Physiological response, yield and dry matter partitioning in blackgram varieties under shading stress in coconut garden

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ABSTRACT

Blackgram [*Vigna mungo* (L) Hepper) is a short duration pulse crop which can be grown as sole or as component crop in intercropping situation. A study was conducted to assess the differential response in physiological traits, root growth, yield and dry matter partitioning in blackgram varieties and its relation with crop performance under shading stress. Twelve varieties and three cultures were tested in coconut garden under a light intensity of 40-46.5 Klux at the instructional farm of College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during rabi 2019. Results of the study revealed significant variation in physiological characters, seed yield and dry matter production among the varieties and cultures. Among the varieties, DBGV 5, CO 6, VBN 6 and Sumanjana recorded higher leaf area index (LAI) and leaf area duration (LAD) at flowering and consequently higher photosynthetic rate under shading stress. Higher dry matter partitioning of assimilates to reproductive parts such as pods and seeds was also noticed in DBGV 5, VBN 5 and Sumanjana resulting in superior yields in DBGV 5 (1,183.33 kg/ha), VBN 5 (916.67 kg/ha) and Sumanjana (906.67 kg/ha) under shaded situations in coconut garden. Varieties with higher LAI and LAD at flowering coupled with greater dry matter partitioning to pods viz DBGV 5, VBN 5 and Sumanjana could be identified as tolerant to shading stress in coconut garden with higher yield.

Keywords: Blackgram; coconut garden; partial shade; photosynthetic rate; varieties; yield

INTRODUCTION

Among pulses, blackgram [*Vigna mungo* (L) Hepper] occupies a major place among the premier pulse crops and is considered as third important pulse crop in India accounting for 13 per cent of the total pulse area and 10 per cent of the total pulse production in the country (Manjri et al 2018). Legumes are sensitive to reduced light levels either due to crop combinations or overcrowding (Hadi et al 2006). Shade is caused by dense plant populations, intercropping, changed planting geometry and excessive vegetative growth, all of which have an impact on plant performance by lowering photosynthetic capability. In coconut plantations of above 40 years, light transmission increases about 50 per cent which makes growing of crops possible in the interspaces (Nelliat et al 1974). The active root zone of coconut is confined only to 25 per cent of the available land area. Hence the interspaces in a coconut garden may be used to produce blackgram. Being a favourable short duration pulse crop, blackgram survives better in all seasons either as sole, intercrop or catch crop. The photosynthetic response of a plant is known to be influenced by the light intensity at which it is cultivated (Valladares 2003). There are also strong links between a crop's yield and its light environment. The selection of suitable pulse species in crop mixes plays a significant role in obtaining the highest yield of pulses under low light conditions. In terms of physiology and yield, the species may react differently to shading stress (Kakiuchi and Kobata 2006). Selection of varieties that perform a stable photosynthesis under different light intensities will be a greater advantage to get high and stable productivity under intercropping condition. In this background the present study was undertaken to assess the differential response in physiological traits, root characters, yield and dry matter partitioning in blackgram varieties and its relation with crop performance under shading stress in partially shaded situation in coconut garden in the southern laterites of Kerala.

