Growth and Development Analysis of Clusterbean \([Cyamopsis\ tetragonoloba\ (L.)\ taub.]\) Genotypes (gum) as Influenced by Plant Density and Bio-Inoculants

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Abstract

The field experiment was conducted under rainfed condition during late Kharif season of 2014 at Agriculture Research Station Annigeri, University of Agricultural Sciences, Dharwad to study the Response of Clusterbean genotypes (gum) to plant density and bio-inoculants. The experimental field was laid out in split-split plot design with three replications. On the basis of results obtained from present investigation Gaurishankar – 9, genotype recorded higher absolute growth rate, leaf area ratio and specific leaf area. HG-365 recorded higher leaf weight ratio. Spacing level of 45 × 15 cm recorded higher absolute growth rate, relative growth rate, leaf area ratio. Spacing level of 30 × 10 cm recorded higher crop growth rate and specific leaf weight. Application of \(Bradyrizhobium\ +\ PSB\ +\ AM\ fungi\) recorded higher absolute growth rate, relative growth rate and crop growth rate.

Keywords

AM fungi, \(Bradyrizhobium\), Gum, Specific leaf area, PSB.

Introduction

Clusterbean \([Cyamopsis\ tetragonoloba\ (L.)\ Taub]\) or Guar is a drought tolerant legume and grown mainly kharif season in arid and semi-arid region of tropical India. Multiple uses of the clusterbean make it as an important component of cropping systems of the region. Of late, it has acquired the status of industrial crop because of high glactomanan content in the endosperm of its seed, which has multiple industrial uses and thus a main foreign exchange earner for the area (Rathore et al., 2007). Clusterbean seed is used as a concentrate for animals and for extraction of gum. Seeds of clusterbean contain 22–33% gum (Choudhary et al., 2014). The gum has its use in several industries, \(viz.\) textiles, paper, petroleum, pharmaceuticals, food processing, cosmetics, mining explosives and oil drilling. In India it is cultivated over an area of 51.51 lakh ha with the production of 24.60 lakh tonnes with an average yield of 478.0 kg per ha (Anon., 2013). India is the leading producer of guar and guar gum in the world and its share is around 80 per cent world production. Bio fertilizers play important role in maintaining the long term soil fertility and sustainability. It may increase yield of crops by 10-30
percent (Khandelwal et al., 2012). Recent investigations, in the cultivation of gum guar have demonstrated commercial possibilities of growing guar under rainfed conditions. This has opened up possibilities of growing new cash crops in the region, although it is yet to find acceptance as a part of the cropping system of northern dry zone of Karnataka, but no systematic work has been conducted on this aspect.

The research information on cultivable aspects is lacking and also performance of different genotypes and spacing levels, hence, there is a need to study the response of clusterbean genotypes (gum purpose) to plant density and bio-inoculants.

**Materials and Methods**

The experiment was conducted at Agricultural Research Station, Annigeri, UAS Dharwad during the late kharif seasons of 2014. The soil was clay having initial soil pH of 7.9 and organic carbon 0.49 % and available N, P and K of 220, 21.87 and 462 kg ha$^{-1}$ respectively. The field was prepared by employing one deep ploughing. The average rainfall of area was 665.9 mm but during 2014 a rainfall of 771.0 mm was received. The experiment was laid out in split –split plot design 3 replications.

Two genotypes (HG- 365 and Gaurishankar - 9), two spacings levels of (30 x 10 cm and 45 x 15 cm) were allotted to main plot, sub plot and four treatments of Bio inoculants (Bradyrhizobium. PSB, AM fungi and Bradyrhizobium + PSB +AM fungi) were allotted to sub sub plot randomly. The crop was sown on 15 July and harvested on 17 November. Seeds of cluster bean were treated with biofertilizers, Bradyrhizobium + PSB @ 750 g ha$^{-1}$ and AM fungi applied at rate of 50 kg ha$^{-1}$. Five random plants were selected from each plot, excluding the border row, for taking observations. Five plants were separated into leaf, stem and reproductive parts and dried in an oven at 70°C until a constant weight is obtained. Total dry matter was calculated by adding the dry weights of different plant parts and expressed as grams per plant.

