RESPONSE OF BLACKGRAM VARIETIES AS AFFECTED BY DIFFERENT PLANT SPACING (VIGNA MUNGO).

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RESPONSE OF BLACKGRAM VARIETIES AS AFFECTED BY DIFFERENT PLANT SPACING

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CERTIFICATE

*This is to certify that the thesis entitled, "**RESPONSE OF BLACKGRAM VARIETIES AS AFFECTED BY DIFFERENT PLANT SPACING**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **KAMILIYA KADER,** Registration no.**19-10396** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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RESPONSE OF BLACKGRAM VARIETIES AS AFFECTED BY DIFFERENT PLANT SPACING

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from March to June 2021 in Kharif I season, to study the response of blackgram varieties and different plant spacing. The experiment consisted of two factors, and followed split plot design with three replications. Factor A:Blackgram varieties (3)*viz*:V_1-BARI Mash 2, V_2-BARI Mash 3, V_3-BARI Mash 4 and Factor B: Different plant spacing (4) *viz*: S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm. Experimental results revealed that different varieties and plant spacing significantly influenced the yield and yield contributing parameters of blackgram. In case of different blackgram varieties the maximum seed yield (1.49t ha-^{1}) was recorded from BARI Mash-3 (V_2)treatment and lowest seed yield (0.96 t ha^{-1}) was obtained from V_1 treatment (BARI Mash-2).The highest yield with BARI Mash-3 (V_2) was attributed due to the highest pods plant^{-1} (6.52), pod length(5.22 cm), seeds pod^{-1} (7.78), 1000-seed weight(42.76 g), biological yield (3.25 t ha^{-1}) and harvest index (45.53 %).However in case of different plant spacing the seed yield ranges between (0.92 -1.46 t ha^{-1}). The highest seed yield (1.46 t ha^{-1}) was recorded in S_4 (30 cm × 15 cm) treatment which was achieved with maximum pods plant^{-1} (6.67), pod length(5.36 cm), seeds pod^{-1} (7.40) and 1000-seed weight(44.11 g).In case of combination, cultivation of BARI Mash-3 (V_2) along with 30 cm × 15 cm spacing (S_4) affected plant growth and yield-contributing characteristics, leading to the maximum seed yield (1.80 t ha^{-1}) compared to other treatment combinations. Therefore, it is suggested that cultivation of BARI Mash-3 along with 30 cm × 15 cm spacing (V_2S_4) could be as optimum in crop management for maximum yield harvest in blackgram.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Ag.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotech.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entom.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

The agricultural industry, which employs 37.98 % of the population overall and contributes roughly 11.63 % of GDP, is the backbone of Bangladesh's economy (BER, 2022). Pulses are a crucial component of the human diet and could be a source of protein for the millions of people of Bangladesh. Pulses are recognized to lessen various non-communicable diseases like colon cancer and cardiovascular disorders and offer considerable nutritional and health benefits (Lukus*et al*., 2020). They contribute 2.3% value added to agriculture in Bangladesh (Rahman, 2017). As the least expensive form of protein, pulses are known as "the meat of the poor." (Jackson*et al*., 2021).Pulses are popular and common food, people take this food almost alternate a day, so, this can play an important role to reduce the malnutrition for the poor people of the country. The per capita consumption of pulse in Bangladesh is only 14.3 g day-^{1},which is far less than the WHO's recommendation of 45 g and the Indian Council of Medical Research's recommendation of 60 g. (Mohiuddin*et al*., 2018).

Farmers can ensure to decrease their poverty by increasing the production of nutrient-rich crops like more pulses and oilseeds. This will also boost nutritional food security (Singh, 2018).Among the pulses, blackgram is one of the most consumed pulses in Bangladesh and is the third most widely grown crop there in terms of both total cultivated area and consumption (BBS, 2021).Having high concentrations of protein (25 g), potassium (983 mg), calcium (138 mg), iron (7.57 mg), niacin (1.447 mg), thiamine (0.273 mg), and riboflavin (0.254 mg) per 100g, blackgram is particularly nutrient-dense crop. Among the pulses, 45-50 % area covered by black gram in Jamalpur and 75-80% area in Sherpur districts. Total cultivated area in Bangladesh is 9805360 hectares of which 44.63%, 18.28% and 10.20% are suitable, moderately suitable and marginally suitable respectively for blackgram production (Mohiuddin *et al*., 2018).

