

# Optimizing Plant Geometry and Nutrient Management for Grain Yield and Economics in Irrigated Greengram

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## Abstract

Greengram (*Vigna radiata* L.) is important pulse crop in India. The yield and economics were increased by optimization of plant geometry and nutrient management under irrigated condition. The field experiment was conducted during *Rabi* season of November 2013 to January 2014 at Tamil Nadu Agricultural University, Agricultural College and Research Institute, Killikulam. An experiment was laid out in randomised block design and replicated thrice and the test variety of the crop greengram (CO 6) was used. The plant geometry of 30 × 30 cm, 25 × 25 cm and 30 × 10 cm was adopted. The Soil Test Crop Response (STCR) based fertilizer application, RDF, FYM and ZnSO<sub>4</sub> was applied in soil as basal. The foliar spray of Pulse Wonder and Pink-pigmented facultative methylootrophs (PPFM) spray was done at one week after flowering and 1% KNO<sub>3</sub> at 50 per cent flowering. Adoption of planting geometry of 30 × 30 cm, application of RDF, 12.5 t of FYM and 25 kg ZnSO<sub>4</sub> as basal and foliar spraying of 1% KNO<sub>3</sub> at 50 per cent flowering recorded higher dry matter production of 2865 kg·ha<sup>-1</sup> and yield attributes *viz.*, number of pod clusters plant<sup>-1</sup> (10.34), number of pods plant<sup>-1</sup> (53.40), number of seeds pod<sup>-1</sup> (13.23), pod length (8.77 cm) and seed test weight (3.42 g). Higher grain yield of 1775 kg·ha<sup>-1</sup>, haulm yield (2920 kg·ha<sup>-1</sup>), harvest index (0.38), net return (57,806 Rs·ha<sup>-1</sup>) and B:C ratio (2.43) were associated with the treatment comprising of 30 × 30 cm spacing, application of RDF, 12.5 t of FYM and 25 kg ZnSO<sub>4</sub> as basal and foliar spraying of 1% KNO<sub>3</sub> at 50 per cent flowering.

## Keywords

Greengram, Plant Geometry, Nutrients, Yield

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## 1. Introduction

Pulses play an important role in Indian agriculture. India is a premier pulse growing country and forms an integral part of cropping system of the farmers all over the country. The present average per capita consumption of pulses in India was  $14 \text{ kg}\cdot\text{year}^{-1}$  against the WHO recommendation of  $20 \text{ kg}\cdot\text{year}^{-1}$ . India grows nearly 23 million ha of pulses with the annual production of 17.02 million tonnes and an average productivity of  $617 \text{ kg}\cdot\text{ha}^{-1}$ . Greengram or mungbean (*Vigna radiata* L.) is one of the most important food legumes in India. It is the third most important pulse crop of India. Greengram is a rich source of protein (24%) and also contributes carbohydrates (60%), fat (1.5%), amino acids, vitamins and minerals etc. Area under greengram in India is 3.80 million hectares with an annual production of 1.1 million tonnes. In Tamil Nadu, the area under greengram is 0.13 million hectares with an annual production of 458.8 tonnes. The average productivity of greengram over globe is  $577 \text{ kg}\cdot\text{ha}^{-1}$  and in India it is  $426 \text{ kg}\cdot\text{ha}^{-1}$ , which is considered to be low [1]. The low productivity of greengram is due to the cultivation of this crop in marginal and sub-marginal lands with poor management practices. Plant geometry plays an important role in the dominance and suppression during the process of competition. Ideal plant geometry is precious and important for better and efficient utilization of available plant growth resources in order to get maximum productivity in crops [2]. Soil application of nutrients will give the initial boost for growing seedling. Farm Yard Manure (FYM) is known to play an important role in improving the fertility and productivity of soils through its positive effects on soil physical, chemical and biological properties and balanced plant nutrient [3].

Foliar application of growth regulators reduces the flower drop and improves the pod formation and seed setting percentage. Increased drought tolerance and reduced flower drop can be achieved in pulses by foliar spray of nutrient like TNAU Pulse Wonder. Foliar application of  $\text{KNO}_3$  increases the relative water content at the maturity stage and increases the crop growth rate and pod development [4]. Spraying Pink-pigmented facultative methylotrophs (PPFM) is also said to influence the crop growth by producing plant growth regulators like zeatin and related cytokinins and auxins [5]. Keeping these views in mind, the present investigation is formulated with the following objectives

- 1) To find out the optimum plant geometry for irrigated greengram;
- 2) To find out the suitable nutrient schedule, foliar application of nutrients and growth regulators for irrigated greengram;
- 3) To work out the economics for optimum plant geometry and nutrient management for irrigated greengram.