MATERIAL and METHODS

The field experiment was carried out in rabi season of 2019 with cropping period extending from October to January 2020 at the instructional farm attached to College of Agriculture, Vellayani, Kerala located at 8° 25' 46" N latitude, 76° 59' 24" E longitude and altitude of 29 m amsl. The region enjoys a humid tropical climate experiencing temperature of 26.9 to 42.2°C and relative humidity of 89 per cent. A total of 244.5 mm rainfall was received in 105 days with an average weekly evaporation of 33.89 mm during the cropping period. Seeds of promising blackgram varieties (12) along with cultures (3) collected from different research stations of south India were evaluated in coconut garden with palms of uniform age (45-50 years old) and planted at a spacing of 7.6 x 7.6 m. The 12 varieties were Sumanjana, DU 1, DBGV 5, VBN 5, VBN 6, VBN 8, Rashmi, CO 6, TAU 1, TAU 2, Blackgold and AKU 15 and the three cultures tested were culture 4.5.8 (T9 x Rusami), culture 4.5.18 (T9 x Rusami) and culture 4.6.1 (T9 x Rusami). The plots were laid out in randomized block design (RBD) replicated thrice. From the base of the palm, two meter radius was left to avoid interruption from coconut roots so that growth and development of intercrop was unaffected. Hence in between two coconut palms 3.6 m space was utilized for sowing blackgram. Land in between the palms was thoroughly ploughed, micro-plots of 1.5 m^2 were taken and applied lime @ 250 kg/ha. The shade level was assessed using light meter and light intensity of 40-46.5 Klux was recorded in the garden equivalent to 50 per cent of that in open condition. Well decomposed farmyard manure was incorporated at the rate of 20 tonnes/ha as basal dose. The recommended nutrients (20:30:30 kg N: P_2O_5: K_2O/ha) were given through urea, Rajphos and muriate of potash (Anon 2016). Half the dose of N and full P and K were given as basal and the remaining half dose of N was given as two foliar sprays at 15 and 30 days after sowing (DAS). Two weedings were done at 15 and 30 DAS with irrigation provided on alternate days. The observations on number and dry weight of nodules were taken at flowering. At flowering photosynthetically active radiation (PAR) and photosynthetic rate were measured and stomatal index as well as LAD were computed. Photosynthetic rate and PAR were measured during the morning hours between 9 and 11 am using portable photosynthetic system (CIRAS-3, PP systems USA) and the values were expressed in μ CO_2 moles/m^2/s. Using the values of leaf area recorded at 30, 45 and 60 DAS, LAD was calculated with the equation proposed by Watson (1947) and expressed in days:

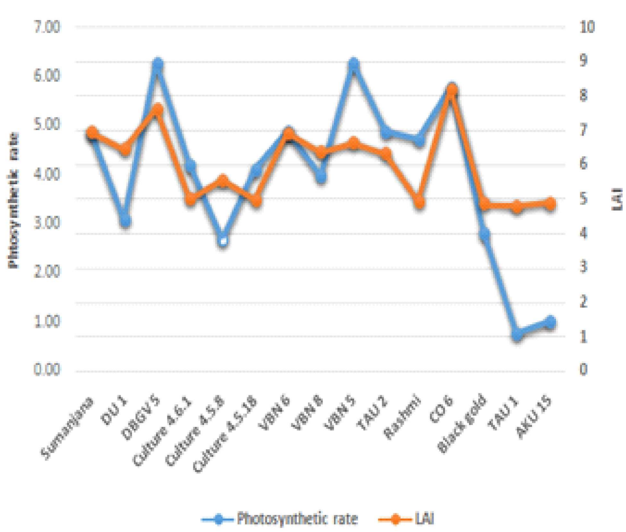

Fig 1. Effect of varietal performance on LAI and photosynthetic rate at flowering

$$\text{Leaf area duration (LAD)} = \frac{L_1 + L_2}{2}(t_2 - t_1)$$

where L_1 and L_2 = Leaf area indices at t_1 and t_2 time respectively

Stomatal index is the ratio of the number of stomata formed to the total number of epidermal cells expressed in percentage where each stomata being counted as one cell. It was computed using the following equation:

$$I = \frac{S}{E + S} \times 100$$

where I: Stomatal index, S: Number of stomata per unit area, E: Number of epidermal cells in the same unit area

All the varieties reached maturity within a range of 80-100 days. A total of three pickings were taken and the observations on sample plants were recorded. Root characters viz rooting length, root volume and root dry weight were recorded at harvest. At harvest, two plants at random were uprooted from each plot. The length of the roots was measured after washing to remove soil particles and dirt. The average rooting length was calculated and expressed in cm. Root volume was measured by water displacement method (Misra and Ahmad 1990). The roots of the observational plants washed with water and made free of adhering soil were immersed in a graduated cylinder containing water. Volume of the displaced water was taken as the volume of the root and its average was expressed in cm^3. The roots of the plants were washed and made free of soil particles and dried in hot air oven at 65 ± 5°C to constant weight and expressed in g. Seed and haulm yield from the net plot was recorded and converted into kg/ha. Dry matter partitioning of plant was done and harvest index was computed. The data were analysed statistically by analysis of variance (ANOVA) for RBD and the significance was tested by F-test (Cochran and Cox 1965).