The main constraints faced by blackgram grower were lack of irrigation facility, non availability of HYV seeds, low output price, labor scarcity, lack of knowledge about improved varieties with their production technology, excessive rainfall after flowering and weak research-extension farmers linkage etc. Farmers also experienced certain issues with marketing, such as a shortage of buyers, unstable prices, a lack of storage facilities, and a high market cost.

Blackgram, a leguminous crop, increased soil fertility and production while fixing atmospheric nitrogen for its growth and development. The availability of HYV seeds and their cultivation using the best agronomic management techniques determines the optimum growth and yield. Improved varieties of different pulse crops hold promise to increase productivity by 20-25%, whereas latest technology comprising varieties and integrated nutrients management and pests has shown 25-42% increase productivity (Pandey *et al*., 2022).Several high producing varieties, including BARI mash-1, BARI Mash-2, BARI Mash-3, and BARI Mash-4, were developed by the Bangladesh Agricultural Research Institute (BARI) (Islam*et al*., 2019).A number of blackgram cultivars have also been created by the Bangladesh Institute of Nuclear Agriculture (BINA). However, local varieties are typically grown by farmers, which has no impact on production. Thus yield should be increased through the wise selection of high producing varieties (Pandey *et al*., 2022).

Plant density can have a major effect on the final yield of most of the legumes and the general response of yield to increasing population is well documented. To realize the maximum yield potential of blackgram during summer and rainy season, maintenance of optimum space made available to individual plant is of prime importance. Row and plant spacing has to be worked out to get desired spacing (Veeramani, 2019). The spacing requirement depends upon the growth behaviour of genotype. Optimum spacing between rows is required to utilize efficiently the available production factors such as moisture, nutrients, sunlight and space which impact on seed yield (Amare and Gebremedhin, 2020). However, the farmers do not follow the above recommendations for crop establishment mainly due to labor shortage as labor demand for rice cultivation is higher during the same period. Therefore, farmers usually broadcast seeds on the harrowed land at different seed rates since there is no recommended package of practices for broadcast blackgram (Ekanayake *et al*., 2011).

Optimum plant density is a primary requirement for abetter crop growth in order to minimize intra-species competition (Zhang*et al*., 2021).So it is required to maintain spacing for obtaining higher yield (Veeramani, 2019).Keeping in view of the above facts, an experiment was planned and under taken on “Response of blackgram varieties as effected byplant spacing” with following objectives:

i. To evaluate the performance of varieties on growth and yield of blackgram
ii. To determine the effect of plant spacing on growth and yield of blackgram.
iii. To study the combined effect of varieties and plant spacing towards maximum yield of blackgram.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding the response of blackgram varieties as affected by sowing method to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of varieties

Subbulakshmi (2022) conducted a field experiments during 2014-15 in Rabi season (October - December) at Agricultural Research station, Kovilpatti to identify the optimum time of sowing and best suitable blackgram variety for rainfed vertisols. Experiment was laid out in split-plot design with three replications. The treatment combinations comprised of three dates of sowing viz., 39th, 41st and 43rd standard weeks (pre- monsoon, monsoon and post-monsoon sowing, respectively) in main plot with four different black gram varieties viz., Vamban (Bg) 6 and Vamban (Bg) 7, NUL 7 and CO 5 in the sub plot. The results revealed that among the varieties tried, CO 5 registered higher growth and yield attributes which reflected on increased grain yield (843 kg ha^{-1}) which was followed by NUL 7 (790 kg ha^{-1}).

