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Physiological Response of Blackgram Varieties to Foliar Nutrition and Growth Regulators under Partial Shade in Coconut Orchard in Kerala

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ABSTRACT

Background: Coconut is one of the major plantation crops in Kerala which are planted at a wider spacing of 7.6 m × 7.6 m giving an ample opportunity for growing intercrops. To enhance soil fertility and productivity of crops inclusion of legumes is a viable option. Blackgram, though a shade sensitive crop performs well in partially shaded coconut gardens due to fast growing nature. The unique ability of biological nitrogen fixation, soil amelioration, carbon sequestration, low water requirement and capacity to withstand extreme drought, pulses have remained an integral component of coconut based cropping system. Since blackgram is a shade sensitive crop, to increase the productivity of blackgram in coconut garden, foliar spray of nutrients and growth regulators is a viable option. Under, shaded or stressed situations, nutrients and plant growth regulators provide optimum vegetative growth by regulating plant growth and architecture. The primary objective of the present study was to investigate the impact of foliar nutrition and growth regulator application on the physiology and yield of different blackgram varieties.

Methods: A field trial was conducted at College of Agriculture, Vellayani, Kerala, India during *rabi* 2020 and *summer* 2020-21. To find the performance of five blackgram varieties. The treatments consisted of five performing blackgram varieties under partial shade *viz*; *Sumanjana,* DBGV 5, VBN 5, VBN 6, CO 6 and foliar sprays of nutrients (19:19:19 NPK, sulphate of potash) and plant growth regulators [naphthalene acetic acid (NAA) and salicylic acid (SA)] alone and in combinations in split plot design at 45 and 60 days after sowing (DAS).

Result: The study identified *Sumanjana* and DBGV 5 as shade adaptive varieties with suitable physiological traits. In both seasons, a higher stomatal conductance and lower stomatal index were observed, indicating a more efficient allocation of resources towards the photosynthetic machinery. Foliar spray of 19:19:19 (1%) and NAA at 40 mg/L and SA at 100 mg/L at 45 and 60 DAS resulted in higher seed yield, dry matter production and also higher net income and benefit cost ratio for these two varieties.

Key words: Blackgram, Coconut garden, Shade, Varieties, Yield.

INTRODUCTION

Among pulses, black gram 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% of total pulse area and 10% of total pulse production in the country. It is also adapted to be used as a catch crop as well as a contingency crop. To encourage and extend black gram cultivation in the prevailing situation of land fragmentation and low availability of cultivable lands in the state of Kerala, India, inclusion of blackgram in coconut gardens as an intercrop is a practical solution. Availability of variety with appreciable grain yield and shade tolerance is common limitation in the popularization of blackgram cultivation in coconut garden.

There are varietal constraints leading to low productivity of blackgram along with other climatic and agronomic constraints. Among fertilizer application practices, foliar application of nutrients is a low-budget, yet effective method. Selection of suitable varieties to the situation coupled with foliar application of nutrients and/or growth regulators can improve the productivity of blackgram. Research works on the effect of foliar application of nutrients and growth regulators to enhance the productivity of blackgram under partial shade is meagre. They also enhance the source-sink relationship and stimulate photo-assimilate translocation thereby helping in effective flower formation, fruit and seed development, ultimately enhancing the productivity of crops. In this backdrop, the current study aimed to assess how foliar nutrition and plant growth regulators affect the physiology and yield of shade-tolerant blackgram varieties that were identified for this purpose.

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MATERIALS AND METHODS

The field trial was conducted at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during *rabi* 2020 and *summer* 2020-21 in partially shaded coconut garden. 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. Soil of the experimental site was sandy clay loam in texture, belonging to the order Oxisols under Vellayani series. The soil was acidic in reaction (pH-6.1), with high organic carbon content (0.92 %), low in N (188.16 kg ha^{-1}), high in P (31.25 kg ha^{-1}) and high in K (340.14 kg ha^{-1}). The total rainfall received during *rabi* 2020 and *summer* 2020-21 was 288.6 mm and 237.1 mm respectively. The experiment was laid out in split plot design, replicated four times with five varieties (v_1- Sumanjana, v_2- DBGV 5, v_3- VBN 5, v_4- VBN 6, v_5- CO 6). These varieties were selected after a preliminary screening under the partial shade in coconut garden in terms of yield per unit area (Pooja *et al.,* 2021) for the main plot treatments. The duration of blackgram varieties in the shaded condition ranged between 90 to 110 days, which were more than that of open condition in general. Six foliar sprays of nutrients with and without plant growth regulators were the subplot treatments (f_1: 19:19:19 (1%) at 45 and 60 DAS, f_2: SOP (0.5%) at 45 and 60 DAS, f_3: NAA 40 mg L^{-1} and salicylic acid 100 mg L^{-1} at pre-flowering (45 DAS) and 15 days later, f_4: $f_3 + f_1$, f_5: $f_3 + f_2$ and f_6: Control - KAU POP).

