Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.2511

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (1):** 504-512 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Dry Matter Production, Photosyntheticaly Active Radiation and Radiation use Efficiency Response of Cluster Bean as Influenced by Genotypes and Planting Density

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Received: 25.01.2017 | Revised: 7.02.2017 | Accepted: 9.02.2017

ABSTRACT

A field experiment was conducted during kharif 2014 at ZAHRS, Shivamogga to examine the response of three cluster bean genotypes viz., RGC-1003, RGC-936 and HG-365 with four planting densities viz., 45 cm x 15 cm, 30 cm x 15 cm, 45 cm x 10 cm and 30 cm x 10 cm. Growth and yield observations were taken in 15 days interval until crop reaches physiological maturity. The experiment was conducted by using randomized complete block design with factorial concept. The spacing of 30 cm x 10 cm planting density was recorded higher total dry matter, leaf area, LAI and interception of light during most of the growth period and attained full radiation interception at 90 DAS than other planting densities. The intercepted PAR, extinction coefficient (k) and radiation use efficiency (RUE) increased with higher planting density. Dry matter production was significantly correlated with RUE (r=0.065). The RUE higher value obtained were (2.14 MJ m^{-2}) for RGC-1003 compared to other genotypes. It was noticed that the conversion efficiency of incident PAR to dry matter production varied much with three genotypes and four levels of spacing. The production of dry matter or productivity of cluster bean is corresponding to solar radiation.

Key words: *Cluster Bean, Spacing, Dry matter production, PAR and RUE*

INTRODUCTION

Cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.), commonly known as guar, is a native of Indian sub-continent, is a drought and high temperature tolerant deep rooted summer annual legume of high social and economic significance. The crop is mainly grown in the arid and semi-arid region of Rajasthan, Haryana, Gujarat, Punjab and to limited extent in UP and MP. The final yield of crop is a continuous interaction of genetic variable and environmental factors to which crop are exposed. Radiation interception by a crop is directly affected by the biomass production of a crop. The interaction of plant growth with their thermal conditions of their environment lies with the phenomenon of growth and development.

Cite this article: Nandini, K.M., Sridhara, S. and Kumar, K., Dry Matter Production, Photosyntheticaly Active Radiation and Radiation use Efficiency Response of Cluster Bean as Influenced by Genotypes and Planting Density, *Int. J. Pure App. Biosci.* **5(1):** 504-512 (2017). doi: http://dx.doi.org/10.18782/2320-7051.2511

The fraction of radiation energy intercepted during the growing period depends on the total intercepted radiation during the various crop growth stages. The canopy architecture also influences the distribution of radiation energy for dry matter accumulation. This affects the efficiency of radiation energy in photosynthesis. Therefore, it is necessary to understand the knowledge of plant environment interaction for increasing productivity of a crop. Cluster bean in our country is extremely low and has been static over the several decades. This may be due to the fact that a very few research has been made to agronomic requirements of the crop for higher productivity. Moreover, some of the constraints like poor production practices such as low plant densities, low soil fertility and inefficient weeding, use of herbicides, pesticides leading to poor production. So in order to exploit and popularize the crop there is a need to conduct research and identifying optimum agronomic practices in different production areas. Planting density is one of the powerful management tool where by grower can strongly influence early season optimum leaf area development and light interception and crop growth. Both intercepted PAR and RUE can be efficiently altered by crop management factor by planting density.

MATERIAL AND METHODS

The field experiment was conducted during *kharif* 2014 at ZAHRS, College of Agriculture, University of Agricultural and Horticultural Sciences (UAHS), Navile, Shivamogga which is situated at 13^0 58 North latitude and 75^0 34 East latitude with an altitude of 650 meters above mean sea level. The soil of experimental site was red clay texture with acidic pH of 5.6 and low available nitrogen (241 kg ha^{-1}), high in available P_2O_5 (87 kg ha^{-1}), low in available K_2O (131.72 kg ha^{-1}). The total rainfall received during the crop growth period was more (494 mm) against the normal (307 mm). Mean minimum and maximum temperature were 30.5^0C and 13.5^0C, respectively during the crop growth period. The experiment was laid out in RCBD with factorial concept and it comprising of Twelve treatments combinations involving four spacing viz., 45 cm x 15 cm, 30 cm x 15 cm, 45 cm x 10 cm and 30 cm x 10 cm and three varieties viz., RGC1003, RGC 936 and HG 365 with replicated thrice.