### Absolute growth rate

Absolute growth rate (AGR) was calculated by using the formula proposed by Radford (1967) and expressed in gram per day per plant (g day$^{-1}$ plant$^{-1}$).

$$\text{AGR} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

- $W_2$ and $W_1$ = Dry weight of whole plant (g) at time $t_2$ and $t_1$ respectively.
- $t_2$ and $t_1$ = Time intervals (days).

### Crop growth rate

Crop growth rate (CGR) is defined as the rate of dry matter produced per unit land area per unit time. It is worked out by the formula proposed by Watson (1952) and expressed as g per cm$^2$ per day.

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times P$$

Where,

- $W_2$ and $W_1$ = Dry weight of whole plant (mg) at time $t_2$ and $t_1$ respectively.
- $t_2$ and $t_1$ = Time intervals (days).
- $P$ = Land area (cm$^2$).
Relative growth rate

Relative growth rate (RGR) is the rate of increase in dry weight per unit dry weight of the plant per unit time and expressed as g per g per day (g g\(^{-1}\) day\(^{-1}\)). It was calculated by the following formula proposed by Radford (1967).

\[
\text{RGR} = \frac{\log W2 - \log W1}{t2 - t1}
\]

Where,

\(W2\) and \(W1\) = Dry weight of whole plant (mg) at time \(t2\) and \(t1\) respectively.
\(t2\) and \(t1\) = Time intervals (days).
\(\log\) = Logarithm to base “e”.

Specific leaf area (SLA)

Specific leaf area is the ratio of leaf area to leaf mass. It is a measure of relative spread of leaf. It is expressed in cm\(^2\)/g.

\[
\text{SLA} = \frac{\text{Leaf area}}{\text{Leaf dry weight}}
\]

Specific leaf weight (SLW)

The specific leaf weight is the ratio of leaf dry weight to leaf area. It indicates the leaf thickness and density and expressed as g /cm\(^2\).

\[
\text{SLW} = \frac{\text{Leaf dry weight}}{\text{Leaf area}}
\]

Leaf area ratio (LAR)

Leaf area ratio is the ratio of leaf area to total plant biomass. It is a measure of leafiness or photosynthetic surface relative to respiratory mass. It is expressed in (cm\(^2\)/g)

\[
\text{LAR} = \frac{\text{Leaf area of plant}}{\text{Total dry weight of plant}}
\]

Leaf weight ratio (LWR)

Leaf weight ratio is the ratio of mass of leaf to total dry mass of plant. It measure of allocation of leaf biomass

\[
\text{LWR} = \frac{\text{Mass of leaf}}{\text{Total mass of plant}}
\]

Results and Discussion

Absolute growth rate (AGR) of clusterbean, genotypes was found significant at 30-60 DAS (Table 1). Gaurishankar - 9 recorded significantly higher AGR compared to the genotype HG – 365. At 30-60 DA, a spacing of 45 × 15 cm (0.57 g day\(^{-1}\) plant\(^{-1}\)) recorded significantly higher AGR when compared to at spacing of 30 × 10 cm. At 30 DAS application of *Bradyrhizobium* + PSB + AM fungi recorded significantly higher AGR (0.59 g plant\(^{-1}\)) when compared to other
treatments. Relative growth rate (RGR) of clusterbean, genotypes was found significant at 30-60 DAS, a spacing level of 45 × 15 cm (0.026 g g⁻¹ day⁻¹) recorded significantly higher RGR when compared to at spacing of 30 × 10 cm (0.024 g g⁻¹ day⁻¹). Crop growth rate (CGR) of clusterbean at 30-60 DAS a spacing level of 30 × 10 cm (0.0081 g cm⁻² day⁻¹) compared to at spacing of 45 × 15 cm (0.0039 g cm⁻² day⁻¹).