Coconut gardens above 40 years of age having a light intensity between 40-46.5 klux, planted at spacing of 7.6 m × 7.6 m was selected and a distance of two-meter radius was left from the base of each coconut palm and beds of size 6 m length and 3 m width were taken as main plots in the interspace between coconut palms. The main plot was later divided into sub plots of size 3 m × 1 m and the seeds of blackgram and were sown at a spacing of 25 cm × 15 cm. The recommended nutrients (20:30:30 kg N: P_2O_5: K_2O ha^{-1}) was given through urea, rajphos and muriate of potash (KAU, 2016). Foliar spray of nutrients and plant growth regulators were done as per the treatments fixed. The foliar spray at 45 DAS coincided with the flower initiation stage and 60 DAS coincided with the completion of flowering and initiation of pod formation stage.

Plant protection measures were taken as and when required. Tobacco caterpillar (*Spodoptera litura*) incidence noticed at 20 DAS was controlled using quinolphos 25 EC (KRUSH) @ 2 mL L^{-1} and the incidence of spotted pod borer (*Maruca vitrata*) at pod maturity stage was controlled using chlorantraniliprole 18.5 SC (CORRAGEN®) @ 3 mL 10 L^{-1} and thiomethoxam (ACTARA 25% WG) @ 0.25 mL L^{-1}. Collar rot disease caused by *Rhizoctonia solani* was managed by spraying carbendazim (BAVISTIN 50 WP) @ 1 g L^{-1}. Data on physiological characters *viz.,* leaf area index, chlorophyll content, stomatal index, stomatal conductance, soluble protein at 50% flowering were recorded from the observational plants and averages worked out. Harvest of pods was completed with three pickings. One day prior to harvest, the observational plants were pulled out and the yield attributing characters and root characters were recorded. The dry pods from individual net plot area were picked, sun dried and threshed separately to determine seed yield. The data was analysed statistically by analysis of variance (ANOVA) for split plot design and the significance was tested by F test.

RESULTS AND DISCUSSION

Physiological characters

Leaf area index was higher during summer compared to *Rabi* season (Table 1). Plants adapt to shading stress by increasing leaf area expansion for maximizing light interception. The varieties Sumanjana and CO 6 recorded higher values of LAI during both the seasons, due to the higher number of leaves recorded in these varieties. Higher leaf area is an adaptation to capture irradiance more efficiently under shaded situation for tolerant varieties, which could contribute to better photosynthesis. Sumanjana and CO 6 were found to be shade adaptive with higher LAI to compensate shade induced reduction in photosynthesis. The foliar application had a significant impact on leaf production and plants treated with major nutrients and plant growth regulators (PGR) showed superior performance in terms of leaf area index (LAI) during both seasons. This improvement could be attributed to the increased availability of nutrients from readily soluble fertilizer used in the foliar spray. Growth promoting substances such as NAA at 20 ppm had a positive effect on cell division and cell elongation leading to enhanced leaf expansion.

Among the interaction effects of varieties and foliar sprays, Sumanjana supplied with 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) recorded higher LAI and was on par with v_5f_3 and v_5f_5 during summer season. In the *Rabi* season, v_1f_4, v_2f_4 and v_3f_4 were on par. Foliar application of fertilizers and PGRs improved the vegetative growth of the plant which contributed to higher LAI and improved photosynthetic efficiency. These results are in accordance with the findings of Dey *et al.* (2017) in mung bean. The higher leaf area index (LAI) observed in the plants could be attributed to the active role of auxins in promoting cell division and cell elongation. The positive influence of foliar spray of nutrients using mineral fertilizers could enhance nutrient availability, which in turn promotes cell division, cell elongation and overall crop growth and development.