The land was prepared by ploughing followed by harrowing and levelling. Farm yard manures was applied 15 days before sowing and incorporated in to the soil. Recommended dose of fertilizers N, P, K kg ha^{-1} were applied in the form of Urea, SSP and MOP. After ten to fifteen days of sowing thinning was done by retaining one healthy seedling $hill^{-1}$ and thereby optimum plant population was maintained. Weed control measures were taken up by spray of alachlor @ 1.0 kg *a.i* ha^{-1} as pre emergent herbicide followed by two hand weeding. Samples of five plants from each plot were taken at 15 DAS interval to determine plant height, leaf area, leaf area index (LAI) and dry matter samplings continued for seven sequences at two weeks interval up to harvest. Leaf area was estimated by disc method and expressed in cm^2 $plant^{-1}$. LAI was computed as the ratio of total leaf area occupied by the plant to the land area covered by the plant as per the formula given by Watson[15]. Total dry matter was determined by drying the above ground parts of the 5 sampled plants at 65^0C for 48 hrs in a hot air oven. Radiation measurement was done by taking average use efficiencies with respect to thermal time, helio thermal as well as photo thermal units as calculated by regressing the above growing biomass against accumulated units. The slope of the regression line indicates the average use efficiency over the growing period.

Rainfall, temperature and sunshine hours data were collected from observatory located at ZAHRS, Shivamogga was converted in to radiation as per the procedure explained by the Monteith[10] and Meek *et al.*[9]. Later the amount of radiation intercepted by the canopy was calculated by using the formula given by Stutzel and Aufhammer[14].

Radiation intercepted by the canopy = $(1- I/I_0)\ e^{-KLAI}$

Where, I = intensity of the light at the point in the canopy

I_0 = light intensity at the top of the canopy

LAI = leaf area index

K = light extinction coefficient, which is assumed to be 0.45 as per the findings Alimadadi[2]. above that point and k represents the extinction coefficient determined empirically.

Radiation use efficiency

It is defined as the amount of dry matter produced per unit of solar radiation or incoming PAR or intercepted PAR and expressed as g MJ^{-1} Kiniry *et al*[7].,

$$RUE = \frac{\text{Above ground biomass (g m}^{-2})}{\sum \text{IPAR (MJ m}^{-2})}$$

Where,

RUE = Radiation use efficiency (MJ m^{-2})

∑ IPAR = Cumulative intercepted Photo synthetically active radiation.

Later average RUE was calculated by regressing the above ground biomass (g m^{-2}) against the cumulative IPAR. Slope of the regression line indicates the RUE over the growth of plants.

The data was analyzed by adapting fisher's method of analysis of variance as outlined by Gomez and Gomez[5].

RESULTS AND DISCUSSION

Planting density influenced most of the observed parameters including plant height, canopy size, radiation interception, RUE and dry matter. Total dry matter production, leaf area, LAI and plant height increased with increasing planting density. Among the different genotypes RGC-1003 recorded significantly higher total dry matter production at harvest (23.38 g $plant^{-1}$) as compared to HG-365 (21.95 g $plant^{-1}$) and RGC-936 (20.28 g $plant^{-1}$). The total dry matter production $plant^{-1}$ was maximum in plants grown at spacing of 30 cm x 10 cm (22.71 g $plant^{-1}$) at 15, 30, 45, 60, 75 and 90 DAS as compared to spacing of 30 cm x 15 cm (22.28 g $plant^{-1}$), 45 cm x 10 cm (21.45 g $plant^{-1}$) and lower total dry matter accumulation was recorded with spacing of 45 cm x 15 cm (21.04 g $plant^{-1}$).Vegetative growth helps in higher absorption of solar radiation helps in production of higher dry matter $plant^{-1}$. Lesser dry matter $plant^{-1}$ in wider spacing due to interception of solar radiation on the soil due to less plant population and loss of available resources. These results are in conformity with the work of Faroda *et al.*[4] and Murade *et al.*[11]. The pattern of production of total biomass is presented in Table.1. The variation in total biomass due to genotypes may be attributed to variation in canopy architecture and duration of leaf and crop growth rate.