Leaf area ratio of clusterbean, genotypes was found significant at 90DAS, HG – 365 (18.88 cm² g⁻¹) recorded significantly higher leaf area ratio compared to the genotype Gaurishankar - 9 (16.23 cm² g⁻¹). Leaf weight ratio of clusterbean, genotypes was found significant at 90DAS, Gaurishankar - 9 (0.294 cm² g⁻¹) recorded significantly higher leaf weight ratio compared to the genotype HG – 365 (0.260 cm² g⁻¹).

**Table 1.** Absolute growth rate, relative growth rate and crop growth rate at different growth stages of cluster genotypes (gum) as influenced by plant density and bio-inoculants

| Treatments | AGR 30-60DAS | AGR 60-90DAS | AGR 90DAS Harvest | RGR 30-60DAS | RGR 60-90DAS | RGR 90DAS Harvest | CGR 30-60DAS | CGR 60-90DAS | CGR 90Harvest |
|------------|-------------|-------------|------------------|-------------|-------------|------------------|-------------|-------------|---------------|
| **Genotype** |             |             |                  |             |             |                  |             |             |               |
| HG-365     | 0.44b       | 0.11a       | 0.12a            | 0.025a      | 0.0028a     | 0.0026a          | 0.0058a     | 0.006a      | 0.007a        |
| Gaurishankar-9 | 0.59a     | 0.10a       | 0.12a            | 0.026a      | 0.0020a     | 0.0020a          | 0.0061a     | 0.005a      | 0.005b        |
| S. Em±      | 0.02        | 0.02        | 0.02             | 0.0001      | 0.0004      | 0.0005           | 0.0003      | 0.0002      | 0.0001        |
| **Spacing** |             |             |                  |             |             |                  |             |             |               |
| 30 x 10 cm | 0.46b       | 0.11a       | 0.12a            | 0.024b      | 0.0026a     | 0.0026a          | 0.0081a     | 0.007a      | 0.009a        |
| 45x 15 cm  | 0.57a       | 0.11a       | 0.12a            | 0.026a      | 0.0023a     | 0.0021a          | 0.0039b     | 0.003b      | 0.003b        |
| S. Em±      | 0.02        | 0.02        | 0.65             | 0.0001      | 0.0005      | 0.0005           | 0.0002      | 0.0001      | 0.0001        |
| **Bio inoculants** |       |             |                  |             |             |                  |             |             |               |
| Bradyrhizobium | 0.52b     | 0.10a       | 21.87a           | 0.025a      | 0.0023a     | 0.0023a          | 0.0059a     | 0.005a      | 0.006a        |
| PSB         | 0.48b       | 0.11a       | 20.64a           | 0.025a      | 0.0027a     | 0.0028a          | 0.0059a     | 0.006a      | 0.007a        |
| AM fungi    | 0.46b       | 0.11a       | 19.98a           | 0.024a      | 0.0027a     | 0.0022a          | 0.0057a     | 0.007a      | 0.006a        |
| Bradyrhizobium + PSB + AM fungi | 0.59a | 0.10a | 24.19a | 0.026a | 0.0020a | 0.0019a | 0.0063a | 0.004a | 0.005a |
| S. Em±      | 0.02        | 0.02        | 0.65             | 0.0001      | 0.0005      | 0.0005           | 0.0002      | 0.0001      | 0.0001        |

