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Dry matter Production and Partitioning of Cluster Bean (*Cyamopsis tetragonaloba* (L). taub.) Genotypes (Gum) as Influenced by Plant Density and Bio-Inoculants

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A B S T R A C T

The field experiment was conducted under rainfed condition during late *Kharif* season of 2014 at Agriculture Resaearch 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 parameters like, total dry matter production per plant, dry matter accumulation in different parts of plant, leaf area and leaf area duration at different growth stages recorded higher with genotype gaurishankar-9 as compared to HG-365. Spacing level of 45 × 15 cm recorded higher total dry matter production per plant, dry matter accumulation in different parts of plant, leaf area and leaf area duration at different growth stages. Application of *Bradyrizhobium* + PSB + AM fungi recorded higher total dry matter production per plant and leaf area.

Introduction

Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] 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 contains 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, 21.87and 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.

Leaf area (cm^2 plant^{-1})

The leaf area was worked out by disc method on dry weight basis at 30, 60, 90 DAS and at harvest as per the procedure suggested by Vivekanandan *et al.*, (1972).

$$LA = \frac{Wa \times A}{Wd}$$

Where,

LA = Leaf area (cm^2 plant^{-1})

Wa = Oven dry weight of all leaves (inclusive of 10 disc weight)

Wd = Oven dry weight of 10 discs in gram,

A = Area of the 10 discs (cm^2)

Leaf area index (LAI)

It is defined as an assimilatory surface per unit area of land. Leaf area index was worked out by dividing the leaf area per plant by land area occupied by the plant (Sestak *et al.*, 1971).

$$LAI = \frac{\text{Leaf area per plant}}{\text{Land area occupied by the plant}}$$

Leaf area duration (LAD)

Leaf area duration is the integral of leaf area index over a growth period (Watson, 1952). LAD for various growth periods was worked

out as per the formula of Power *et al.*, (1967) and expressed in days.

$$LAD = \frac{(L_1 + L_2)}{2} \times (t_2 - t_1)$$

Where,

L_1 = LAI at time t_1, L_2= LAI at time t_2, $t_2 - t_1$= Time interval in days

The data recorded on various parameters were subjected to Fisher's method of analysis of variance and interpretation of the data as given by Gomez and Gomez (1984).The level of significance used in 'F' and 't' test was P = 0.05. Critical difference (CD) values were calculated where the 'F' test was found significant. In case of non-significant effects, values of standard error of means alone were presented in Tables. The mean value of sub sub plot and interaction were separately subjected to Ducan's multiple range test (DMRT) using the corresponding error mean sum of squares and degrees of freedom values.

Results and Discussion

Total dry matter production of clusterbean, genotypes was found significant at all growth stages except at 30 DAS (Table: 1). Gaurishankar - 9 recorded significantly higher total dry matter production at 60 (21.12 g plant^{-1}), 90 DAS (23.99 g plant^{-1}) and at harvest (26.18g plant^{-1}) when compared to the genotype HG – 365. At 60, 90 DAS and at harvest, at spacing of 45 × 15 cm recorded significantly higher total dry matter production (20.30, 23.37 and 27.06 g plant^{-1} respectively) when compared to at spacing of 30 × 10 cm (17.10, 19.97 and 23.18 g plant^{-1} respectively). At 30 DAS, *Bradyrhizobium* + PSB + AM fungi recorded significantly higher total dry matter production (3.47 g plant^{-1}) and was found on par with *Bradyrhizobium* and PSB alone (3.33 and 3.47 g plant^{-1} respectively). At 60, 90 DAS and at harvest, *Bradyrhizobium* + PSB + AM fungi was recorded significantly higher total dry matter production (21.30, 24.19 and 27.06 g plant^{-1} respectively) when compared to other treatments. Differences in dry matter production were mainly because of various physiological factors specially photosynthetic capacity and reproductive phase. The photosynthetic activity of plants at various stages of crop growth can be assessed through leaf area, dry matter accumulation in leaves which in turn influence photosynthetic ability of plant and its performance finally on yield of any crop. The dry matter accumulated in leaves of Gaurishankar - 9 was 11.1, 20.7, 28.5 and 10 per cent higher at 30, 60, 90 DAS and at harvest respectively over HG - 365. Dry matter accumulation in leaves of clusterbean genotypes were found significant at all growth stages. The genotype, Gaurishankar - 9 recorded significantly higher dry matter accumulation in leaves at 30 (1.89g plant^{-1}), 60 (7.71 g plant^{-1}), 90 DAS (7.02 g plant^{-1}) and at harvest (1.05g plant^{-1}) compared to genotype HG – 365. Dry matter accumulation in leaves significantly varied due to spacing levels at 60 and 90 DAS. At 60 and 90 DAS, at spacing of 45 × 15 cm recorded significantly higher dry matter accumulation in leaves (7.30 and 6.54 g plant^{-1}respectively) compared to the spacing of 30 × 10 cm. Bio- inoculant treatments had significant influence on dry matter accumulation in leaves at 60 and 90 DAS. At 60 and 90 DAS, *Bradyrhizobium* + PSB + AM fungi was recorded significantly higher dry matter accumulation in leaves (8.07 and 7.25 g plant^{-1} respectively) over other treatments. Dry matter accumulation in the stem of clusterbean genotypes were found significant at all growth stages except at 30 DAS. Gaurishankar – 9 recorded significantly higher dry matter accumulation in the stem at

