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Identification of Low Light Tolerant Blackgram Varieties with Respect to Morpho-physiology and Yield

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ABSTRACT

Background: Blackgram is generally considered as a shade sensitive crop. Nevertheless, it fits well in intercropping, crop rotation and crop mixture in coconut gardens thus forming an integral part of cropping systems of the tropics. To encourage and extend blackgram cultivation in coconut gardens, suitable varieties tolerant to shade, need to be identified. The current study aims to screen shade tolerant blackgram varieties with respect to morpho-physiological characters and yield.

Methods: Field experiment was conducted during *Rabi* 2019 at College of Agriculture, Vellayani, Kerala, India. Uniformly spaced coconut palms of age above 40 years were selected having a light intensity of 40-46.5 Klux. Twelve promising blackgram varieties along with three cultures were evaluated under low light intensity in coconut garden. Morpho-physiological attributes and yields were recorded and analysed statistically.

Result: Superior growth attributes and physiological parameters like stomatal frequency, chlorophyll content, photosynthetic rate and transpiration rate were recorded in varieties namely, DBGV 5, Sumanjana and VBN 5. These varieties were found tolerant to low light intensity with DBGV 5 recording significantly higher yield (1183.33 kg ha^{-1}) followed by VBN 5 (916.67 kg ha^{-1}) and Sumanjana (906.67 kg ha^{-1}) and could be recommended as suitable for intercropping in coconut garden.

Key words: Blackgram, Coconut garden, Growth attributes, Low light tolerance, Partial shade, Physiology, Seed yield, Varieties.

INTRODUCTION

Pulses are the cheapest and pioneer source of protein for human diet having immense potential in improving human health, conserving soil, protecting the environment and contributing to global food security (Pooja and Ameena, 2021). Among pulses, blackgram is a much-preferred short duration crop as it survives better in all seasons either as sole crop, intercrop or catch crop accounting for 13 per cent of total pulse area and 10 per cent of total pulse production in the country (Manjri *et al*., 2018). To encourage and extend blackgram cultivation in the prevailing fragmented land holding and low availability of cultivable lands, inclusion in coconut gardens as an intercrop is a practical solution. Light transmission increases about 50 per cent in coconut plantations of above 40 years, which makes growing of intercrops possible in their interspaces (Nelliat *et al.,* 1974). The active root zone of coconut is confined only to 25 per cent of the land area which give ample scope for growing short duration pulses such as blackgram by effectively utilizing the interspaces in coconut garden. It also serves as an additional income for farmers. However, there exist a relation between the yield of a crop and its light environment.

In general, legumes are sensitive to reduced light levels and yield reduction by reduced light depends upon crop species as well as degree of shading. Grain yield of pulse species has been reported to reduce, when intercropped with cereals (Singh *et al.,* 2009). Morphological and physiological parameters of intercrops varied considerably due to the prevailing partial shaded condition in the coconut garden and hence affecting the yield. According to Vendramini *et al*. (2002), leaf characteristics, usually reflect adaptive strategies in plants to important environmental factors, including light, temperature, air, and nutrition. Differences of light intensity affect the external morphology of leaves, internal anatomy, and physiological characteristics (Kong *et al*., 2016). To obtain maximum yield under low light, selection of suitable varieties plays an important role in intercropping. Different varieties respond differently to shading stress in terms of morpho-physiology as well as yield. Availability of suitable varieties with appreciable grain yield and shade tolerance is common limitation in the popularization of blackgram cultivation in coconut garden (Abraham *et al.,* 1992). Therefore, the present field investigation was carried out to identify the low light tolerant

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blackgram varieties by comparing their relative performance in terms of morpho-physiological variations and yield under partially shaded situation in coconut garden.