Chlorophyll content

The results revealed that the chlorophyll content varied significantly among the varieties during both the seasons. During summer, the highest chlorophyll content was recorded by the variety DBGV 5 (1.96 mg g^{-1} fresh tissue) while during *Rabi*, Sumanjana recorded the same (2.36 mg g^{-1} fresh tissue). This observation could be attributed to the fact that leaves grown under shaded conditions tend to have

Table 1: Effect of varieties and foliar application on seed yield of black gram during *summer* 2020 and *Rabi* 2021.

Treatments	*Summer* 2020					*Rabi* 2020-21				
	LAI	Chlorophyll content (mg g^{-1} FW)	Stomatal index (%)	Stomatal conductance (m moles m^{-2} s^{-1})	Soluble protein (mg g^{-1} FW)	LAI	Chlorophyll content (mg g^{-1} FW)	Stomatal index (%)	Stomatal conductance (m moles m^{-2} s^{-1})	Soluble protein (mg g^{-1} FW)
Main plot- varieties (V)										
v_1- Sumanjana	5.42	1.91	15.16	30.22	17.66	5.02	2.36	13.34	28.34	17.17
v_2- DBGV 5	3.84	1.96	16.81	29.04	17.91	4.89	2.27	14.98	21.86	16.86
v_3- VBN 5	4.68	1.57	17.21	24.04	17.66	4.60	1.88	15.34	24.58	16.66
v_4- VBN 6	5.27	1.51	20.75	23.07	17.48	5.06	1.82	16.40	26.06	16.73
v_5- CO 6	5.60	1.70	18.89	26.05	17.24	5.08	2.04	16.07	27.5	16.75
SEm±	0.07	0.02	0.20	0.38	0.20	0.07	0.06	0.33	0.21	0.25
CD (0.05)	0.219	0.048	0.857	1.011	NS	0.207	0.021	1.035	0.653	NS
Sub plot- foliar spray (F)										
f_1- 19:19:19 @ 1%	4.79	1.70	17.91	25.99	17.73	4.45	2.03	14.93	25.15	16.67
f_2- SOP @ 0.5%	4.64	1.62	18.52	24.84	17.46	4.89	1.94	15.18	24.36	16.91
f_3- NAA 40 mg L^{-1} and SA 100 mg L^{-1}	4.98	1.80	18.16	27.68	17.41	5.23	2.17	15.63	24.95	16.79
f_4- f_3 + f_1	5.59	1.88	17.70	28.84	17.85	5.55	2.25	15.61	29.46	17.25
f_5- f_3 + f_2	5.32	1.81	18.04	27.72	17.64	5.11	2.17	15.26	26.69	16.66
f_6- Control (KAU POP)	4.46	1.55	17.96	23.83	17.46	4.35	1.89	14.76	23.38	16.71
SEm±	0.22	0.23	0.21	0.33	0.25	0.06	0.028	0.31	0.33	0.510
CD (0.05)	0.077	0.064	0.600	0.920	NS	0.021	0.078	NS	0.945	NS

a higher concentration of chlorophyll per unit of fresh mass. The increased chlorophyll content in shaded leaves led to enhanced photosynthetic efficiency. Kaleeswari *et al*. (2022) observed that with the increasing N levels in blackgram, leaf chlorophyll and nitrogen content increased linearly. The subplot factor f_4 recorded higher chlorophyll content during both the seasons. The enhanced absorption and translocation of nutrients through foliar application could have contributed to increased chlorophyll synthesis and improved photosynthetic activity. This, in turn, can lead to higher efficiency in converting light energy into chemical energy, ultimately promoting better growth and productivity in plants. The increase in chlorophyll content reflects increased PS II photochemistry, photosynthates production and dry matter accumulation. Foliar application of salicylic acid influenced different physiological and biochemical aspects of green gram plant via increasing assimilation rate which revealed increase in chlorophyll content and hill reaction activity in the leaf. The treatment combination v_1f_4 recorded the highest chlorophyll that can augment the rate of photosynthesis for better accumulation of photoassimilates.

