	2500	2500	2500	2500
	chemical spray and irrigation	1500	1500	1500	1500	1500	1500	1500	1500	1500

4	**Fertilizer cost**									
a)	Urea	586.87	586.87	586.87	586.87	586.87	586.87	586.87	586.87	586.87
b)	DAP	3375	3375	3375	3375	3375	3375	3375	3375	3375
c)	MOP	0	0	0	0	0	0	0	0	0
	Application charges	314	314	314	314	314	314	314	314	314
6	**Foliar nutrition**									
a)	NAA	-	-	-	-	-	-	166	-	-
b)	IAA	-	10000	-	-	-	-	-	-	-
c)	GA3	-	-	-	1800	-	-	-	-	-
d)	Ethrel	-	-	1325	-	-	-	-	-	-
e)	Boran	1190	-	-	-	-	-	-	-	-
f)	Thiourea	-	-	-	-	258	-	-	-	-
g)	Salicylic acid	-	-	-	-	-	50	-	-	-
h)	Feso4	-	-	-	-	-	-	-	750	-
7	**Plant protection chemicals**									
a)	Profenofos	550	550	550	550	550	550	550	550	550
b)	Carbendazim	142	142	142	142	142	142	142	142	142
	Application charges	300	300	300	300	300	300	300	300	300
8	Inter cultivation	1250	1250	1250	1250	1250	1250	1250	1250	1250
9	Hand weeding	1500	1500	1500	1500	1500	1500	1500	1500	1500
10	Harvesting and threshing charges	3000	3000	3000	3000	3000	3000	3000	3000	3000
11	Land revenue	100	100	100	100	100	100	100	100	100
12	Cost of cultivation	25357.87	34167.87	25492.87	25967.87	24425.87	24217.87	24333.87	24917.87	24167.87
13	Gross returns	64120	67480	59320	75720	63520	61280	67640	58160	51200
14	Net returns	38762.13	33312.13	33827.13	49752.13	39094.13	37062.13	43306.13	33242.13	27032.13
15	B:C Ratio	2.52	1.97	2.32	2.91	2.6	2.5	2.77	2.33	2.11

Supporting file 2: Cost of cultivation and price of inputs and outputs

	Particulars	Unit	Cost/ Unit (Rs.)	Units used/ha	Cost (Rs./ha)
1	**Land preparation**				
	a) Disc ploughing	Hour	500	8	4,000
	b) Harrowing	Hour	250	8	2,000
2	**Labour**				
	a) FYM	Man day (8 hours)	150	7	1,050
	b) Sowing (Dibbling of seeds)			10	1,500
	c) Weeding			10	1500
	d) Chemical spray and irrigation			15	1500
	e) Harvesting			10	1500
	f) Threshing, cleaning and bagging			15	1500
3	**Inputs**				
	a) Seeds	kg	70	15	1,050
	b) FYM	tons	550	5	2,750
	c) Fertilizers				
	d) Urea	kg	5.70	*	*

The increased seed yield might be attributed due to variation in yield components like number of pods per cluster, number of clusters per plant, number of seeds per pod and test weight which had direct influence on the seed yield. GA_3 enhanced culmination in a number of ontogenic-developmental phases requiring specific nutrients to sustain the metabolic status of the flowering and seed developmental stages. It is also effected in activation of various internal mechanism related with plant growth and development, plant behaviour and metabolism. Other factors which indirectly influence the seed yield are growth attributes like plant height, number of branches and dry matter production. The results are parallel with the findings of Subramani *et al.,* (2002), Chandrashekhar and Bangarusamy (2003) in mung bean, Dixit and Elamathi (2007) in green gram and Bora and Sharma (2006) in pea. Thus, findings of the research will certainly help to increase seed yield in farmers' field by foliar application of growth regulator particularly gibberellic acid.

Benefit Cost ratio

Gross return (rupees ha^{-1})

Significantly higher gross return was obtained on foliar application of GA_3 (@ 30 ppm) by registering 75,720-rupees ha^{-1} in comparison to control (51,200-rupees ha^{-1}). Gross return was at par with foliar application of NAA 40 ppm (67,640-rupees ha^{-1}) (Table 3).

Net returns (rupees ha^{-1})

Significantly higher net return (49,752.13-rupees ha^{-1}) was obtained on foliar application of GA_3 (@ 30 ppm) in comparison to control (27,032.13-rupees ha$^{-1)}$). It was at par with foliar application of NAA 40 ppm (43,306.13-rupees ha^{-1}).

Benefit cost ratio (B: C)

Significantly higher B: C ratio (2.91) was obtained on foliar application of GA_3 (@ 30 ppm) in comparison to control (2.11). It was at par with foliar application of NAA 40 ppm (2.77).

The higher gross returns, net returns and B: C ratio obtained with these treatments was ultimately due to higher productivity in terms of yield. Similar results were also reported by Chandrasekhar and Bangarusamy (2003) in black gram, and Dixit and Elamathi (2007) in green gram.

In conclusion, pulses constitute a paramount ingredient which can help to alleviate malnutrition and malnourishment in ballooning vegetarian diet based Indian population. Application of recommended dose of fertilizer as a basal dose and foliar application of GA_3 (@ 30 ppm) to black gram once at flower initiation and second at pod setting stage is prerequisite for higher growth parameters and ultimately yield. The economic analysis indicated significantly higher gross returns, net returns and B: C ratio in this condition. Thus, foliar application of nutrients and growth regulators using water-soluble fertilizer is one of the possible ways to enhance seed yield and quality in black gram.

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Author's contribution

First and fourth authors were involved in field preparation, data collection and statistical analysis. Second and third authors were engaged in writing of research paper and structure of manuscript.

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