60 (7.23 g plant^{-1}), 90 DAS (7.86 g plant^{-1}) and at harvest (9.11 g plant^{-1}) compared to genotype HG - 365 (5.97, 6.68 and 7.72 g plant^{-1} respectively). The spacing had significant influence on dry matter accumulation in stem at all growth stages except at 30 DAS. At 60 and 90 DAS and harvest, at spacing of 45 × 15 cm was recorded significantly higher dry matter accumulation in stem (7.23, 7.94 and 9.06 g plant^{-1} respectively) compared to spacing of 30 × 10 cm. Bio- inoculant treatments had significant influence on dry matter accumulation in stem at 60, 90 DAS and at harvest and had non-significant effect on dry matter accumulation in stem at 30 DAS. At 60 DAS, *Bradyrhizobium* + PSB + AM fungi recorded significantly higher dry matter accumulation in stem (7.30 g plant^{-1}) when compared to other treatments.

At 90 DAS and at harvest *Bradyrhizobium* + PSB + AM fungi was recorded significantly higher dry matter accumulation in stem (7.88 and 9.05 g plant^{-1} respectively) and was found on par with *Bradyrhizobium* (7.26 and 8.42g plant^{-1} respectively). Gaurishankar - 9 recorded significantly higher dry matter accumulation in reproductive parts at 60 (6.17 g plant^{-1}), 90 DAS (9.11 g plant^{-1}) and at harvest (16.03 g plant^{-1}) compared to the genotype HG – 365. Dry matter accumulation in reproductive parts varied significantly due to influence of spacing treatments. At 60, 90 DAS and at harvest, spacing of 45 × 15 cm recorded significantly higher dry matter accumulation in reproductive parts at 60 (5.78 g plant^{-1}), 90 DAS (8.89 g plant^{-1}) and at harvest (15.56 g plant^{-1}) compared to spacing of 30 × 10 cm. Bio- inoculant treatments had significant effect on dry matter accumulation in reproductive parts at 60, 90 DAS and at harvest. At 60 DAS, *Bradyrhizobium* + PSB + AM fungus was recorded significantly higher dry matter accumulation in reproductive parts (5.93 g plant^{-1}) over other treatments. At 90 DAS, *Bradyrhizobium* + PSB + AM fungus was recorded significantly higher dry matter accumulation in reproductive parts (9.05 g plant^{-1}) over other treatments and this was on par with *Bradyrhizobium* (8.42 g plant^{-1}). At harvest *Bradyrhizobium* + PSB + AM fungus was recorded significantly higher dry matter accumulation in reproductive parts (16.97 g plant^{-1}) over other treatments. The higher dry matter accumulation might be due to higher leaf area, leaf area index and leaf area duration. Leaf area which is also an important part of the plant that determines the photosynthetic ability growth and dry matter production.

Leaf area of clusterbean varied significantly due to genotypes at all growth stages (Table: 3). The genotype, Gaurishankar - 9 recorded significantly higher leaf area at 30 (189.72 cm^2 plant^{-1}), 60 (670.38 cm ^{2} plant^{-1}), 90 DAS (448.19 cm ^{2} plant^{-1}) and at harvest (99.76 cm^2 plant^{-1}) compared to genotype HG - 365 (158.38, 517.49, 312.85 and 81.19 cm^2 plant^{-1} respectively). The spacing of 45 × 15 cm recorded significantly higher leaf area at 30 (184.61 cm^2 plant^{-1}), 60 (642.82 cm^2 plant^{-1}), 90 (412.65 cm^2 plant^{-1}) and at harvest (96.11cm^2 plant^{-1}) when compared to at spacing of 30 × 10 cm (163.49, 545.05, 348.38 and 84.85 cm^2 plant^{-1} respectively).

Bio-inoculant treatments had significant effect on leaf area at all growth stages except at 30 DAS. At 60, 90 DAS and at harvest *Bradyrhizobium* + PSB + AM fungi recorded significantly higher leaf area (704.28, 439.26 and 103.88 cm^2 plant^{-1} respectively) compared to other treatments. Between the genotypes of clusterbean, Gaurishankar - 9 recorded significantly higher leaf area index at 30 (0.44), 60 (1.55), 90 DAS (1.03) and at harvest (0.24) when compared to the genotype HG - 365 (0.37, 1.21, 0.69 and 0.19 respectively).