Stomatal index

It is the number of stomata compared to total number of epidermal cells expressed in percentage. Crops with lower stomatal index are preferred as they reduce transpiration rate and improve photosynthetic rate to the optimum. Sumanjana recorded the lowest stomatal index during both the seasons which could be inferred as a more efficient investment in photosynthetic machinery. Foliar spray significantly influenced stomatal index and f_4 recorded lower stomatal index in summer. The observed effects could be attributed to the influence of foliar spray of salicylic acid, which can alter the balance of endogenous hormones in plants. This hormonal modulation may induce stomatal closure, reduce transpiration rates and ultimately improve the photosynthetic capacity of the plants. By reducing water loss through transpiration, the plants can maintain optimal leaf hydration and enhance their photosynthetic efficiency, leading to increased photosynthate production and subsequent dry matter accumulation. The lower stomatal index was recorded in v_1f_4 and was on par with v_1f_3 and v_1f_5. Similar results of lower stomatal index due to foliar spray of NAA was also reported by Jahan and Yasmin (2017).

Stomatal conductance

It is the ability of stomata for gaseous exchange. During both the seasons, Sumanjana consistently exhibited the highest stomatal conductance during the flowering stage. This suggested that Sumanjana had a higher rate of gas exchange, allowing for efficient uptake of carbon dioxide and release of oxygen without significant loss of photosynthetic productivity. As a result, these plants were able to express their genetic potential and achieve optimal growth and development even under partial shade. Foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in higher stomatal conductance during both the seasons. Increased stomatal conductance with foliar spray of salicylic acid was earlier reported by (Khan *et al.,* 2010). The main plot and subplot effect was reflected in interaction with v_1f_4 having the highest stomatal conductance during both the seasons. The content of soluble protein was unaffected due to main effects and interaction effects during both the seasons. However, the content was higher during the summer season compared to *Rabi* season.

Yield

The cumulative effect of growth attributing characters was manifested in the final yield, which showed considerable variation across different varieties in both seasons (Table 2). Both Sumanjana and DBGV 5 exhibited higher seed yield per plant in both seasons. The foliar spray also significantly affected the seed yield per plant and foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in the highest seed yield per plant, during both the seasons. The control treatment as per KAU package was having the lowest seed yield per plant during both the seasons.

Among the treatment combinations, higher seed yield was produced by Sumanjana and DBGV 5 along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later. The increased yield might be attributed to the balanced export of nutrients during critical stages, such as flowering and fruit setting, along with the use of growth regulators that promote greater flower retention. The availability of nitrogenous fertilizers promoted photosynthesis, leading to enhanced utilization of photosynthates and an increased allocation of these resources towards the economically valuable parts of the plant. This observation aligns with the current findings. Sarkar *et al*. (2021) documented that foliar fertilization is best suited for *Rabi* pulses rather than top dressing or placement of fertilizers.

Sumanjana and DBGV 5 recorded higher seed yield/ha during both the seasons. The subplot treatment of foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) revealed the highest seed yield ha^{-1} during both the seasons. Reducing the abortion rate could have significantly increased the number pods per plant and number of seeds per pod in soybean as observed by (Khatun *et al*., 2016). Reduced flower drop and increased pod set percentage due to the foliar application of nutrients might have increased seed yield of pulses.

Main and subplot effects were reflected in the interaction and higher seed yield was recorded in Sumanjana along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) and was on par with DBGV 5 along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_2f_4) in the summer season. During *Rabi* season, the highest seed was recorded in v_1f_4 followed by

Table 2: Effect of varieties and foliar application on seed yield and dry matter production of blackgram during *summer* 2020 and *Rabi* 2021.