## 2. Materials and Methods

### 2.1. Experimental Site and Initial Soil Characteristics

Field experiment was conducted during *Rabi* season of November 2013 to January 2014 at Agricultural College and Research Institute, Killikulam, located at Southern agro-climatic zone of Tamil Nadu at  $8^{\circ}46'$  North latitude and  $77^{\circ}42'$  East longitude and at an altitude of 40 m above mean sea level. The climate of the experimental site is semi-arid tropics and the mean annual rainfall is 786.6 mm received in 40 rainy days. The soil of experimental site was sandy clay loam in texture (23.67% clay, 13.65% silt, 36.52% fine sand and 25.99% coarse sand) with low in available nitrogen, medium in available phosphorus and high in available potassium. The soil was analysed 270, 13 and  $233 \text{ kg}\cdot\text{ha}^{-1}$  of  $\text{KMnO}_4\text{-N}$ , Olsen-P and  $\text{NH}_4\text{OAc-K}$ , respectively with EC of  $0.22 \text{ d}\cdot\text{Sm}^{-1}$ , pH of 7.1 and organic carbon of 0.59%.

### 2.2. Experimental Design, Selection of Cultivar and Sowing

Experiment was laid out in randomised block design with eleven treatments. The treatments were replicated thrice. The gross plot- $7.5 \text{ m} \times 3 \text{ m}$  ( $22.5 \text{ m}^2$ ) and net plot-for  $30 \times 10 \text{ cm}$  spacing - $6.9 \text{ m} \times 2.8 \text{ m}$  ( $19.3 \text{ m}^2$ ), for  $25 \times 25 \text{ cm}$  spacing - $7.0 \text{ m} \times 2.5 \text{ m}$  ( $17.5 \text{ m}^2$ ) and for  $30 \times 30 \text{ cm}$  spacing - $6.9 \text{ m} \times 2.4 \text{ m}$  ( $16.6 \text{ m}^2$ ). Green gram (*Vigna radiata* L.) variety CO 6 maturing in 62 - 67 days and the germination percentage of 95 were sown at the rate of  $20 \text{ kg}\cdot\text{ha}^{-1}$ , and suitable for cultivation in Tamil Nadu.

### 2.3. Treatment Details

As per the treatment schedule farm yard manure ( $12.5 \text{ t}\cdot\text{ha}^{-1}$ ) and recommended dose fertilizer (25:50:25:20

NPKS  $\text{kg}\cdot\text{ha}^{-1}$ ) and Soil Test Crop Response based fertilizer application (13:25:13 NPK  $\text{kg}\cdot\text{ha}^{-1}$ ) were applied as basal, Zinc Sulphate ( $25 \text{ kg}\cdot\text{ha}^{-1}$ ) was applied as split of 15 DAS and 25 DAS. Foliar spraying of Potassium nitrate (1%) at 30 DAS, Pulse Wonder ( $5 \text{ kg}\cdot\text{ha}^{-1}$ ) at 50% flowering and spraying of Pink-pigmented facultative methylotrophs (2%) at one week after flowering.

T<sub>1</sub>—25 × 25 cm spacing + STCR based fertilizer application.

T<sub>2</sub>—T<sub>1</sub> + ZnSO<sub>4</sub> + Pulse Wonder.

T<sub>3</sub>—T<sub>1</sub> + ZnSO<sub>4</sub> + Pulse Wonder + PPFM spray.

T<sub>4</sub>—25 × 25 cm spacing + RDF + FYM + ZnSO<sub>4</sub>.

T<sub>5</sub>—T<sub>4</sub> + 1% KNO<sub>3</sub>.

T<sub>6</sub>—30 × 30 cm spacing + STCR based fertilizer application.

T<sub>7</sub>—T<sub>6</sub> + ZnSO<sub>4</sub> + Pulse Wonder.

T<sub>8</sub>—T<sub>6</sub> + ZnSO<sub>4</sub> + Pulse Wonder + PPFM spray.

T<sub>9</sub>—30 × 30 cm spacing + RDF + FYM + ZnSO<sub>4</sub>.

T<sub>10</sub>—T<sub>9</sub> + 1% KNO<sub>3</sub>.

T<sub>11</sub>—30 × 10 cm spacing + RDF + FYM + ZnSO<sub>4</sub>.

(Note: FYM—12.5 t·ha<sup>-1</sup> as basal; STCR—13:25:13 NPK  $\text{kg}\cdot\text{ha}^{-1}$  as basal; RDF—25:50:25:20 NPKS  $\text{kg}\cdot\text{ha}^{-1}$  as basal; ZnSO<sub>4</sub>—25  $\text{kg}\cdot\text{ha}^{-1}$ ; spraying of Pulse Wonder @ 5  $\text{kg}\cdot\text{ha}^{-1}$  at 50% flowering and spraying of PPFM—2% at one week after flowering).