Table.1 Total dry matter accumulation per plant and dry matter accumulation in reproductive of clusterbean at different growth stages as influenced by genotypes, plant density and bio-inoculants

Treatments	Total dry matter production at 30 DAS	Total dry matter production at 60 DAS	Total dry matter production at 90 DAS	Total dry matter production at harvest	Dry matter accumulation in reproductive parts (60DAS)	Dry matter accumulation in reproductive parts (90DAS)	Dry matter accumulation in reproductive parts at harvest
Genotype							
HG-365	2.96a	16.28b	19.35b	22.65b	4.17b	7.64b	14.18b
Gaurishankar-9	3.57a	21.12a	23.99a	26.18a	6.17a	9.11a	16.03a
S. Em±	**0.16**	**0.51**	**0.76**	**0.53**	**0.19**	**0.18**	**0.23**
Spacing							
30 x 10 cm	3.20a	17.10b	19.97b	23.18b	4.56b	7.85b	14.65b
45x 15 cm	3.33a	20.30a	23.37a	25.65a	5.78a	8.89a	15.56a
S. Em±	**0.10**	**0.74**	**0.76**	**0.31**	**0.14**	**0.24**	**0.23**
Bio inoculants							
Bradyrhizobium	3.33ab	19.08b	21.87b	24.84b	5.28b	8.42ab	15.42b
PSB	3.19ab	17.60bc	20.64b	23.21c	4.93bc	8.13b	14.46b
AM fungi	3.07b	16.83c	19.98b	22.56c	4.53c	7.90b	13.56c
Bradyrhizobium + PSB + AM fungi	3.47a	21.30a	24.19a	27.06a	5.93a	9.05a	16.97a
S. Em±	**0.10**	**0.55**	**0.65**	**0.72**	**0.16**	**0.27**	**0.44**

Table.2 Dry matter accumulation in leaves and stem of clusterbean at different growth stages as influenced by genotypes, plant density and bio-inoculants

Treatments	Dry matter accumulation in leaves (30DAS)	Dry matter accumulation in leaves (60DAS)	Dry matter accumulation in leaves (90DAS)	Dry matter accumulation in leaves (Harvest)	Dry matter accumulation in stem (30DAS)	Dry matter accumulation in stem (60DAS)	Dry matter accumulation in stem (90DAS)	Dry matter accumulation in stem at harvest
Genotype								
HG-365	1.69b	6.14b	5.03b	0.95b	1.28a	5.97b	6.68b	7.72b
Gaurishankar-9	1.89a	7.71a	7.02a	1.05a	1.67a	7.23a	7.86a	9.11a
S. Em±	**0.03**	**0.20**	**0.14**	**0.01**	**0.13**	**0.11**	**0.01**	**0.07**
Spacing								
30 x 10 cm	1.74a	6.56b	5.51b	0.97a	1.45a	5.98b	6.60b	7.77b
45x 15 cm	1.84a	7.30a	6.54a	1.03a	1.50a	7.23a	7.94a	9.06a
S. Em±	**0.06**	**0.13**	**0.16**	**0.02**	**0.05**	**0.31**	**0.28**	**0.29**
Bio inoculants								
Bradyrhizobium	1.87a	7.21b	6.19b	0.99a	1.47a	6.59b	7.26b	8.42ab
PSB	1.75ab	6.37c	5.55c	1.04a	1.44a	6.29b	6.96b	8.13b
AM fungi	1.61ab	6.07c	5.10c	0.93a	1.46a	6.23b	6.98b	8.06b
Bradyrhizobium + PSB + AM fungi	1.93a	8.07a	7.25a	1.04a	1.54a	7.30a	7.88a	9.05a
S. Em±	**0.07**	**0.21**	**0.21**	1.03	**0.06**	**0.18**	**0.24**	**0.25**

Table.3 Leaf area, leaf area index and leaf area duration of clusterbean at different growth stages as influenced by genotypes, plant density and bio-inoculants