The amount of PAR intercepted by cluster bean was significantly influenced by genotypes. Higher amount of PAR was intercepted by genotypes RGC-1003 (33.47 MJ m^{-2} to 494.96 MJ m^{-2}), HG-365 (29.83 to 458.74 MJ m^{-2}) and RGC-936 (28.19 to 86.62 MJ m^{-2}) at 30 DAS to 90 DAS (Table 2). Amount of cumulative PAR intercepted by cluster bean was significantly influenced by different spacing. Higher amount PAR was intercepted by the plants grown at 30 cm x 10cm (43.58 MJ m^{-2} to 638.57 MJ m^{-2}), as compared to other spacing 45 cm x 15 cm (19.57 MJ m^{-2} to 285.31 MJ m^{-2}) this variation in PAR interception may be attributed to variation in canopy development (Table 2).

Radiation interception by a crop is directly affected by the biomass production during different crop growth stages and it can be analysed from intercepted radiation. Among the genotypes, significantly higher RUE (2.14 MJ m^{-2}) was noticed with RGC-1003 as compared to HG-365 (2.02 MJ m^{-2}) and RGC-936 (1.96 MJ m^{-2}). Similarly, the spacing of plants grown at 30 cm x 10 cm spacing recorded significantly higher RUE (2.13 MJ m^{-2}) superior over 30 cm x 15 cm (2.06 MJ m^{-2}) and was on par with 45 cm x 10 cm (2.03 MJ m^{-2}) than 45 cm x 15 cm (1.95 MJ m^{-2}) (Figure 1). This higher RUE shows the efficient dry matter accumulation and partioning to various plant parts. The relationship between net biomass accumulation and intercepted radiation was linear throughout most of the crop growth, till the end of pod filling. The decrease RUE prior to maturity was due to leaf shedding similarly Kiran and Roy[8] reported in urd bean.

Highest plant density had consistently greater fractional interception of light during the entire growing period and reached full interception during earlier growing stages. At later stages it decreases due to leaf senescence. The RUE of different planting density of cluster bean are shown in the figure 2. With respect to interactions 30 cm x 10 cm spacing with RGC-1003 genotype recorded higher Radiation use efficiency (2.28 MJ m^{-2}), The RUE of cluster bean genotypes grown at different spacing are shown in the figure 3.

The variation in PAR interception may be attributed to variation in canopy development, since the amount of PAR intercepted is a function of LAI. In the present study higher leaf area index was observed in RGC-1003 (2.24) as compared to HG-365 (2.07) and RGC-936 (1.93) (Table 3). Decrease of LAI might be due to leaf shedding. Leaf area index reaches maximum just before pod maturity and decreases thereafter in all the genotypes. Higher leaf area index helps in better utilization of light and nutrients and LAI up to 3.0 is desirable which increased the grain yield[3] in cluster bean.

Significantly, higher leaf area was observed in genotype RGC-1003 (955.94 $cm^{-2}plant^{-1}$) at 60-75 DAS as compared with other genotypes HG-365 (889.90 cm^{-2} $plant^{-1}$) and RGC-936 (827.71cm^{-2} $plant^{-1}$) (Table 3). Progressive increase in leaf area was observed from 15 days up to 75 days after sowing. Higher leaf area helps in the better photosynthesis, there by more transformation of source to the other parts. This investigation is supported by the works of researchers Rana *et al.*[12] and Ahamed *et al.*[1] in mung bean. The higher fractional interception with increasing planting density at 30 cm x 10 cm was arising mainly from the leaf area (927.92 cm^{-2} $plant^{-1}$) and LAI (3.09) at 75 DAS compared with other planting densities.

Genotypes exhibited significant difference with respect to plant height from 15 DAS to harvest. Significantly higher plant height (53.06 cm) at 90 DAS was recorded with genotype RGC-1003 as compared to HG-365 (47.23 cm) and RGC-963 (43.29 cm) due to genetic make-up of genotypes (Table.3). Among the planting density 30 cm x 10 cm produced taller plants (49.51cm) as compared to others. The greater plant height with closer spacing 30 cm x 10 cm was attributed to relatively thick stand within the row which encouraged vertical growth of the plants rather than the vegetative growth.These results are in confirmity with the findings of Hussain *et al.*[6] and Singh *et al.*[13].