Treatment	*Summer* 2020				*Rabi* 2020-21				Pooled mean seed yield (kg ha^{-1})
	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	TDMP (kg ha^{-1})	Harvest index	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	TDMP (kg ha^{-1})	Harvest index	
Main plot- varieties (V)									
v_1- Sumanjana	1530	3513	5028	0.30	1447	3472	4900	0.29	1489
v_2- DBGV 5	1501	3534	5020	0.30	1446	3440	4865	0.30	1473
v_3- VBN 5	1259	2832	4076	0.31	1230	2823	4033	0.30	1244
v_4- VBN 6	1203	2497	3685	0.33	1176	2486	3642	0.32	1189
v_5- CO 6	1367	2841	4192	0.33	1314	2783	4077	0.32	1341
SEm(±)	13.8	32.2	35.9	0.01	22.3	44.9	39.82	0.01	12.9
CD (0.05)	42.44	99.24	110.79	NS	68.76	138.50	122.710	NS	37.29
Sub plot- foliar spray (F)									
f_1- 19:19:19 @ 1%	1319	2913	4216	0.31	1279.77	2855	4135	0.31	1299
f_2- SOP @ 0.5%	1288	2963	4236	0.31	1246.81	2873	4120	0.30	1267
f_3- NAA 40 mg L^{-1} and SA 100 mg L^{-1}	1419	3172	4576	0.31	1365.95	3071	4437	0.31	1392
f_4- $f_3 + f_1$	1536	3314	4835	0.32	1473.51	3313	4786	0.31	1505
f_5- $f_3 + f_2$	1439	3117	4542	0.32	1387.43	3011	4399	0.31	1413
f_6- control (KAU POP)	1230	2781	3997	0.31	1181.88	2762	3944	0.30	1206
Sem (±)	18.8	40.8	44.4	0.01	18.36	41.3	47.6	0.04	13.0
CD (0.05)	52.96	99.24	125.15	NS	51.728	116.24	133.99	NS	36.30

v_2f_4. Foliar nutrients usually penetrate the leaf cuticle or stomata and enter the cells facilitating the easy entry of nutrients. The increase in the number of pods per plant and seed yield per plant could be attributed to the effective fulfilment of crop demand through higher assimilation and translocation of photosynthates from source (leaves) to sink (pods). This process was facilitated by the foliar spray of 19:19:19, with a balanced ratio providing the required nutrients for optimal growth.

Pooled analysis on seed yield revealed Sumanjana and DBGV 5 to be better performers under partial shade with seed yield of 1489 kg ha^{-1} and 1473 kg ha^{-1} respectively. The subplot factor f_4 recorded the highest seed yield (1505 kg ha^{-1}). The combination of main and subplot factors as v_1f_4 recorded the highest seed yield (1725 kg ha^{-1}) followed by v_2f_4 (1626 kg ha^{-1}) which is deduced to be due to the positive interaction of individual effects (Fig 1). Better crop growth enhanced the absorption of nutrients through root and enhanced the synthesis of IAA, carbohydrate and N metabolism which ultimately led to higher economic yield. The production of higher seed yield due to nutrients and growth regulators could be attributed to the fact that plants treated with macro nutrients and growth regulators remained physiologically more active to build up sufficient food reserves for the developing flowers and seeds.

Among the treatment combinations, Sumanjana (v_1) with f_4 produced higher LAI, chlorophyll content and stomatal conductance, at flowering during summer and *Rabi.* LAI, Higher measure of leafiness of the crop in relation to land area (LAI) resulted in increased photosynthetic efficiency coupled with increased capacity of utilization of photo accumulates by the growing tissues and their utilization reflected in the yield attributes. The enhanced chlorophyll content indicated an improved capacity for light absorption, while increased stomatal conductance suggested better CO_2 uptake. These factors combined enhanced the efficiency of photosynthesis, resulting in an increased production of photosynthates. Higher source capacity along with better translocation and partitioning to the reproductive sinks might have contributed final yield of shade tolerant varieties in this experiment.

A correlation analysis was done to examine the linear relationships among physiological parameters with yield (Table 3a and 3b). The analysis revealed that seed yield had a significant and positive correlation with chlorophyll content and stomatal conductance during the summer, while with chlorophyll content alone during the *Rabi* season. The significant association between chlorophyll content and seed yield at the phenotypic levels was reported by (Baroowa *et al*., 2015). On the other hand, the stomatal index showed a significant negative correlation with seed yield during the summer and had a weak correlation during the *Rabi* season. This suggests that the physiological characteristics, namely chlorophyll content and stomatal conductance, directly influenced the yield of blackgram under conditions of low light intensity.

Table 3a: Effect of correlation on physiology, seed yield, haulm yield and TDMP of blackgram during summer 2020.

