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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Abstract

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 (GA₃) @ 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. GA₃ application also showed significant positive impact on the income of farmers. Thus, foliar application of GA₃ at pre-flowering stage is essential for high crop yield in black gram.

Keywords
Black gram, Growth regulators, GA₃, Micronutrient, Seed yield, B:C ratio

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° 30’ N, 76° 05’ 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, P2O5 33 and K2O 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, GA3 @ 30 ppm, thiourea @ 500 ppm, salicylic acid @ 100 ppm, NAA @ 40 ppm, boron (0.5%) and FeSO4 (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/plot), seed yield (kg/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 Deotal 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 hectar (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 + GA₃ @ 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 + FeSO₄ @ (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; GA₃: Gibberellic acid, FeSO₄: 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 T₉.
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 + GA₃ @ 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 + FeSO₄ @ (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 GA₃. Supporting files are also attached for calculation of B C ratio

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        | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 |
|         | application                  |    |    |    |    |    |    |    |    |    |
|         | 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 |
|   | Fertilizer cost                  | a) | b) | c) | d) | e) | f) | g) | h) |   |
|---|---------------------------------|----|----|----|----|----|----|----|----|----|
|   | Urea                            | 586.87 | 586.87 | 586.87 | 586.87 | 586.87 | 586.87 | 586.87 | 586.87 | 586.87 |
|   | DAP                             | 3375 | 3375 | 3375 | 3375 | 3375 | 3375 | 3375 | 3375 | 3375 |
|   | MOP                             | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|   | Application charges             | 314 | 314 | 314 | 314 | 314 | 314 | 314 | 314 | 314 |
| 6 | Foliar nutrition                |    |    |    |    |    |    |    |    |    |
|   | NAA                             | - | - | - | - | - | - | 166 | - | - |
|   | IAA                             | - | 10000 | - | - | - | - | - | - | - |
|   | GA3                             | - | - | - | 1800 | - | - | - | - | - |
|   | Ethrel                          | - | - | 1325 | - | - | - | - | - | - |
|   | Boran                           | 1190 | - | - | - | - | - | - | - | - |
|   | Thionea                         | - | - | - | 258 | - | - | - | - | - |
|   | Salicylic acid                  | - | - | - | - | 50 | - | - | - | - |
|   | Feso4                           | - | - | - | - | - | - | 750 | - | - |
| 7 | Plant protection chemicals      |    |    |    |    |    |    |    |    |    |
|   | Profenofos                      | 550 | 550 | 550 | 550 | 550 | 550 | 550 | 550 | 550 |
|   | 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) |        |                  |               |               |
| c) Weeding                |        |                  |               |               |
| d) Chemical spray and irrigation |        |                  |               |               |
| e) Harvesting             |        |                  |               |               |
| f) Threshing, cleaning and bagging |        |                  |               |               |
| 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. GA₃ 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 affected 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), Chandrashekar 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 GA₃ (@ 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 GA₃ (@ 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 GA₃ (@ 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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