Vishnu *et al.* (2022) conducted a study during summer 2021 at Department of Agronomy, Agricultural College and Research Institute, Madurai, Tamil Nadu to identify the influence of different levels of irrigation to meet the optimum crop water requirement of high yielding varieties. The experiment was carried out in split plot design with three irrigation regimes 100% ETc, 75% ETc, 50% ETc and five black gram varieties ADT 3, ADT 6, VBN 8, VBN 11, TBG 104 and each treatment was replicated thrice. Results indicated that, VBN 11 when irrigated based on 75% ETc recorded higher plant height (48.75 cm), number of branches per plant (19.08), leaf area index (4.02), SPAD values (48.60), pods per $plant^{-1}$ (42.62), seeds pod^{-1} (6.33) and 100 seed weight (4.70) with seed yield of 960 kg/ha and water use efficiency (2.87).

Kumar and Kumar (2021) carried out an investigate to study the effect of different dates of sowing on growth, yield attributes and yield of various cultivars of kharif blackgram (*Vigna mungo* L.) during kharif season 2019 at Student's Research Farm, Department of Agriculture, Khalsa College, Amritsar reported that among blackgram cultivars, the higher seed yield was observed in Mash 114 (10.19 q/ha) which was significantly 14% and 32% superior over Mash 338 and KUG 479 respectively. This variety also recorded higher number of pods/plant (23.6), seeds/pod (6.4) and seed weight/plant (3.2 g) comparable to other varieties.

Sunil *et al.* (2020) reported that among the varieties tested, evaluated, the check LBG 791 substantially recorded more branches (4.92) than KU 14-8. (1.68). The probable reason for this may be the genetically potential of the genotype that has helped in producing more number branches on blackgram variety.

Mane *et al.* (2018) reported that the blackgram variety BDU-1 was found to be highly productive as compared to TAU-1 and AKU-15. Variety BDU-1 produced maximum pods plant^{-1} i.e. 24.54 was significantly superior over variety TAU-1 i.e.23.77, and variety AKU-15 i.e. 21.83.

Patidar and Singh (2018) carried out a field experiment during rainy season of 2017 at the Instructional Farm, A.K.S. University, Satna (M.P.) to study the effect of varieties and dates of sowing on growth, yield and quality of black gram (*Vigna mungo* L) and reported that the variety T-9 recorded significantly higher growth and yield-attributes, yield and nutritional quality of blackgram. Amongst the four varieties, T-9 resulted in significantly taller plants (35.5 cm) over other varieties.

Siddikee *et al.* (2018) reported that among the blackgram varieties BARI Mash-3 produced the tallest plant (34.20, 43.82, 53.31, 57.93 and 60.95 cm) at 30, 45, 60, 75 DAS and at harvest respectively. In comparison, the shortest plant height (27.03, 37.37, 41.62, 43.89 and 46.93 cm) at 30, 45, 60, 75 DAS and at harvest respectively was recorded from local variety.

Jadhav *et al.* (2014) conducted a field experiment during Kharif season 2012-13 at experimental farm, AICRP on Water Management, MKV, Parbhani, to entitled the performance of blackgram [*Vigna mungo* (L.) Hepper] varieties to different sowing dates and reported that the mean total dry matter per plant was influenced due to black gram varieties. Variety BDU-1 Produce significantly more dry matter as compared to TAU-1 and TPU-4 at all growth stages. This might be due to higher biomass potential of the variety such differential dry matter production in different black gram variety

BDU-1 produced significantly more dry matter as compared to TAU-1 and TPU-4 at all growth stages.

Panotra *et al.* (2016) directed a field experiment at Agricultural Research Farm, Baruat, U.P during 2008 and 2009 to assess the performance of Black gram under different varieties (T-9, PU-19 and PU-35) and concluded that variety of black gram PU-35 produce maximum grain yield (11.07 qha-^{1}) followed by PU-19 (10.67 qha-^{1}) and minimum grain yield (10.33 qha-^{1}) was for T-9 variety.

Anitha *et al.* (2015) reported that the genotype IC398971 was found to be physiologically efficient even with water deficit stress and also recorded moderate seed yield. While the genotype PU-19 +with moderate physiological values registered highest seed yield under both well watered and water deficit stress conditions. Amongst seventeen genotypes, these two genotypes were tolerant to water deficit stress with better stability of physiological and yield parameters.