MATERIALS AND METHODS

The field trial was conducted at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during *Rabi* 2019 in coconut garden of above 40 years of age having a light intensity between 40-46.5 Klux, planted at spacing of 7.6 m x 7.6 m. The field was situated at 8° 25' 46" N latitude, 76° 59' 24" E longitude and altitude of 29 m above the mean sea level. The weather parameters during the cropping season is represented (Fig 1). Seeds of promising blackgram varieties 12 nos along with culture (3 nos) collected from different research stations of South India *viz.*, Sumanjana, DU 1, DBGV 5, VBN 5, VBN 6, VBN 8, Rashmi, CO 6, TAU 1, TAU 2, Blackgold, AKU 15, Culture 4.5.8 (T 9 x Rusami), Culture 4.5.18 (T 9 x Rusami) and culture 4.6.1 (T 9 x Rusami) were raised in plots (1.5 m x 1 m) laid out in randomized block design (RBD) with three replications. A distance of two-meter radius was left from the base of palm to avoid root interference making a length of 3.6 m in between the palms for sowing. Land was ploughed and crop was sown at a spacing of 25 cm x 15 cm in the raised beds. The recommended nutrients (20:30:30 kg N: P_2O_5: K_2O ha^{-1}) were given through urea, rajphos and muriate of potash (KAU, 2016). Half the dose of N, 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 data on growth characters *viz.,* plant height, number of branches and number of leaves per plant were recorded at monthly intervals from the observational plants and averages worked out. Observations on leaf are index (LAI), stomatal frequency, chlorophyll content (a, b and total chlorophyll) and proline content were estimated at 50% flowering of the plants.

To calculate leaf area index, leaf area per plant was computed using length and breadth measurement method expressed in cm^2.

$$\text{Leaf area} = L \times B \times K \text{ x } n$$

Where, L = length of leaf (cm), B = breadth of leaf (cm), K (constant value) = 0.631 (Montgomery, 1911), n = number of leaves.

Using the calculated value of leaf area per plant, LAI was computed with the formula,

$$\text{LAI} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

Stomatal frequency was determined by counting the number of stomata of adaxial and abaxial surface of leaf in the microscope field of view and expressed as number of stomata mm^{-2}. Chlorophyll a, b and total chlorophyll contents were estimated by the method suggested by Arnon (1949) in which, the fully opened second leaf from the top of plants were used and the values expressed in mg g^{-1} of fresh weight (fw) of leaf. Proline content was estimated using the procedure described by Bates *et al.* (1973) and expressed the concentration of proline as:

$$\mu \text{ moles } g^{-1} \text{ tissue} = \frac{[\mu \text{ g proline /mL} \times \text{mL toluene}] \times 5}{115.5 \text{ x weight of sample (g)}}$$

where,
115.5 is the molecular weight of proline.

Observations on photosynthetic rate and transpiration rate were measured at morning time between 9 am and 11 am using Portable Photosynthetic System (CIRAS-3, PP systems U.S.A). Depending on the varietal characters, the varieties and cultures became mature in 80-100 days and a total of three pickings were taken. The yield was recorded from the net plot area and expressed in kg ha^{-1}. The data was analysed statistically by analysis of variance (ANOVA) for RBD and the significance was tested by F test (Cochran and Cox, 1965).

RESULTS AND DISCUSSION

Growth characters

The growth characters *viz.,* plant height, number of leaves per plant, number of branches per plant at monthly interval and leaf area index at 50% flowering of varieties and cultures under partial shade situation are presented in Table 1. Among the varieties, DBGV 5, CO 6 and Sumanjana were found to grow taller right from one month after sowing (MAS) till harvest under low light while culture 4.5.18, culture 4.5.8 and VBN 5 maintained a shorter stature. Increased plant height is an adaptation to grow better in low light intensity. The varieties that have grown taller (DBGV 5, CO 6 and Sumanjana) were found adapted to partially shaded conditions by stem elongation for radiation energy capture and use in photosynthesis. Similar results of increment in plant height with shade was observed by Lakshmamma and Rao (1996) in blackgram and Hossain *et al.* (2017) and Nair (2020) in green gram under partially shaded coconut garden. Keuskamp *et al.* (2010) reported that as shading stimulates the synthesis of auxin and gibberellins, plant show increased height and etiolated leaves, since these hormones promotes cell division, cell elongation, apical dominance and inter nodal elongation.

Number of leaves per plant also varied between varieties under low light intensity at 1 MAS and at harvest. The varieties that have grown taller namely DBGV 5, CO 6, Sumanjana, VBN 5 and VBN 6 produced more number of leaves at 1 MAS. Attridge (1990) observed that low light intensity will promote a greater number of leaves to expose more photosynthetic area under limited illumination. At 2 MAS, significant difference in terms of number of leaves per plant was not evident among the varieties/cultures. This could be related to the attainment of peak flowering stage by all the varieties and cultures at around 50-60 days, leading to the utilization of photosynthates for reproductive