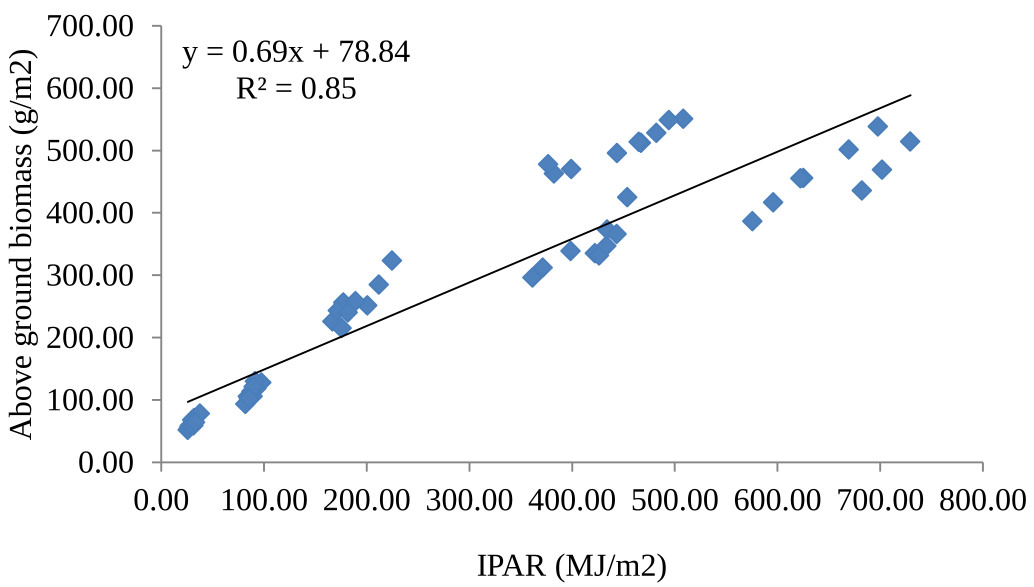

Fig. 1: Radiation use efficiency of cluster bean as influenced by genotypes

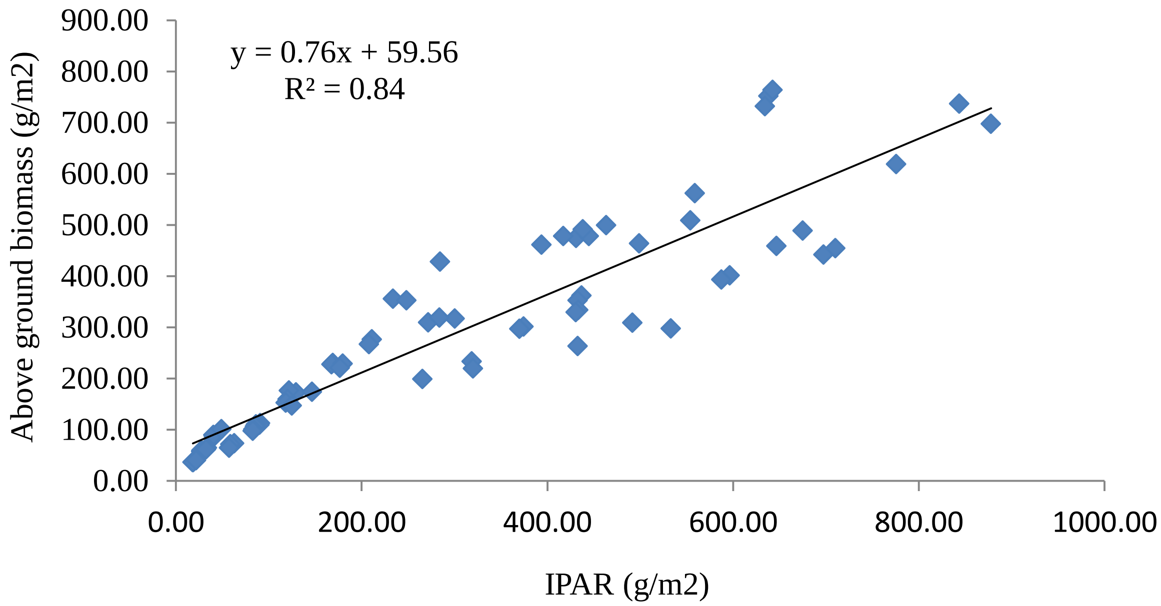

Fig. 2: Radiation use efficiency of cluster bean as influenced by spacing

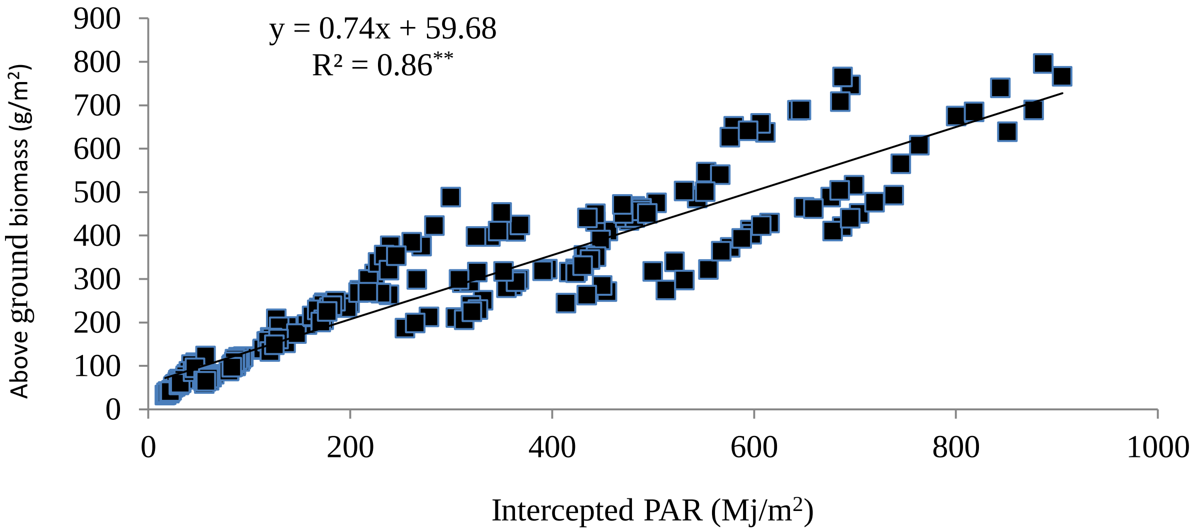

Fig. 3: Radiation use efficiency of cluster bean as influenced by spacing and genotypes

Table 1: Total dry matter (TDM) (g plant^{-1}) of cluster bean as influenced by spacing and genotypes at different days after sowing

Treatments	Days after sowing					
Spacing (S)	15	30	45	60	75	90
45x15 cm	2.54	4.68	10.55	14.51	19.36	21.04
30x15 cm	2.78	4.91	11.16	15.13	20.39	22.28
45x10 cm	2.68	4.76	10.86	14.85	19.63	21.45
30x10 cm	2.90	5.14	11.49	15.51	20.75	22.71
F-test	*	*	*	*	*	*
S.Em ±	0.03	0.04	0.14	0.19	0.14	0.16
C.D. at 5%	0.09	0.13	0.42	0.57	0.40	0.48
Genotypes (G)						
RGC-1003	3.12	5.41	12.04	16.22	21.69	23.38
RGC-936	2.42	4.39	9.94	13.87	18.39	20.28
HG-365	2.64	4.83	11.06	14.91	20.01	21.95