Treatments	Leaf area (30DAS)	Leaf area (60DAS)	Leaf area (90DAS)	Leaf area (Harvest)	Leaf area index (30DAS)	Leaf area index (60DAS)	Leaf area index (90DAS)	Leaf area index (Harvest)	Leaf area duration (30 - 60DAS)	Leaf area duration (60 - 90DAS)	Leaf area duration (90 DAS - Harvest)
Genotype											
HG-365	158.38b	517.49b	312.85b	81.19b	0.37b	1.21b	0.69b	0.19b	23.81b	28.57b	13.22b
Gaurishankar-9	189.72a	670.38a	448.19a	99.76a	0.44a	1.55a	1.03a	0.24a	29.88a	38.79a	19.08a
S. Em±	**5.01**	**17.09**	**8.45**	**1.62**	**0.01**	**0.05**	**0.02**	**0.004**	**0.73**	**1.61**	**0.32**
Spacing											
30 x 10 cm	163.49b	545.05b	348.38b	84.85b	0.54a	1.81a	1.12a	0.28a	35.30a	43.89a	21.01a
45x 15 cm	184.61a	642.82a	412.65a	96.11a	0.27b	0.95b	0.61b	0.14b	18.39b	23.48b	11.28b
S. Em±	**1.83**	**16.27**	**8.71**	**1.18**	**0.01**	**0.05**	**0.04**	**0.01**	**0.66**	**1.03**	**0.82**
Bio inoculants											
Bradyrhizobium	175.85a	620.94b	393.02b	91.48b	0.41a	1.47b	0.93a	0.22ab	28.27b	36.15a	17.17a
PSB	169.58a	526.54c	348.20c	84.99bc	0.40a	1.21c	0.76b	0.20bc	24.20c	29.62b	14.41b
AM fungi	170.10a	523.99c	341.60c	81.56c	0.40a	1.22c	0.75b	0.19c	24.31c	29.51b	14.05b
Bradyrhizobium + PSB + AM fungi	180.67a	704.28a	439.26a	103.88a	0.42a	1.62a	1.01a	0.24a	30.60a	39.45a	18.95a
S. Em±	**4.90**	**17.79**	**13.19**	**2.51**	**0.01**	**0.04**	**0.05**	**0.01**	**0.74**	**1.46**	**0.81**

The spacing of 30 × 10 cm realized significantly higher leaf area index at 30 (0.54), 60(1.81), 90 DAS (1.12) and at harvest (0.28) when compared to the spacing of 45 × 15 cm (0.27, 0.95, 0.61 and 0.14 respectively). Bio- inoculant treatments had significant effect on leaf area index at all growth stages except at 30 DAS. At 60 DAS and at harvest, *Bradyrhizobium* + PSB + AM fungi recorded significantly higher leaf area (1.62 and 0.24 respectively) when compared to other treatments. At 90 DAS, *Bradyrhizobium* + PSB + AM fungi recorded significantly higher leaf area (1.01) and was found on par with *Bradyrhizobium* alone (0.93) over other treatments. The LAI is often used as vital indicator of plant growth for evaluating assimilation, transpiration rates and is a major factor for determining the solar radiation interception, photosynthesis and therefore yield of clusterbean. Gaurishankar - 9 recorded higher LAI at all growth stages compared to HG - 365. Similarly, Gaurishankar - 9 realised higher LAD (29.8 days) during 30 - 60 DAS than HG - 365 (23.8 days). Total number of nodules and nodule dry weight recorded higher in case of genotype Gaurishankar - 9 (Guriqbal *et al.*, 2012 in urdbean).These indicated that genotype Gaurishankar - 9 produced higher dry matter as compared to HG – 365 (Table 22 and Fig. 6). Similar results of higher dry matter production were also reported by Ashwathanarayana (2014) in clusterbean and Madhu (2013) in mungbean.

Between the genotypes of clusterbean, Gaurishankar - 9 recorded significantly higher leaf area duration 30- 60 DAS (29.88 days), 60- 90 DAS (38.79 days) and 90 - harvest (19.08 days) when compared to the genotype HG – 365. The spacing of 30 × 10 cm recorded significantly higher leaf area duration at 30- 60 DAS 35.30 days), 60- 90 DAS (43.89 days) and 90 - harvest (21.01 days) compared to a spacing of 45 × 15 cm. Bio- inoculant treatments had significant effect on leaf area duration at 30- 60 DAS, 60- 90 DAS and 90 - harvest. At 30- 60, *Bradyrhizobium* + PSB + AM fungi recorded significantly higher leaf area duration (30.60 days). At 60- 90 DAS *Bradyrhizobium* + PSB + AM fungi recorded significantly higher leaf area duration (39.45 days) and this was found on par with *Bradyrhizobium* alone (36.15 days). At 90 DAS - harvest, same trend was followed as that of 60 -90 DAS.

Gaurishankar - 9 recorded higher total dry matter production per plant, dry matter accumulation in different plant parts like leaves, stem and reproductive parts, leaf area and leaf

area duration at different growth stages. The spacing level of 45 × 15 cm higher total dry matter production per plant, dry matter accumulation in different plant parts like leaves, stem and reproductive parts, leaf area and leaf area duration at different growth stages compared to spacing level of 30 × 10 cm. Application *Bradyrizhobium* + PSB + AM fungi recorded higher total dry matter production per plant, dry matter accumulation in different plant parts like leaves, stem and reproductive parts, leaf area and leaf area duration at different growth stages of crop compared to the other treatments.

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