Sharma (2015) conducted the experiment laid out in randomized block design with three replications and 10 treatment combinations of five blackgram varieties i.e. JU-3, AKU 9802, RBU-38, KU96-3 and TPU-4 at two row spacings i.e. 30cm and 45cm.Variety KU 96-3 and RBU-38 produced higher values of growth and yield attributing parameters and seed and straw yields of black gram.

Pulp Sharma *et al*. (2012) carried out as experiment at Department of Plant Breeding and Genetics, Punjab Agriculture University, Ludhiana to evaluate the performance and growth analysis in blackgram and reyealed that blackgram genotype Mash-1 recorded highest biological yield (8313 kg ha^{-1}) over Mash338 (6110 kg ha^{-1}).

Revanappa *et al.* (2012) conducted field experiment at Dharwad to study the Genotype x Environment and stability analysis for grain yield in black gram. They observed that K-7-7 (1050 kg ha^{-1}) and DU-1 (1024 kg ha^{-1}), top yielding genotypes, on the basis of stability parameters which exhibited the stable performance over locations. The other genotypes like, BDU-3-3, T-9 and DU-3 also gave higher yields.

Gangwar *et al.* (2012) conducted field experiment to study the performance of spring planted urdbean varieties under different dates of sowing. They concluded that the variety PU-19 took significantly more number of days to flowering over T-9 and PU-

31. Pant U-31 produced significantly maximum plant height, number of trifoliate leaves and dry matter than rest of all the varieties.

Mondal *et al.* (2011) conducted an experiment on four genotypes of mung bean (MB-35, MB-45, MB-16 and MB-43) and found the significant differences in pods per plant, yield per plant and seed index due to varieties.

Verma *et al.* (2011) revealed that the black gram variety Type-9 recorded significantly higher grain yield (1351 kg ha^{-1}), harvest index, net returns and benefit: cost ratio than cv. Pant Urd-35 and Vallabh Urd-1.

Rathore *et al.* (2010) conducted field experiment to study the effect of sowing time and fertilization on productivity and economics of urdbean genotypes. He reported that the variety Barkha having lower maturity period than other varieties so as to gave higher seed yield (1103 kg ha^{-1}) as compared to T-9 and TAU-1.

Konda *et al.* (2009) conducted field experiment to study the genotypes of black gram based on stability parameters. The genotypes namely TAU-1, BDU-2, BDU-4 were identified as stable parameters for yield, its component traits and for quality characters.

Miah *et al.* (2009) conducted an experiment on four mungbean (*Vigna radiata* (L.) Wilczek) varieties viz BINA moog2, BINA moog5, BINA moog6 and BINA moog7 to identify the suitable variety(s) of summer mungbean. Among the varieties BINA moog7 gave significantly higher pods per plant and seed and straw yield than other varieties.

Kumar *et al.* (2007) conducted field experiment at Pantnagar to study the effect of sowing dates on different urdbean cultivars. A variety Narendra U-1 gave higher grain and straw yields than Pant-U-19 and U-35.

Kandasamy and Kuppusamy (2007) conducted field experiment at Annamalai University, (Tamil Nadu) to study the performance of black gram genotypes under different dates of sowing with six varieties *viz*., ADT-3, ADT-5, VBN-2, VBN-3, CO-5 and T-9. A variety ADT-3 recorded the highest values of all growth and yield parameters as compared to other varieties and gave the highest seed yield of 811 kg ha^{-1} than other varieties.

Eswari and Rao (2007) conducted field experiment to study the response of different genotypes to higher yield characters. They studied eleven genotypes of black gram and reported that genotypes LBG-709, LBG-693, LBG-712 and MBG-207 were found to be the most desirable genotypes for high seed yield, pods plant^{-1}, earliness, seeds pod^{-1} and seed weight.

Dattatri *et al.* (2007) conducted field experiment at CRIDA Campus, Hyderabad and reported that during *rabi*season, variety LBG-645 gave the highest yield of 1510 kg ha^{-1} and the variety LBG-623 recommended for uplands of Andhra Pradesh for all the seasons which is a short duration(70-75days) and photosensitive.