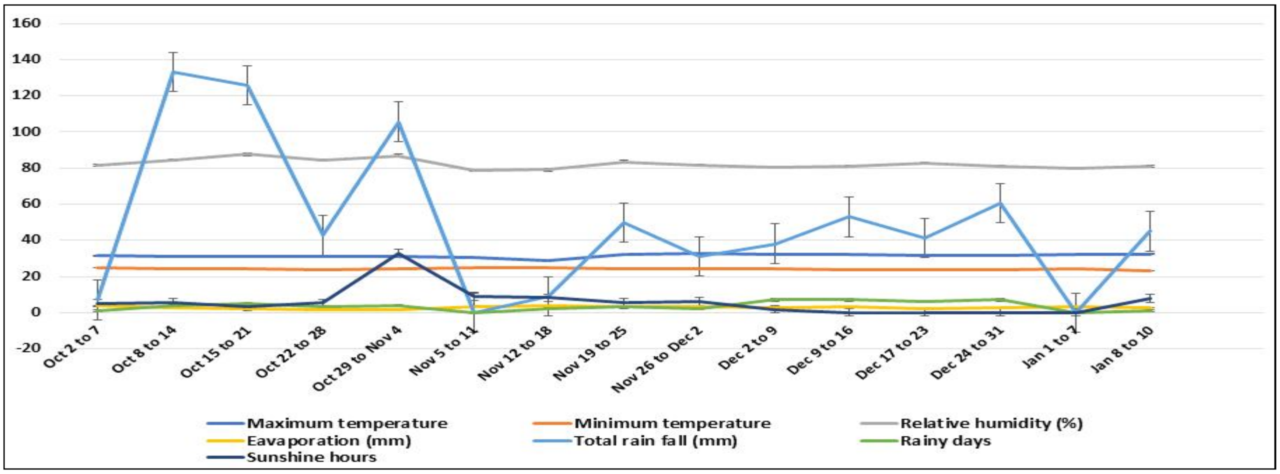

Fig 1: Weather parameters during the cropping period.

Table 1: Effect of treatments on growth characters such as plant height, number of leaves, number of branches at monthly interval and leaf area index at flowering.

Treatment	Plant height (cm)			Number of leaves			Number of branches			Leaf area index
(variety)	1 MAS	2 MAS	At harvest	1 MAS	2 MAS	At harvest	1 MAS	2 MAS	At harvest	(at flowering)
Sumanjana	44.34	85.10	96.83	7.33	11.00	5.22	1.00	2.44	2.44	4.88
DU 1	41.17	70.27	73.63	6.07	12.01	6.78	1.00	2.89	3.00	4.54
DBGV 5	47.70	87.97	96.89	7.56	12.11	6.67	1.00	2.33	2.56	5.36
Culture 4.6.1	38.79	76.83	86.17	5.74	12.22	6.22	1.00	2.22	2.56	3.52
Culture 4.5.8	33.77	59.06	62.77	5.41	10.78	8.10	1.00	2.83	3.00	3.90
Culture 4.5.18	32.17	65.17	77.77	4.00	10.83	8.56	1.00	2.33	3.33	3.50
VBN 6	43.86	79.66	91.53	7.00	11.22	6.78	1.00	2.22	2.67	4.86
VBN 8	35.66	62.94	69.20	5.89	11.11	5.66	1.00	2.44	2.78	4.48
VBN 5	43.33	83.33	95.73	6.78	11.78	6.11	1.00	2.22	2.33	4.66
TAU 2	39.00	66.50	70.23	6.11	11.11	7.98	1.00	2.55	2.56	4.45
Rashmi	40.13	73.60	75.50	5.70	10.89	7.67	1.00	2.22	2.78	3.48
CO 6	47.44	85.80	95.33	7.33	13.00	6.77	1.00	2.72	2.44	5.77
Blackgold	40.17	67.26	71.13	6.19	10.78	6.43	1.00	1.78	2.21	3.43
TAU 1	40.84	74.43	78.44	6.15	10.55	4.33	1.55	1.89	2.11	3.36
AKU 15	40.03	77.82	79.17	6.29	10.11	5.22	1.33	2.11	2.56	3.45
SEm±	1.27	2.77	2.76	0.40	0.75	0.61	0.09	0.30	0.30	0.28
CD (0.05)	3.686	8.065	8.022	1.176	NS	1.764	0.261	NS	NS	0.809

growth rather than vegetative growth. The leaf production capacity and leaf persistence of each variety and culture was lower at the time of harvest. Lesser production of leaves could be due to the utilization of energy for flower and pod formation rather than vegetative growth. Lesser production and persistence of leaves during harvest stage was also reported by Yamini (2019) in blackgram variety CO 6 in open condition. Number of branches per plant also showed the same trend as that of number of leaves which could be due to the lesser vegetative growth during the later period of growth as well as increased influx of photosynthates to the reproductive parts (Deol *et al.,* 2018).