F-test	*	*	*	*	*	*
S.Em ±	0.03	0.04	0.12	0.17	0.12	0.14
C.D. at 5%	0.08	0.11	0.36	0.49	0.35	0.42
Interaction (S X G)						
45x15 cm + RGC-1003	2.78	5.10	11.56	15.40	21.03	22.58
45x15 cm + RGC-936	2.29	4.23	9.45	13.42	17.55	19.08
45x15 cm + HG-365	2.55	4.72	10.63	14.71	19.49	21.46
30x15 cm + RGC-1003	3.23	5.39	12.19	16.42	21.78	23.15
30x15 cm + RGC-936	2.44	4.45	10.05	14.04	19.05	21.39
30x15 cm + HG-365	2.66	4.90	11.23	14.93	20.33	22.30
45x10 cm + RGC-1003	3.00	5.21	11.78	15.95	21.26	23.18
45x10 cm + RGC-936	2.44	4.35	9.83	13.79	17.99	19.61
45x10 cm + HG-365	2.60	4.73	10.95	14.81	19.65	21.55
30x10 cm + RGC-1003	3.47	5.94	12.61	17.10	22.69	24.61
30x10 cm + RGC-936	2.50	4.53	10.44	14.25	18.98	21.03
30x10 cm + HG-365	2.74	4.97	11.42	15.18	20.58	22.50
F-test	*	*	NS	NS	NS	*
S.Em ±	0.05	0.08	0.25	0.33	0.24	0.28
C.D. at 5%	0.16	0.23	-	-	-	0.84

Table 2: PAR (MJ m^{-2}) of cluster bean as influenced by spacing, genotypes and their interaction