**Table 2.** Specific leaf area and specific leaf weight at different growth stages of cluster genotypes (gum) as influenced by plant density and bio-inoculants

| Treatments | Specific leaf area (cm²/g) at 30 DAS | Specific leaf area (cm²/g) at 60 DAS | Specific leaf area (cm²/g) at 90 DAS | Specific leaf weight (g /cm²) at Harvest | Specific leaf weight (g /cm²) at 30 DAS | Specific leaf weight (g /cm²) at 60 DAS | Specific leaf weight (g /cm²) at 90 DAS | Specific leaf weight (g /cm²) at harvest |
|------------|-------------------------------------|-------------------------------------|-------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
| **Genotype** |                                     |                                     |                                     |                                        |                                        |                                        |                                        |                                        |
| HG-365     | 94.89b                              | 85.07a                              | 66.74a                              | 85.99b                                 | 0.0107a                                | 0.0120a                                | 0.0164a                                | 0.0119a                                |
| Gaurishankar-9 | 102.59a   | 87.02a                              | 65.35b                              | 96.61a                                 | 0.0100b                                | 0.0117a                                | 0.0157b                                | 0.0107b                                |
| S. Em±      | 4.89                                | 3.97                                | 1.23                                | 1.19                                   | 0.0005                                 | 0.0005                                 | 0.0001                                 | 0.0001                                 |
| **Spacing** |                                     |                                     |                                     |                                        |                                        |                                        |                                        |                                        |
| 30 x 10 cm | 95.82b                              | 83.83b                              | 65.83a                              | 87.85b                                 | 0.0107a                                | 0.0121a                                | 0.0163a                                | 0.0117a                                |
| 45x 15 cm  | 101.67a                             | 88.27a                              | 66.26a                              | 94.75a                                 | 0.0100b                                | 0.0116b                                | 0.0159b                                | 0.0109b                                |
| S. Em±      | 3.04                                | 1.37                                | 1.43                                | 2.48                                   | 0.0003                                 | 0.0002                                 | 0.0003                                 | 0.0003                                 |
| **Bio inoculants** |                            |                                     |                                     |                                        |                                        |                                        |                                        |                                        |
| Bradyrhizobium | 94.32a     | 86.09a                              | 68.58a                              | 92.76ab                                 | 0.0107a                                | 0.0118a                                | 0.0159a                                | 0.0110ab                               |
| PSB         | 97.66a                             | 84.00a                              | 62.24a                              | 83.63b                                 | 0.0104ab                                | 0.0124a                                | 0.0163a                                | 0.0123a                                |
| AM fungi    | 106.48a                            | 87.15a                              | 68.79a                              | 87.45b                                 | 0.0097a                                | 0.0116a                                | 0.0155a                                | 0.0116ab                               |
| Bradyrhizobium + PSB + AM fungi | 96.50a | 86.95a | 64.58a | 101.36a | 0.0108a | 0.0117a | 0.0167a | 0.0103b |
| S. Em±      | 4.99                                | 3.44                                | 4.11                                | 4.13                                   | 0.0005                                 | 0.0005                                 | 0.0009                                 | 0.0006                                |

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Table 3: Leaf area ratio and leaf weight ratio at different growth stages of cluster genotypes (gum) as influenced by plant density and bio-inoculants