The results revealed remarkable influence of shading stress on LAI of blackgram varieties and cultures tested. Taller plants with more number of leaves at 50% flowering resulted in a notable increase in LAI in both CO 6 and DBGV-5 recording 5.77 and 5.36 and least in TAU 1 with a value of 3.36. Those varieties with tolerance to low light intensity were found to have developed more assimilatory area for high photosynthesis thereby contributing additional source activity. According to Fitter and Hay (1981), plants under the shaded condition adapt to low light intensity conditions by increasing the leaf area to obtain a larger surface for light absorption. This indicated that change in leaf morphology in response to shade maximized capture of the growth limiting resource (light) which is more extreme in shade adapted species (Lambers *et al.,* 1998).

Physiological characters and yield

The effect of varieties and cultures on physiological characters *viz.,* stomatal frequency, photosynthetic rate, transpiration rate, water use efficiency, proline content and chlorophyll content are presented in Table 2. Results revealed that physiological and biochemical characters of varieties and cultures varied significantly in response to low light intensity. In general, abaxial surface possessed more number of stomata than adaxial to reduce transpiration loss (Kong *et al.,* 2016). Under shading stress, VBN 6, CO 6, VBN 5, DBGV 5 and Sumanjana recorded more number of stomata in the abaxial surface than adaxial showing 64-73% increase in stomatal frequency on the abaxial surface than adaxial compared to other varieties. However, more stomata favours more transpiration and hence these varieties recorded higher transpiration rate under low light intensity (Table 2). It was in contrary to results obtained by Flanagan *et al.* (1997), who reported reduction in stomatal frequency under shade to reduce transpiration rate. The photosynthetic rate was significantly superior (8.97 µ moles CO_2 m^{-2} sec^{-1}) for the varieties DBGV 5 and VBN 5 due to higher LAI at flowering as LAI is considered as an indicator of photosynthetic efficiency. DBGV 5, VBN 5, Sumanjana and CO 6 adapted to the water loss by increasing the photosynthetic rate and thereby higher water use efficiency under partially shaded coconut garden. Light intensity in the interspaces was enough to drive the photosynthates and other vital physiological processes for DBGV 5, VBN 5, Sumanjana and CO 6. Shading can prevent water stresses through evapotranspiration and nutrient stresses by matching growth to available nutrients thereby increasing the water use efficiency in shaded environments (Habib *et al.,* 2020).

Proline is an enzyme which is produced in response to stress condition in plants and is considered as a defence mechanism in plants (Liang *et al.,* 2013). The blackgram varieties and cultures grown under low light intensity has shown no significant variation in proline content, also the proline concentration was negligible (0.030-0.045 µ g g^{-1} of soil) compared to open condition, where proline concentration may go up to 70-200 µ g g^{-1} of soil (Geetha, 2004). This might be due to less water stress under low light intensity, low evaporation and high soil moisture content. This observation highlights the suitability of blackgram in partially shaded coconut gardens, as the low light intensity was not limiting stress factor under the given climatic and management practices considered in the study.

Significant variation in chlorophyll a, b and total chlorophyll contents were observed among the varieties and cultures under low light intensity. Chlorophyll a and total chlorophyll contents were higher for the variety DBGV 5 and was on par with Sumanjana. The increased content of chlorophyll in these varieties under shading stress might be to enhance the efficiency of light absorption indicating its adaptation to low light intensity. Higher value of chlorophyll b was recorded by the varieties VBN 8, VBN 5, TAU 1 and culture 4.5.18. According to Watson and Dallwitz (1992), one of the characteristics of the adjustment to low irradiation due to shade is an increase in leaf chlorophyll content. This

Table 2: Effect of treatments on physiological and biochemical parameters at flowering.