## 2.4. Observations

### 2.4.1. Dry Matter Production

Five plants plot<sup>-1</sup> at random were collected from the sampling rows of each plot by pulling out the plants. Plants were air dried and then oven dried at  $65^\circ\text{C} \pm 5^\circ\text{C}$  till a constant weight was obtained. The weight was recorded using an electronic top pan balance and expressed in  $\text{kg}\cdot\text{ha}^{-1}$ .

### 2.4.2. Number of Pod Clusters Plant<sup>-1</sup>

The numbers of pod clusters from the tagged plants were counted and the mean value number plant<sup>-1</sup> was recorded.

### 2.4.3. Number of Pods Plant<sup>-1</sup>

The number of pods per plant was counted from five tagged plants and mean number of pods plant<sup>-1</sup> was recorded.

### 2.4.4. Number of Seeds Pod<sup>-1</sup>

Number of seeds was counted from ten pods randomly selected from the five tagged plants in each net plot and the mean number of seeds pod<sup>-1</sup> was worked out.

### 2.4.5. Grain Yield

For determining grain yield, all the pods were harvested separately and threshed manually by beating with sticks, cleaned and dried to 12 per cent moisture level and the grain yield from net plot was calculated and expressed in  $\text{kg}\cdot\text{ha}^{-1}$ .

### 2.4.6. Haulm Yield

The haulms from net plot after final picking of pods were cut at ground level dried and the weight of haulms recorded in  $\text{kg}\cdot\text{ha}^{-1}$ .

### 2.4.7. Harvest Index

The harvest index was calculated with the help of the following formula given by [6].

$$\text{Harvest index} = \frac{\text{Economic yield (kg}\cdot\text{ha}^{-1})}{\text{Biological yield (kg}\cdot\text{ha}^{-1})}$$

## 2.5. Statistical Analysis

The observed data on crop were statistically analysed by following procedure for randomised block design. Critical differences were worked out at five per cent probability level, wherever the treatments were significant. The treatment differences that were non-significant at five per cent were denoted as NS [7].

## 3. Results and Discussion

### 3.1. Dry Matter Production

The dry matter production is the most important parameters to assess the crop growth and productivity. Dry matter production showed a rapid increase from 30 DAS to harvest. Wider plant spacing of 30 × 30 cm, application of RDF, 12.5 t of FYM and 25 kg of ZnSO<sub>4</sub> as basal and spraying of 1% KNO<sub>3</sub> at 50 per cent flowering (T<sub>10</sub>) was found to accumulate more dry matter and it was on par with the treatment comprising of 30 × 30 cm plant spacing, application of RDF, 12.5 t of FYM and 25 kg of ZnSO<sub>4</sub> as basal (T<sub>9</sub>) at all the observed stages of crop growth (Table 1). This might be due to better utilization of available growth resources viz., nutrient, moisture and solar radiation to a greater extent and accumulation of photosynthates and application of fertilizer enhanced the nitrogen level in soil and microbial activity and this was reflected in total dry weight of the plants. Spraying of 1% KNO<sub>3</sub> facilitated the nutrients availability to the crops even during the flowering period was given by [8].

### 3.2. Yield Attributes

The treatment comprising of 30 × 30 cm plant spacing, application of RDF, 12.5 t of FYM and 25 kg of ZnSO<sub>4</sub> as basal and foliar spraying of 1% KNO<sub>3</sub> at 50 per cent flowering (T<sub>10</sub>) was produced more number of pod clusters plant<sup>-1</sup>, pods plant<sup>-1</sup> and seeds pod<sup>-1</sup> (Table 1) and it was statistically on par with 30 × 30 cm plant spacing,

**Table 1.** Effect of planting geometry, soil and foliar nutrition on dry matter production (kg·ha<sup>-1</sup>) and yield parameters of irrigated greengram.