Treatments	Days after sowing					
Spacing (S)	15	30	45	60	75	90
45x15 cm	19.57	59.61	129.96	301.51	485.78	285.31
30x15 cm	29.75	86.86	186.54	414.95	660.59	448.78
45x10 cm	29.07	86.03	184.07	411.00	643.99	414.04
30x10 cm	43.58	123.73	255.60	537.35	832.50	638.57
F-test	*	*	*	*	*	*
S.Em ±	0.51	0.43	5.25	1.89	3.43	8.66
C.D. at 5%	1.50	1.26	1.78	5.57	10.12	25.57
Genotypes (G)						
RGC-1003	33.47	93.08	197.27	432.07	683.39	494.96
RGC-936	28.19	85.24	181.14	403.45	627.86	386.32
HG-365	29.83	88.86	188.72	413.09	655.89	458.74
F-test	*	*	*	*	*	*
S.Em ±	0.44	0.37	1.54	1.63	2.97	7.50
C.D. at 5%	1.30	1.09	4.54	4.82	8.77	22.14
Interactions (SXG)						
45x15 cm + RGC-1003	20.87	62.07	136.41	312.15	508.58	314.64
45x15 cm + RGC-936	18.36	56.87	123.42	290.76	460.37	228.81
45x15 cm + HG-365	19.48	59.89	130.05	301.60	488.39	312.47
30x15 cm + RGC-1003	32.66	89.87	194.63	431.54	684.41	495.47
30x15 cm + RGC-936	27.42	83.44	178.80	403.17	637.97	385.67
30x15 cm + HG-365	29.17	87.28	186.19	410.14	659.40	465.20
45x10 cm + RGC-1003	31.50	89.01	191.21	425.40	670.52	480.02
45x10 cm + RGC-936	27.15	82.89	176.71	398.44	614.01	336.82
45x10 cm + HG-365	28.58	86.18	184.28	409.18	647.44	425.26
30x10 cm + RGC-1003	48.83	131.36	266.81	559.18	870.05	689.70
30x10 cm + RGC-936	39.82	117.75	245.64	521.42	799.11	593.99
30 10 cm + HG-365	42.09	122.08	254.36	531.45	828.33	632.02
F-test	*	*	NS	NS	NS	NS
S.Em ±	0.88	0.73	3.07	3.26	5.94	15.00
C.D. at 5%	2.60	2.17	-	-	-	-

Table 3: The effect of planting density and genotypes on plant height, leaf area, leaf area index and total dry matter of cluster bean

Spacing (S)	Plant height (cm)	Leaf area cm^{-2} $plant^{-1}$	Leaf area index	Total dry matter (g)
45x15 cm	46.6	863.06	1.28	21.04
30x15 cm	48.23	905	2.01	22.28
45x10 cm	47.1	868.75	1.93	21.45
30x10 cm	49.51	927.92	3.09	22.71
F-test	*	*	*	*
S.Em ±	0.4	7.4	0.03	0.16
C.D. at 5%	1.17	21.85	0.1	0.48
Genotypes (G)				
RGC-1003	53.06	955.94	2.24	767.36
RGC-936	43.29	827.71	1.93	692.36
HG-365	47.23	889.9	2.07	717.64
F-test	*	*	*	*
S.Em ±	0.34	6.41	0.03	3.69
C.D. at 5%	1.01	18.92	0.08	10.9
Interaction (S X G)				
45x15 cm + RGC-1003	51.75	918.33	1.36	22.58
45x15 cm + RGC-936	42.11	802.5	1.19	19.08
45x15 cm + HG-365	45.93	868.33	1.29	21.46
30x15 cm + RGC-1003	53.27	959.58	2.13	23.15
30x15 cm + RGC-936	43.85	854.58	1.9	21.39
30x15 cm + HG-365	47.57	900.83	2	22.3
45x10 cm + RGC-1003	52.54	926.25	2.06	23.18
45x10 cm + RGC-936	42.39	805.42	1.79	19.61
45x10 cm + HG-365	46.37	874.58	1.95	21.55
30x10 cm + RGC-1003	54.67	1019.58	3.4	24.61
30x10 cm + RGC-936	44.83	848.33	2.83	21.03
30 10 cm + HG-365	49.03	915.83	3.05	22.5
F-test	NS	NS	NS	*
S.Em ±	0.69	12.82	0.06	0.28
C.D. at 5%	49.76	-	-	0.84

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