RESULTS and DISCSSION

The physiological parameters viz stomatal index, LAD and PAR varied significantly among varieties and cultures tested (Table 1). At flowering, total stomatal index was higher for the varieties DBGV 5, VBN 8, TAU 2 and Sumanjana. However increased persistence of leaf at flowering (LAD) was registered in varieties DBGV 5, CO 6, VBN 6 and Sumanjana which promoted more absorption of solar radiation. Setiawati et al (2018) reported that species with higher stomatal index tend to be more responsive to the increase in CO_2 and hence the rate of photosynthesis is greater. Higher leaf area index coupled with increased persistence of leaf might have enhanced PAR and photosynthetic rate (Fig 1) in varieties DBGV 5 and VBN 5. In order to maximise the quantity of light absorbed and the quantum yield for CO_2 absorption during photosynthesis in the shade, the quantity of light absorbed and the quantum yield for CO_2 uptake both must be maximised (Hadi et al 2006). The varieties DBGV 5, VBN 5 and Sumanjana had adapted to low light intensity under coconut garden by increasing the LAI and LAD thereby improving the photosynthetic rate thus negating the effect of higher stomatal index which otherwise might have contributed to yield reduction. Yao et al (2017) reported that shade tolerant soybean cultivar L32 had increased PSII activity and energy transmission from PSII to PSI as well as improved photosynthetic capacity and yield.

Improved physiological attributes under low light helped the plant to produce more seed and haulm yield (Table 2). According to Lemaire et al (2007) PAR has prodigious role in deciding the yield of a crop especially under low light intensity. The elevated PAR recorded in the variety DBGV 5 recorded significantly higher seed yield of 1,183.33 kg/ha followed by VBN 5 (916.67 kg/ha) and Sumanjana (906.67 kg/ha). Improved physiological characters like LAD, LAI, PAR and photosynthetic rate registered in these varieties might have resulted in superior seed yield under low light condition. Varieties and cultures varied significantly with respect to haulm yield also. Highest haulm yield was recorded in the varieties DBGV 5, VBN 5, Sumanjana and CO 6. The better performance in terms of seed as well as haulm yield of these varieties in coconut garden could largely be connected to its efficiency in capturing the solar radiation (55%) not intercepted by the canopy (Liyanage and Dasanayake 1993). It could be concluded that the light intensity levels in the interspaces in coconut gardens were sufficient to drive photosynthesis and related physiological processes to overcome the shading stress in DBGV 5, VBN 5 and Sumanjana.

Similar to seed yield, different varieties and cultures showed variability in dry matter partitioning and harvest index (Table 2). Different PAR levels had a substantial impact on the dry matter accumulation in the leaf, stem and pod affecting the plant's overall dry matter output (Akhter et al 2016). In the present study, the varieties DBGV 5, VBN 5 and Sumanjana were having more assimilates in the reproductive parts than the vegetative parts which contributed to more seed yield. On the other hand, the shoot weight and leaf dry weight were recorded highest by the culture 4.5.8 and consequently it produced lowest seed yield among all the varieties and cultures under study. The added effect of vegetative and reproductive parts resulted in variation in total dry matter production with higher value registered by the varieties AKU 15, VBN 8, VBN 5 and DBGV 5. Harvest index, an important parameter in deciding the yield of crop also varied significantly and the varieties Sumanjana, DBGV 5 and VBN 6 recorded higher harvest index. Seed yield of green gram was improved as a result of maintaining a relatively high total dry matter output while simultaneously improving the harvest index (Natarajan and Palanisamy 1988). This could be due to better partitioning of source to sink thereby accumulation of more photosynthates

Table 1. Stomatal index, LAD and PAR and root characters of blackgram varieties under shading stress

Treatment	Stomatal index (%)	LAD (days)	PAR (μ moles /sec/m^2)	Number of nodules	Dry weight of nodules (g)	Rooting length (cm)	Root volume (cm^3)	Dry weight of root (g)
T_1- Sumanjana	20.80	50.83	183.67	18.33	0.41	21.33	6.67	2.02
T_2- DU 1	17.55	47.47	127.00	18.67	0.53	22.13	6.33	2.03
T_3- DBGV 5	23.33	58.40	374.67	17.00	0.49	25.17	7.10	2.24
T_4- Culture 4.6.1	17.08	41.28	189.33	17.33	0.51	20.33	7.00	2.10
T_5- Culture 4.5.8	16.79	43.08	178.00	16.33	0.48	25.33	6.33	2.25
T_6- Culture 4.5.18	16.85	35.34	149.00	17.33	0.51	20.33	5.87	2.01
T_7- VBN 6	19.75	53.48	222.33	20.67	0.53	28.50	5.43	2.23
T_8- VBN 8	20.03	48.06	233.33	17.67	0.49	22.33	7.07	2.13
T_9- VBN 5	16.95	49.22	374.00	24.00	0.46	22.67	6.07	2.14
T_{10}- TAU 2	22.10	48.16	231.00	19.00	0.54	21.00	5.97	2.20
T_{11}- Rashmi	15.44	37.77	194.67	19.00	0.53	21.33	7.00	2.18
T_{12}- CO 6	18.53	65.66	287.00	22.00	0.33	22.67	6.67	2.27
T_{13}- Blackgold	18.16	35.75	143.33	23.33	0.53	21.67	5.33	2.27
T_{14}- TAU-1	15.45	34.89	143.67	19.67	0.36	23.67	7.33	2.23
T_{15}- AKU-15	17.48	41.50	176.33	20.67	0.44	22.67	4.67	2.23
SEm±	1.21	2.93	9.01	1.79	0.06	1.65	0.93	0.063
$CD_{0.05}$	3.450	8.542	25.69	NS	NS	NS	NS	NS