Treatments		Dry matter (kg·ha <sup>-1</sup> )	Number of pod cluster plant <sup>-1</sup>	Number of pods plant <sup>-1</sup>	Number of seeds pod <sup>-1</sup>
<b>a. Spacing 25 × 25 cm</b>					
T <sub>1</sub> :	STCR based fertilizer application	1581	6.00	35.2	11.13
T <sub>2</sub> :	STCR based fertilizer application + ZnSO <sub>4</sub> + Pulse Wonder	1689	6.35	36.5	11.21
T <sub>3</sub> :	STCR based fertilizer application + ZnSO <sub>4</sub> + Pulse Wonder + PPFM spray	1927	7.00	41.4	12.41
T <sub>4</sub> :	RDF + FYM + ZnSO <sub>4</sub>	2025	7.43	41.7	12.43
T <sub>5</sub> :	RDF + FYM + ZnSO <sub>4</sub> + 1% KNO <sub>3</sub>	2167	7.67	42.8	12.47
<b>b. Spacing 30 × 30 cm</b>					
T <sub>6</sub> :	STCR based fertilizer application	1667	7.00	39.1	12.29
T <sub>7</sub> :	STCR based fertilizer application + ZnSO <sub>4</sub> + Pulse Wonder	1915	7.25	40.9	12.40
T <sub>8</sub> :	STCR based fertilizer application + ZnSO <sub>4</sub> + Pulse Wonder + PPFM spray	2362	8.32	52.8	12.85
T <sub>9</sub> :	RDF + FYM + ZnSO <sub>4</sub>	2605	9.41	52.9	12.97
T <sub>10</sub> :	RDF + FYM + ZnSO <sub>4</sub> + 1% KNO <sub>3</sub>	2865	10.34	53.4	13.23
<b>c. Spacing 30 × 10 cm</b>					
T <sub>11</sub> :	RDF + FYM + ZnSO <sub>4</sub>	1435	5.33	23.5	9.40
<b>SEd</b>		<b>70</b>	<b>0.49</b>	<b>1.7</b>	<b>0.29</b>
<b>CD (P = 0.05)</b>		<b>146</b>	<b>1.02</b>	<b>3.5</b>	<b>0.61</b>

application of RDF, 12.5 t of FYM and 25 kg of ZnSO<sub>4</sub> as basal (T<sub>9</sub>). The increase in yield attributes at wider planting geometry (30 × 30 cm) might be due to better crop growth, resulted by utilization of more sunlight, soil nutrients and water [9]. Soil application of FYM along with RDF could have provided the ideal soil health by supplying all plant essential nutrients for plants for increased photosynthesis and enhanced the translocation of the photosynthates which accumulated more dry matter in plants. The better translocation of the accumulated photosynthates resulted in crop with more number of yield contributing characters. Further, addition of ZnSO<sub>4</sub> could have increased the availability of micronutrients in soil as well as increased the rate of photosynthesis and along with spraying of 1% KNO<sub>3</sub> supplement the plant nutrients at the critical stage reduced the moisture stress in plants. Thaloath *et al.* (2006) [10] reported that foliar application of potassium is essential in maintenance of osmotic potential and water uptake and had a positive impact on stomatal closure which increases tolerance to water stress. The treatment comprising of 30 × 10 cm plant spacing, application of RDF, 12.5 t of FYM and 25 kg of ZnSO<sub>4</sub> as basal (T<sub>11</sub>) had recorded the lowest number of yield parameters.

### 3.3. Grain Yield

Adoption of plant spacing of 30 × 30 cm with application of RDF, FYM and ZnSO<sub>4</sub> as basal and foliar spraying of 1% KNO<sub>3</sub> at 50 per cent flowering (T<sub>10</sub>) resulted in higher grain yield of 1775 kg·ha<sup>-1</sup>, haulm yield of 2920 kg·ha<sup>-1</sup> and harvest index of 0.38 in irrigated greengram (Table 2). Hussain *et al.* (2008) [11] stated that, increase in yield at wider planting geometry might be due to better crop growth rate and lesser competition for resources between plants for water and soil nutrients led to produce more pods in greengram. The application of recommended dose of fertilizers which would have increased the soil fertility and favoured for better nutrient supply during early establishment stages which resulted in better plant growth, DMP and nutrient uptake, which attributed positive influence on the yield attributes of the greengram and eventually in the yield. Seed yield is mainly dependent on source sink relationship was given by [12].

Positive influence of wider spacing and nutrient application methods on various plant growth characters *viz.*, plant height, leaf area and total dry matter production eventually resulted in higher seed yield.

Farm yard manure act as nutrient reservoir and upon decomposition produces organic acids, thereby absorbed

**Table 2.** Effect of planting geometry, soil and foliar nutrition on grain yield (kg·ha<sup>-1</sup>) and economics of irrigated greengram.