Aher *et al.* (2006) conducted an experiment at MPKV, Rahuri during *kharif* 2000 to study the effect of yield and yield contributing characters on black gram. They reported that the genotype TAU-1 (12.845g) had a higher average number of grains plant^{-1} (284.51). Higher number of clusters plant^{-1}, number of pods plant^{-1}, number of pods cluster^{-1} and test weight leads to higher yield in the varieties TAU-1, AKU-7, Pant-U30 and T-9.

Gupta *et al.* (2006) reported that UG-218 urdbean variety produces significantly higher pods/plant, 1000 seed weight, seed yield as well as straw yield over other two varieties (Type-9 and Pant-U19).

Yadahalli *et al.* (2006) conducted an field experiment at Dharwad to study the response of growth factors in relation to yield of black gram. A K-3 variety showed higher values of growth characters such as plant height, number of branches, leaf area, LAI and total dry matter production as compared to genotypes TAU-1 and Manikya. However, the leaf area index of TAU-1 and Manikya were on par during flowering stage.

Manivannan *et al.* (2005) reported that the blackgram genotype VBG 55 is a hybrid derivative of CO 4 x PDU 102. It matures in 75-80 days. It has recorded an average seed yield of 782, 737 and 793 kg/ha during kharif, rabi and summer seasons respectively.

Bhairappanavar *et al.* (2004) conducted an field experiment at Kathalagere (KN) to study evaluation of promising genotypes of blackgram under different sowing dates and recorded that genotypes LBG-62 recorded significantly higher seed yield (1293 kg ha^{-1}) followed by TU-94-2 (1121 kg ha^{-1}).

Durga *et al.* (2003) reported that urdbean cultivar LBG-20 had a higher yield than LBG-623, while LBG-20 was more efficient in avoiding early drought stress than LBG-632.

Ihsanullah *et al.* (2002) found that among different varieties of mashbean, the seed yield increased in sequence of NARC mash-1 (557.1 kg ha-1) > NARC mash-4 (520.8kg ha^{-1}) > NARC mash-2 (430.8 kg ha^{-1}).

Biswas *et al*. (2002) reported that leaf area index of black gram was influenced due to variety at different growth periods, it is increased slowly up to 22 DAE and thereafter it increased till 57 DAE and then declined sharply. Crop growth rate increased gradually and attained a peak at 57 DAE and thereafter it showed a rapid decline.

Patra *et al.* (2001) conducted a field experiment at Chiplima, (Orissa) to study the response of black gram varieties to dates of sowing during winter. He showed that the highest seed yield was recorded from PU-19 (1070 kg ha^{-1}) and PU-30 (1036 kg ha^{-1}). Maximum pods $plant^{-1}$, pod length and 1000 grain weight were recorded from PU-19 and PU-30, respectively. The longest (112 days) and shortest (92 days) maturation periods were recorded from LBG 648 and KU 301, respectively.

Singh and Singh (2000) conducted an field experiment at Pantnagar (U.P.) to study the growth pattern of promising urdbean genotypes and concluded that total dry matter accumulation and its partitioning to different parts were higher in the genotype IPU 94-1 followed by UPU 97-10, IPU 94-2, UG-218, PU-19 at all stages of crop growth.

2.2 Effect of different plant spacing

Pandey*et al.* (2022) conducted a field experiment during Zaid 2021 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) to study the effect of spacing on growth and yield of varieties of black gram (*Vigna mungo* L.)The experiment was laid out in Randomized Block Design with nine treatments each replicated thrice on the basis of one year experimentation. The treatments which are T1= 25 cm x 20 cm + SHEKHAR 2, T2= 25 cm x 20 cm + PANT U-35, T3:=25 cm x 20 cm + T9, T4= 30 cm x 15 cm + SHEKHAR 2, T5= 30 cm x 15 cm + PANT U-35, T6= 30 cm x 15 cm + T9, T7=45 cm x 10 cm + SHEKHAR 2, T8=45 cm x 10 cm + PANT U-35, T9=45 cm x 10 cm + T9 used. The results showed that application of 45 cm x 10 cm + SHEKHAR 2 was recorded significantly higher plant height (44.58 cm), nodules/plant (9.17), no. of Branches/plant (6.87), plant dry weight (7.08 g/plant), pods/plant (64.64), seeds/pod (8.20), test weight (38.5 g) whereas maximum crop growth rate (4.36 g/m2 /day) was recorded with treatment 30 cm x 15 cm + T9. However, higher Seed yield (1062.86 kg/ha) were obtained with application of 30 cm x 15 cm + SHEKHAR 2 as compared to other treatments.