	Leaf area index	Chlorophyll content (mg g^{-1})	Stomatal index (%)	Stomatal conductance (m moles m^{-2} s^{-1})	Soluble protein (mg g^{-1} FW)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	TDMP (kg ha^{-1})
Leaf area index	1							
Chlorophyll content (mg g^{-1})	0.021^{NS}	1						
Stomatal index (%)	0.146^{NS}	-0.525**	1					
Stomatal conductance (m moles m^{-2} s^{-1})	0.089^{NS}	0.947**	-0.510**	1				
Soluble protein (mg g^{-1} FW)	-0.299^{NS}	0.312^{NS}	-0.313^{NS}	0.227^{NS}	1			
Seed yield (kg ha^{-1})	0.156^{NS}	0.935**	-0.479**	0.943**	0.213^{NS}	1		
Haulm yield (kg ha^{-1})	-0.148^{NS}	0.916**	-0.609**	0.909**	0.280^{NS}	0.908**	1	
TDMP (kg ha^{-1})	-0.068^{NS}	0.938**	-0.585**	0.935**	0.267^{NS}	0.950**	0.993**	1

Table 3b: Effect of correlation on physiology, seed yield, haulm yield and TDMP of blackgram during *Rabi* 2020-21.

	Leaf area index	Chlorophyll content (mg g^{-1})	Stomatal index (%)	Stomatal conductance (m moles m^{-2} s^{-1})	Soluble protein (mg g^{-1} FW)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	TDMP (kg ha^{-1})
Leaf area index	1							
Chlorophyll content (mg g^{-1})	0.417*	1						
Stomatal index (%)	0.131^{NS}	-0.404*	1					
Stomatal conductance (m moles m^{-2} s^{-1})	0.522**	0.207^{NS}	-0.051^{NS}	1				
Soluble protein (mg g^{-1} FW)	0.438*	0.409*	-0.350^{NS}	0.366*	1			
Seed yield (kg ha^{-1})	0.475**	0.947**	-0.320^{NS}	0.272^{NS}	0.398*	1		
Haulm yield (kg ha^{-1})	0.192^{NS}	0.832**	-0.539**	0.057^{NS}	0.427*	0.799**	1	
TDMP (kg ha^{-1})	0.345^{NS}	0.938**	-0.474**	0.168^{NS}	0.447*	0.940**	0.920**	1

Economic analysis

The economic analysis for the different combinations revealed that the varieties Sumanjana (v_1) or DBGV 5 (v_2) supplied with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) found to be profitable recording higher gross returns, net returns and benefit cost ratio (BCR) during both the seasons (Table 4). The higher

Table 4: Effect of varieties and foliar application on economics.

Treatments	Cost of cultivation (` ha^{-1})	*Summer* 2020			*Rabi* 2020-21			Mean net income (` ha^{-1})	Mean BCR
		Gross income (` ha^{-1})	Net income (` ha^{-1})	BCR (` ha^{-1})	Gross income	Net income	BCR (` ha^{-1})		
v_1f_1	61974	117920	55946	1.90	112147	50173	1.81	53060	1.86
v_1f_2	61499	111938	50440	1.82	110318	48820	1.79	49630	1.81
v_1f_3	62742	121982	59240	1.94	113142	50400	1.80	54820	1.87
v_1f_4	67592	139976	72384	2.07	136031	68439	2.01	70411	2.04
v_1f_5	67117	129440	62323	1.93	120553	53435	1.80	57879	1.87
v_1f_6	56284	113192	56908	1.92	97441	41157	1.73	49033	1.83
v_2f_1	61974	120247	58273	1.94	114183	52209	1.84	55241	1.89
v_2f_2	61499	115798	54300	1.88	114066	52567	1.85	53433	1.87
v_2f_3	62742	121982	59240	1.94	119074	54332	1.80	57786	1.87
v_2f_4	68532	137077	68544	2.00	123040	56508	1.90	61526	1.95
v_2f_5	68057	123083	55026	1.81	122195	54138	1.80	54582	1.81
v_2f_6	56284	102206	45923	1.82	101313	45029	1.80	45476	1.81
v_3f_1	61974	94506	32533	1.52	93666	31693	1.51	32113	1.52
v_3f_2	61499	91946	30448	1.50	90753	29254	1.48	29851	1.49
v_3f_3	62742	109866	47124	1.75	105183	42441	1.68	44782	1.72
v_3f_4	68532	111360	42828	1.62	109070	40537	1.59	41682	1.61
v_3f_5	68057	103803	35746	1.53	101368	33311	1.49	34528	1.51
v_3f_6	56284	92843	36559	1.65	90336	34052	1.61	35306	1.63
v_4f_1	61974	88036	26062	1.42	87630	25657	1.41	25859	1.42
v_4f_2	61499	95957	34458	1.56	87006	25507	1.41	29982	1.49
v_4f_3	62742	104716	41974	1.67	97414	34671	1.55	38322	1.61
v_4f_4	68532	101444	32912	1.48	102617	34084	1.50	33498	1.49
v_4f_5	68057	104106	36049	1.53	99911	31854	1.47	33951	1.50
v_4f_6	56284	83251	26967	1.48	89722	33439	1.59	30203	1.54
v_5f_1	61974	106880	44906	1.72	104282	42309	1.68	43607	1.70
v_5f_2	61499	99626	38128	1.62	96581	35082	1.57	36605	1.60
v_5f_3	62742	108965	46222	1.74	111567	48825	1.78	47524	1.76
v_5f_4	68532	124575	56043	1.82	118645	50112	1.73	53078	1.78
v_5f_5	68057	115321	47263	1.69	110943	42886	1.63	45075	1.66
v_5f_6	56284	100662	44378	1.79	88850	32567	1.58	38472	1.69