Treatments	Grain yield (kg·ha <sup>-1</sup> )	Harvest index	Net return (Rs·ha <sup>-1</sup> )	B:C ratio
<b>a. Spacing 25 × 25 cm</b>				
T <sub>1</sub> : STCR based fertilizer application	1161	0.37	34,492	2.16
T <sub>2</sub> : STCR based fertilizer application + ZnSO <sub>4</sub> + Pulse Wonder	1219	0.37	35,618	2.12
T <sub>3</sub> : STCR based fertilizer application + ZnSO <sub>4</sub> + Pulse Wonder + PPFM spray	1409	0.37	45177	2.37
T <sub>4</sub> : RDF + FYM + ZnSO <sub>4</sub>	1428	0.37	40,054	2.02
T <sub>5</sub> : RDF + FYM + ZnSO <sub>4</sub> + 1% KNO <sub>3</sub>	1488	0.36	41,718	2.02
<b>b. Spacing 30 × 30 cm</b>				
T <sub>6</sub> : STCR based fertilizer application	1224	0.37	38,208	2.29
T <sub>7</sub> : STCR based fertilizer application + ZnSO <sub>4</sub> + Pulse Wonder	1385	0.36	45,066	2.42
T <sub>8</sub> : STCR based fertilizer application + ZnSO <sub>4</sub> + Pulse Wonder + PPFM spray	1586	0.36	55,224	2.39
T <sub>9</sub> : RDF + FYM + ZnSO <sub>4</sub>	1689	0.37	54,735	2.41
T <sub>10</sub> : RDF + FYM + ZnSO <sub>4</sub> + 1% KNO <sub>3</sub>	1775	0.38	57,806	2.43
<b>c. Spacing 30 × 10 cm</b>				
T <sub>11</sub> : RDF + FYM + ZnSO <sub>4</sub>	1053	0.35	18,773	1.47
<b>SEd</b>	<b>72</b>	-	-	-
<b>CD (P = 0.05)</b>	<b>150</b>	-	-	-

ions are released slowly during entire growth period leading to higher seed yield and yield components in greengram [13]. Some of plant nutrients when added to the soil in the inorganic form have low efficiency as compared with the effect of same nutrients applied along with organic manures. Thus, organic manures favoured for increased efficiency of applied nutrients and also helped to solve the problem of micronutrients deficiency in soil which have important role in producing higher grain yield [14].

Moreover, application of  $ZnSO_4$  could have enhanced the plant nutrition increases the assimilate production and photosynthesis efficiency at seed filling stage which leads to 41% of higher yield when compared to control. Further, spraying of 1%  $KNO_3$  met the nutrient demand of the crop at the critical stage, would have resulted in better crop growth and development and ultimately the yield attributing characters and yield. The balanced supply of nutrients could have induced more flower and fruiting bodies production and moreover, reduction in flower shedding due to foliar spray [15].

The treatment comprising of  $30 \times 10$  cm plant spacing, application of RDF, 12.5 t of FYM and 25 kg of  $ZnSO_4$  as basal ( $T_{11}$ ) recorded the lowest grain yield of  $1053 \text{ kg}\cdot\text{ha}^{-1}$ . This may be due to more competition for resources between plants for water and soil nutrients led to produce lesser yield. The recommended dose of fertilizer treatments recorded higher yield as compared to STCR based fertilizer application treatments.

Highest harvest index of 0.38 was registered in the treatment comprising of  $30 \times 30$  cm plant spacing, application of RDF, 12.5 t of FYM and 25 kg of  $ZnSO_4$  as basal and foliar spraying of 1%  $KNO_3$  at 50 per cent flowering ( $T_{10}$ ). The lowest harvest index (0.35) was registered in the treatment comprising of  $30 \times 10$  cm plant spacing, application of RDF, 12.5 t of FYM and 25 kg of  $ZnSO_4$  as basal ( $T_{11}$ ).

#### 4. Economic Analysis

The economic indicators of various treatments were worked out based on the yield data and including other input costs. Among the different treatments combination, sowing the irrigated greengram at  $30 \times 30$  cm plant spacing, application of RDF, 12.5 t of FYM and 25 kg of  $ZnSO_4$  as basal and foliar spraying of 1%  $KNO_3$  at 50 per cent flowering ( $T_{10}$ ) recorded the highest net return ( $57,806 \text{ Rs}\cdot\text{ha}^{-1}$ ) and Benefit Cost ratio (2.43) (Table 2). This was due to full utilization of organic and inorganic nutrients and foliar spray of 1%  $KNO_3$  was increased the grain and haulm yield of irrigated greengram.

#### 5. Conclusion

Based on the present findings, it is recommended that combined of  $30 \times 30$  cm plant spacing, application of RDF, 12.5 t of FYM and 25 kg  $ZnSO_4$  as basal and foliar spraying of 1%  $KNO_3$  at 50 per cent flowering enhances the grain yield of irrigated greengram resulting higher economic returns.

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