Treatment (variety)	Stomatal frequency (lower)	Stomatal frequency (upper)	Photosynthetic rate (µ mol CO_2 m^{-2} sec^{-1})	Transpiration rate (m mol H_2O m^{-2} sec^{-1})	WUE (m mol CO_2 mol^{-1} H_2O)	Proline content (µ g proline ml^{-1})	Chlorophyll a (mg g^{-1} fw)	Chlorophyll b (mg g^{-1} fw)	Total chlorophyll (mg g^{-1} fw)
Sumanjana	400.00	275.00	6.93	0.333	23.54	0.041	1.86	0.62	3.19
DU 1	300.00	208.33	4.43	0.273	16.27	0.038	1.38	0.70	2.09
DBGV 5	416.67	275.00	8.97	0.370	24.59	0.034	1.91	0.53	3.25
Culture 4.6.1	341.67	225.00	6.00	0.393	15.50	0.033	1.31	0.54	1.86
Culture 4.5.8	316.67	250.00	3.83	0.260	15.21	0.031	1.39	0.54	1.83
Culture 4.5.18	300.00	225.00	5.90	0.297	18.40	0.037	1.30	0.88	2.30
VBN 6	466.67	308.33	6.97	0.327	21.46	0.031	1.60	0.65	2.75
VBN 8	316.67	241.67	5.70	0.373	15.39	0.036	1.53	0.91	2.40
VBN 5	416.67	266.67	8.97	0.427	21.08	0.035	1.50	0.83	2.83
TAU 2	308.33	208.33	7.00	0.387	18.57	0.036	1.29	0.64	2.50
Rashmi	300.00	225.00	6.77	0.410	16.81	0.038	1.35	0.70	2.65
CO 6	433.33	316.67	8.27	0.353	23.80	0.030	1.58	0.70	2.66
Blackgold	291.67	258.33	4.03	0.257	15.64	0.040	1.31	0.67	2.63
TAU 1	283.33	216.67	1.13	0.117	9.79	0.045	1.44	0.79	2.71
AKU 15	275.00	233.33	1.47	0.143	10.74	0.043	1.39	0.71	2.11
SEm±	17.56	14.90	0.20	0.030	1.731	0.003	0.07	0.058	0.16
CD (0.05)	51.119	43.375	0.587	0.088	5.041	NS	0.210	0.169	0.45

increase is related to the increase of light harvesting complex (Light Harvesting Complex II) and the enlargement of the antenna in photosystem II which resulted in increased light capture efficiency. In leaves of plants grown under lower light intensities, the plastid was limited in number and they are arranged at right angles to the light rays and were larger in size thus increasing the area of light absorption. Araki *et al.* (2014) studied the impact of shading on growth and photosynthetic efficiency in green gram and reported that plants under shade treatment showed an increased amount of chlorophyll content per unit leaf area.

Effect on treatments on seed yield

The perusal of data on grain yield revealed significantly higher seed yield by the variety DBGV 5 with 1183.33 kg ha^{-1} (Fig 2); followed by VBN 5 (916.67 kg ha^{-1}) and Sumanjana (906.67 kg ha^{-1}) under shading stress. These varieties were found tolerant to shading stress which could be recommended as suitable for intercropping in coconut garden which a light intensity ranging 40-46.5 Klux. Higher seed yields in these three varieties could be attributed to its better growth characters such as taller plants, more number of branches and leaves per plant, high leaf area index as

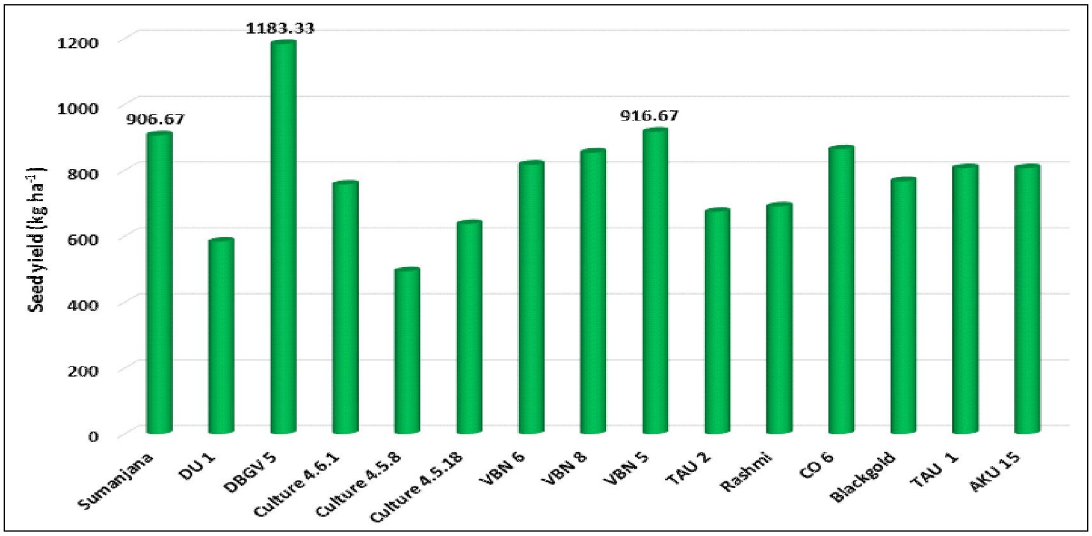

Fig 2: Effect of varieties and cultures on seed yield (kg ha^{-1}).