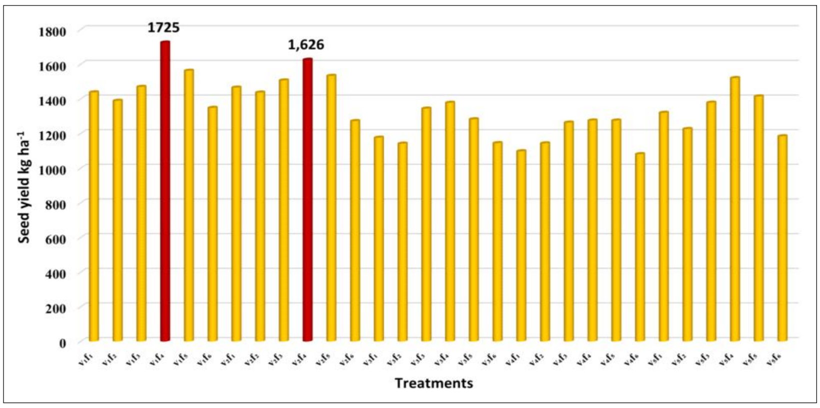

Fig 1: Interaction effect of varieties and foliar spray of nutrients and plant growth regulators on pooled seed yield.

economic benefits could be attributed to the higher seed yields realized, the treatments being the cumulative effects of the varieties and application of foliar nutrients and plant growth regulators.

Mean values of net return (` 70411 $ha^{-1}$) and B: C ratio (2.04) were also the highest for the treatment $v_1f_4$, followed by the $v_2f_4$. The treatment combination $v_1f_4$ and $v_2f_4$ produced ` 21378 and ` 16050 as additional mean net income compared to its respective controls. There was 30.36 percent and 26.09 percent increase in net income in v_1f_4 and v_2f_4 compared to control (v_1f_6 and v_2f_6 respectively). Mamathasree (2014) and Kumar *et al*. (2018) obtained higher net returns and BCR in red gram and blackgram respectively due to foliar application of water-soluble fertilizer 19:19:19 at 2 per cent at flowering and pod development stages. Yalagar *et al*. (2021) also found that, application of recommended nutrients to pigeonpea coupled with foliar spray of 19:19:19 (1%) at flower initiation and peak flowering stage is optimum for higher net returns (` 65908 $ha^{-1}$) and BCR (3.49). Shwetha *et al.* (2021) registered higher net return (` 161,159 ha^{-1}) and B:C ratio (4.19) in pigeon pea due to the foliar application of pulse magic (1%) + 19:19:19 (1%) + 50 ppm NAA + Borax (0.2%).

CONCLUSION

The study demonstrated that foliar spray had a significant impact on leaf production in blackgram and shade adaptive varieties treated with a combination of major nutrients and plant growth regulators exhibited superior physiological characteristics and yield. The present study revealed that, the varieties DBGV 5 and Sumanjana, could perform better under partially shaded coconut garden. Higher yield could be realized in these varieties under partial shade with recommended dose of KAU POP supplemented with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering (35 DAS) and 15 days later. Sumanjana and DBGV 5 with f_4 recorded higher mean net income and mean B:C ratio.

Conflict of interest

There is no conflict of interest among authors in publication.

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