Table 2. Dry matter partitioning, seed yield, haulm yield and harvest index of blackgram varieties under shading stress

Treatment	Shoot weight (g)	Leaf weight (g)	Pod weight (g)	Seed weight (g)	TDMP (g)	Seed yield (kg/ha)	Haulm yield (kg/ha)	Harvest index
T_1- Sumanjana	3.033	1.95	6.60	4.4	13.57	906.67	2,975.00	0.24
T_2- DU 1	3.483	2.97	4.78	3.19	13.23	583.33	2,100.00	0.19
T_3- DBGV 5	5.603	3.33	8.16	5.44	19.3	1,183.33	3,325.00	0.23
T_4- Culture 4.6.1	5.953	4.09	5.76	3.84	17.87	756.67	2,100.00	0.18
T_5- Culture 4.5.8	7.463	4.61	3.25	2.16	17.53	310.00	1,960.00	0.11
T_6- Culture 4.5.18	6.083	5.03	5.08	3.39	18.17	636.67	2,245.83	0.16
T_7- VBN 6	4.933	2.40	6.30	4.2	15.83	853.33	2,852.50	0.21
T_8- VBN 8	7.253	4.83	6.09	4.06	20.27	816.67	2,158.33	0.17
T_9- VBN 5	5.793	4.91	6.66	4.44	19.47	916.67	3,050.83	0.19
T_{10}- TAU 2	4.383	4.56	5.29	3.53	16.4	673.33	2,298.33	0.18
T_{11}- Rashmi	5.443	4.30	5.38	3.59	17.27	690.00	2,181.67	0.17
T_{12}- CO 6	5.823	3.31	6.36	4.24	17.73	863.33	2,975.00	0.18
T_{13}- Blackgold	5.033	4.24	5.82	3.88	17.33	766.67	2,158.33	0.18
T_{14}- TAU-1	4.413	4.92	6.04	4.03	17.57	806.67	2,070.83	0.18
T_{15}- AKU-15	6.843	5.01	6.26	4.03	20.3	806.67	2,187.50	0.17
SEm±	0.001	0.001	0.27	0.27	0.72	71.95	153.70	0.02
$CD_{0.05}$	0.004	0.002	0.785	0.786	2.06	209.520	438.86	0.050

to growing reproductive parts rather than vegetative parts (Manoj et al 2019).

The response of varieties and cultures on number and dry weight of nodules at flowering and root characters viz rooting length, root volume and dry weight of root at harvest are presented in Table 1. Under low light intensity in coconut garden, root characters showed no significant variation among the varieties. Vidal et al (1996) observed reduced nodule activity under low light intensity compared to open condition. All root characters recorded under this study were higher compared to results obtained by Yamini (2019) under open condition. It is contrary to the results obtained by Wang et al (2003) who reported that the root characters viz rooting length, root value and root dry weight increased under high light intensity compared to low light.

CONCLUSION

It can be concluded from the study that the interspaces in coconut garden were sufficient to grow the short duration blackgram with efficient utilization of resources. The increased PAR along with LAD augmented photosynthetic rate thereby yield of varieties. Among the varieties and cultures tested in coconut gardens with 40-46.5 Klux light intensity, DBGV 5 recorded the highest seed yield (1,183.33 kg/ha) in shaded condition prevailing in coconut garden followed by VBN 5 and Sumanjana with seed yields of 916.67 and 906.67 kg/ha respectively confirming its capacity to perform better under the shade levels in coconut gardens of southern lateritic soils of Kerala.

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