Sasidhar*et al*. (2022) carrieda field experiment out during *zaid* season of 2021 at crop research farm of SHUATS, Prayagraj to study about the Effect of Spacing and biofertilizer on growth and yield of blackgram (*Vignamungo* L.) The experiment was laid out in randomized block design by keeping three spacing levels, *i.e.* S=(20 × 10 cm), S2 = (25 × 10 cm) and S3 = (30 × 10 cm) and Biofertilizers *i.e.* PSB and Rhizobium and which was replicated three. Results revealed that spacing of 30 × 10 cm + Rhizobium , PSB recorded significantly higher in plant height (43.88 cm), number of branches per plant (6.81), number of nodules per plant (25.84), number of pods per plant (37.30), number of seeds per pod (7.51) test weight (37.73 g), grain yield (836 kg/ha) and stover yield (2144 kg/ha) and plant dry weight (6.77 g/plant), crop growth rate results are showed in 20 x 10 cm + rhizobium + PSB. However, net returns (54550.00 INR/ha) and B:C ratio (2.62) was also obtained with the application of spacing 30 × 10 cm + rhizobium + PSB.

Bonepally *et al.* (2021) reported that the number of pods per plant (66.30), number seeds per pod (7.80), 1000 seed weight (37.33 g), grain yield (854 kg/ha), Stover yield (2072 kg/ha), biological yield (2926 kg/ha) and harvest index (29.17%) was found to be maximum in treatment combination with 30 × 10 cm^2 + 40 kg/ha of phosphorus as compared to rest of the treatments which is beneficial for blackgram production.

Kailash (2020) carried out an experiment at the research field of Gokuleshwor Agriculture and Animal Science College Baitadi, Nepal from August 5, 2019, to November 10, 2019, to evaluate the impact of plant spacing on yield and yield contributing traits of black gram. The experiment was carried out at four levels of spacing viz. T_1 (30×5 cm), T_2 (30×10 cm), T_3 (45×10 cm) and T_4 (60×10 cm). The experiment was laid out in Randomized Complete Block Design having four replications. The differential plant spacing showed remarkable differences in yield and yield contributing traits of black gram cultivation practices at 0.05 level of significance. The highest plant spacing of 60×10 cm performed better in yield contributing traits such as; number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1}. Whereas, the maximum straw yield was found at closure spacing of 30×5 cm. Similarly, grain yield and harvest index were found superior at the spacing of 30×10 cm.

Kumar and Rajput (2020) carried out an experiment to study the effect of variety and spacing on growth and yield of blackgram (*Vignamungo* L.) under vertisol of chhattisgarh reported that 20×5 cm at 20 DAS and at harvest was found effective in plant population and plant height, 45×10 cm at 20, 40 and 60 DAS was found effective in enhancing growth of branches and 30×10 at harvest was found effective in dry matter production of blackgram showed at par with 45×10 cm. The findings revealed that crop geometry (cm) 30×10 recorded significantly higher yield attributing characters, yield, gross return and net return. Variety Indira Urd-1 produced to significant higher growth parameters, yield attributing characters and net return and return per rupee invested as compared to Pratap Urd-1. The interaction between spacing and variety revealed that crop geometry 30×10 with variety Indira Urd-1 was produce significant higher seed yield as compared to other treatment combinations.

Kabir and Sarkar (2018) reported that spacing of 30×10 cm gave the highest number of pods per plant, the highest grain yield, and the highest stover yield.