| Treatments          | Leaf area ratio cm² / g at 30 DAS | Leaf area ratio cm² / g at 60 DAS | Leaf area ratio cm² / g at 90 DAS | Leaf area ratio cm² / g at Harvest | Leaf weight ratio (g/plant) at 30 DAS | Leaf weight ratio (g/plant) at 60 DAS | Leaf weight ratio (g/plant) at 90 DAS | Leaf weight ratio (g/plant) at Harvest |
|---------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Genotype            | HG-365                            | 30 x 10 cm                        | 45 x 15 cm                        | HG                              | 54.09a                               | 32.33a                               | 16.23b                               | 3.65a                               | 0.571a                               | 0.381a                               | 0.260a                               | 0.043a                               |
|                     | Gaurishankar-9                    | 54.10a                            | 31.85a                            | 18.88a                           | 3.82a                               | 0.531a                               | 0.368a                               | 0.294b                               | 0.040a                               |
| S. Em±              | 4.52                              | 1.68                              | 0.21                              | 0.10                             | 0.019                               | 0.021                               | 0.003                               | 0.001                               |
| Spacing             | 30 x 10 cm                        | 52.31b                            | 32.40a                            | 17.42a                           | 3.71a                               | 0.549a                               | 0.387a                               | 0.274a                               | 0.042a                               |
|                     | 45 x 15 cm                        | 55.88a                            | 31.78a                            | 17.69a                           | 3.76a                               | 0.552a                               | 0.363a                               | 0.280a                               | 0.040a                               |
| S. Em±              | 1.58                              | 1.77                              | 0.48                              | 0.10                             | 0.004                               | 0.015                               | 0.011                               | 0.001                               |
| Bio inoculants      | Bradyrhizobium                    | 53.13a                            | 32.87a                            | 18.24a                           | 3.70a                               | 0.563a                               | 0.381a                               | 0.284ab                              | 0.040b                               |
|                     | PSB                               | 53.70a                            | 30.70a                            | 16.76a                           | 3.78a                               | 0.550a                               | 0.371a                               | 0.269ab                              | 0.045a                               |
|                     | AM fungi                          | 56.11a                            | 31.55a                            | 16.95a                           | 3.62a                               | 0.531a                               | 0.363a                               | 0.254b                               | 0.042ab                               |
|                     | Bradyrhizobium + PSB + AM fungi   | 53.43a                            | 33.24a                            | 18.27a                           | 3.84a                               | 0.558a                               | 0.384a                               | 0.301a                               | 0.039b                               |
| S. Em±              | 2.27                              | 1.22                              | 0.93                              | 0.17                             | 0.013                               | 0.011                               | 0.012                               | 0.001                               |

Specific leaf area of clusterbean, genotypes was found significant at 30DAS, Gaurishankar - 9 (102.59 cm² g⁻¹) recorded significantly higher specific leaf area compared to the genotype HG – 365 (94.89 cm² g⁻¹), a spacing of 45 x 15 cm (101.67 cm² g⁻¹) recorded significantly higher specific leaf area when compared to at spacing of 30 x 10 cm (95.82 cm² g⁻¹). At the time of harvest Gaurishankar - 9 (96.61 cm² g⁻¹) recorded significantly higher leaf specific area compared to the genotype HG – 365 (85.99 cm² g⁻¹), a spacing of 45 x 15 cm (94.75 cm² g⁻¹) recorded significantly higher leaf specific area when compared to at spacing of 30 x 10 cm (87.85 cm² g⁻¹). Application of Bradyrhizobium + PSB + AM fungi recorded significantly higher specific leaf area (101.36 cm² g⁻¹) when compared to other treatments at the time of harvest. Specific leaf weight of clusterbean, HG – 365 (0.0107 g cm⁻²) genotypes was found significant at 30DAS, recorded significantly higher specific leaf area compared to the genotype Gaurishankar - 9 (0.0100 g cm⁻²), a spacing of 30 x 10 cm (94.75 g cm⁻²) recorded significantly higher specific leaf weight when compared to at spacing of 45 x 15 cm (87.85 g cm⁻²). At 90 DAS Specific leaf weight of clusterbean, HG – 365 (0.0164 g cm⁻²) genotypes was found significant recorded significantly higher specific leaf weight compared to the genotype Gaurishankar - 9 (0.0157 g cm⁻²), a spacing of 30 x 10 cm (0.0163 g cm⁻²) recorded significantly higher specific leaf weight when compared to spacing level of 45 x 15 cm (0.0159 g cm⁻²). At the time of harvest, HG – 365 (0.0107 g cm⁻²) genotypes was found significant and recorded higher specific leaf weight compared to the genotype Gaurishankar - 9 (0.0100 g cm⁻²), a spacing of 30 x 10 cm (94.75 g cm⁻²) recorded significantly higher specific leaf weight when compared to at spacing of 45 x 15 cm (87.85 g cm⁻²) (Tables 2 and 3).
genotype recorded higher specific leaf weight at different growth stages. The spacing level of 30 × 10 cm recorded significantly higher specific leaf weight at different growth stages.

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