Table 3. Effect of correlation on growth, physiological and seed yield of blackgram under partially shaded condition.

	Plant height (1 MAS)	Plant height 2 MAS)	(Plant height(at harvest)	Number of leaves (1 MAS)	Number of leaves (2 MAS)	Number of leaves (at harvest)	LAI	Total chlorophyll	WUE	Photo-synthetic rate	Seed yield
Plant height (1 MAS)	1.000										
Plant height (2 MAS)	0.708**	1.000									
Plant height (at harvest)	0.682**	0.904**	1.000								
Number of leaves (1 MAS)	0.802**	0.589**	0.582**	1.000							
Number of leaves (2 MAS)	0.297*	0.343*	0.272^{NS}	0.137^{NS}	1.000						
Number of leaves (at harvest)	-0.215^{NS}	-0.363*	-0.262^{NS}	-0.274^{NS}	0.230^{NS}	1.000					
LAI	0.516**	0.492**	0.538**	0.493**	0.548**	0.088^{NS}	1.000				
Total chlorophyll	0.063^{NS}	0.141^{NS}	0.233^{NS}	0.032^{NS}	-0.085^{NS}	-0.083^{NS}	0.104^{NS}	1.000			
Photosynthetic rate	0.417**	0.407**	0.554**	0.332*	0.362*	0.293^{NS}	0.632**	0.243^{NS}	1.000		
WUE	0.113^{NS}	0.164^{NS}	0.027^{NS}	0.213^{NS}	-0.071^{NS}	-0.364*	-0.039^{NS}	-0.036^{NS}	-0.602**	1.000	
Seed yield	0.561**	0.611**	0.641**	0.587**	0.059^{NS}	-0.388**	0.305*	0.335*	0.366*	0.147^{NS}	1.000

* Significant at 1% ** Significant at 5%

well as physiological characters such as total chlorophyll content, more stomatal frequency in abaxial surface, higher photosynthetic rate and water use efficiency. More assimilate area might have increased the photosynthetic area and increased the sink activity. Seed yield of grain legume is generally related to physiological characters like leaf area index and photosynthetic efficiency (Johnson and Pendleton, 1968 in soybean, Flinn and Pate, 1970 in field peas). As suggested by Babu *et al.* (1985) in blackgram, leaf photosynthesis is one of the basic physiological attributes upon which plant biomass production depends. More influx of photosynthetic assimilates might have reached reproductive parts which ultimately resulted in highest yield of blackgram variety DBGV 5 followed by VBN 5 and Sumanjana. Hence it could be confirmed that plant height, leaf area index, total chlorophyll content and photosynthetic rate could be considered as indicators for shade tolerance in blackgram.

Correlation analysis of growth, physiological and yield attributes and yield are presented in Table 3. It was found that seed yield was significantly and positively correlated with plant height at 1, 2 MAS and at harvest, number of leaves at 1 MAS, LAI, photosynthetic rate and water use efficiency at flowering. Association of plant height and number of leaves with seed yield was significant and positive at the phenotypic levels reported by Tabasum *et al.* (2010) and Parihar *et al.* (2018). Increased yield due to higher LAI and photosynthetic rate in soybean was reported by Fan *et al.* (2019). Hence it is evident that the morpho physiological characters have direct influence in contributing the yield of blackgram under low light intensity.

CONCLUSION

The study revealed that the blackgram variety DBGV 5 performed better in terms of morphological and physiological characters and recorded superior yield followed by VBN 5 and Sumanjana which projects the capacity of these varieties to tolerate partial shade in coconut gardens. Hence it can be concluded that DBGV 5, VBN 5 and Sumanjana could be successfully raised as intercrop in the leftover space of coconut gardens for superior performance and better utilization of available space and obtaining additional income from the intercropping system in coconut gardens.

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