Tigga *et al*. (2017) carried out a field experiment at Department of Agronomy, College of Agriculture, IGKV, Raipur (Chhattisgarh), India during winter season of 2013-14 to study the performance of different genotypes pigeon pea with planting geometry. The genotype and planting geometry significantly influenced the growth parameter, seed yield, stalk yield, harvest index, yield attributes (viz. seed pod^{-1}, pod plant^{-1}, seed plant^{-1} and 100 seed weight). Among the six genotypes (Asha, Rajeev lochan, RPS- 2007-106, Laxmi, RPS2008-4 and RPS-2007-10) tested, genotype Asha (1281 kg ha^{-1}) recorded significantly highest seed yield over the other genotype. In the two planting geometry significantly maximum seed yield of 1235 kg ha^{-1} was realized with spacing of 45 cm × 10 cm and was higher yield than the yield recorded with spacing of 60 cm x 10 cm (1085 kg ha^{-1}). The Genotype Asha gave maximum seed pod^{-1} (4.23), pod plant^{-1} (132.00), seed plant^{-1} (557.27) and 1000 seed weight (11.22 g) over rest of the genotypes. Pigeon pea sown with wider geometry of 60 cm x 10 cm gave maximum seed pod (4.05), pod plant^{-1} (124.50), seed plant^{-1} (496.67) and 100 seed weight (11.10) compared to narrow spacing of 45 cm × 10 cm. In conclusion among the genotype Asha was the best variety in terms of growth and yield in winter season planting of pigeon pea.

Vakeswaran *et al.* (2016) conducted a field experiment during summer season of 2015-16 to study the effect of time of sowing, spacing between plants and fertilizer levels of green gram (Vigna radiata (L.) Wilczek) on seed yield attributing characters. Five levels of fertilizer doses, three different time of sowing and three spacing levels were imposed along with control under split plot design with three replications. Field data were recorded on pods per plant, number of seeds per pod, seed yield per plant, seed yield per ha. and 1000 seed weight were recorded. Analysis revealed that all the characters are significantly different among the treatments. Early sowing during summer i.e on march 20th with the spacing of 25 × 10 cm recorded higher pods per plant (18.40), number of seeds per pod (13.08), seed yield per plant (6.9 g), seed yield per ha.(8.9 q.) and 1000 seed weight (39 g).

Tanya *et al.* (2015) carried out an investigation at experimentation centre and research field of School of Forestry and Environment, SHIATS, Allahabad, to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (Leucaena leucocephala) based agro silviculture system. The maximum plant height (36.73 cm), absolute growth rate (0.79 g day^{-1}), number of pods (15.63 pods plant^{-1}), number of grains (8.6 grains pod^{-1}) and straw yield (14.23 q ha^{-1}) was recorded in Treatment T_6 (30 × 15 cm with T_9 variety). Whereas, maximum number of branches (7.26 branches plant^{-1}), leaves (21.73 leaves plant^{-1}), nodules (16.75 nodules plant^{-1}), dry weight (23.96 g), pod length (8.11 cm) and test weight (4.53 g) was recorded in treatment T9 (40 × 15 cm with T_9 variety). Grain yield (8.13 q ha^{-1}) and harvest index (37.87 %) was recorded in treatment T_3 (20 × 15 cm with T_9 variety) and treatment T_8 (40 ×15 cm with Shekhar 2 variety) respectively.

Singh and Yadav (2013) carried a field investigation out at the research farm area of R.A.K. College of Agriculture, Sehore (M.P.) during the Kharif season of 2012, reported that the experiment was laid out in randomized block design with three replications and 10 treatment combinations of five blackgram varieties i.e. JU-3, AKU-9802, RBU-38, KU96-3 and TPU-4 at two row spacing i.e. 30 cm and 45 cm. The seed and straw yield of blackgram was maximum with 30 cm spacing (641 and 1059 kg ha^{-1}, respectively) However, the grain yield with 30 cm spacing was significantly superior over 45 cm spacing.

Rasul *et al*. (2012) conducted field trial at Faisalabad, Pakistan and reported that the highest nodule per plant (11.34), branches per plant (6.24), pod per plant and seed yield (675.84 kg ha^{-1}) of mungbean with 30 cm row spacing.

Sathe and Patil (2012a) conducted a field trial on pigeon pea at Nagpur during semi *rabi* season of 2009-10 and they recorded higher plant height under 45 cm × 15 cm spacing at 90, 120 DAS and at harvest. Mean number of branches per plant, mean number of leaves per plant and mean dry matter accumulation per plant at 60, 90, 120 DAS and at harvest recorded maximum at spacing of 60 cm × 30 cm.

From Ludhiana, Punjab, Singh *et al*. (2012a) noted that when mungbean was sown at spacing of 30 cm × 15 cm resulted in higher plant height, number of branches per plant, pods per plant and 100-seed weight as compared to spacing of 45 cm × 15 cm.

Asaduzzaman *et al.* (2010) carried out an experiment at the Research Field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh reported that the plant spacing did not show remarkable differences in dry matter production at early stages of crop growth. The spacing of 30 × 10 cm^2 showed its advantages by producing 7.96-16.19 % higher yield compared to other spacing.

Kachare *et al*. (2009) conducted a field trial at Mahatma Phule Krishi Vidyapeeth, Rahuri during *Kharif* season on green gram and concluded that 30.00 cm × 11.25 cm spacing recorded highest number of pods per plant (22.77), higher number of seeds per pod (9.47), 1000 seed weight (3.33 g) and seed yield per plant (6.27 g).

Bavalgave *et al.* (2008) conducted a field trial at Latur, Maharashtra during *rabi* season on *kabuli* chickpea and reported that 30 cm x 10 cm produced the highest grain yield while number of pod per plant and pod weight per plant were higher in 45 cm × 15 cm spacing.

Achakzai and Panizai (2007) reported that except, harvest index all the parameters including growth, yield and yield components were not influenced significantly by various levels of row spacing. Maximum harvest index of mashbean (61.44%) was obtained in row spacing of 40 cm which is statistically at par with four other spacing *viz;* 20, 25, 30 and 35 cm. Results further revealed that number of pods/plant (0.744) and grain yield/plant (0.888) were highly-significant and positively correlated with grain yield.

Singh *et al*. (2007) conducted an experiment at Ludhiana, Punjab on mungbean and revealed that the highest number and dry weight of nodules per plant, branches per plant, pods per plant were obtained with spacing of 30 cm × 10 cm, but spacing of 25 cm × 10 cm recorded higher seed yield which was statistically at par with 20 cm × 10 cm and significantly superior to 30 cm × 10 cm spacing.

Patel *et al.* (2005) reported that in blackgram, planting geometry had no significant effects on growth and seed yield. Planting geometry of 40×15 cm^2 recorded the highest plant height, root length, number of leaf/plant, number of branches/plant and biomass/plant than rest of the planting geometries. They also reported that Planting geometry of 30×10 cm^2 and 30×15 cm^2 gave higher seed yield over the rest of the planting geometries.

Singh *et al.* (2006) carried out a field trial at Pantnagar during *kharif*, 2000-2001 in urd bean. They revealed that wider spacing (30 cm) produced higher number of pods per plant (43.1), number of grains per pod (7.6) and grain yield per plant (6.7 g).

Ihsanullah *et al.* (2002) reported that highest plant height (47.50cm) was observed in 43 cm × 7 cm spacing in mungbean.

Govinda and Yadav (2001) conducted a field experiment at Department of Agronomy, IAAS, Rampur, Chitwan, Nepal reported that yield difference due to row spacing variations was significant. Row spacing of 30 and 40 cm gave comparable yield (351.8 and 374.0 kg/ha, respectively) and significantly higher than closure row spacing.

Khan and Asif (2001) was conducted a field experiment at Department of Agronomy, Bahauddin Zakariya University Multan, Pakistan reported that the plant spacing significantly affected the seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), biomass (kg ha^{-1}) and harvest index (%) of mashbean.

Achakzai and Panizai (2007) stated that maximum harvest index of0.61 was got in row spacing of 40 cm, which is statistically at parwith four other spacing viz; 20, 25, 30 and 35 cm.

CHAPTER-III

MATERIALS AND METHODS

A field experiment entitled "Response of blackgram varietiesas affected bydifferent plant spacing" was conducted during the *kharif* season of 2021. The predominant edaphic and climatic conditions during the crop period, selection of site, cropping history along with the criteria used for treatment evaluation and methods adopted during experimentation are presented in this chapter.

3.1 Experimental period

The experiment was conducted during the period from March to June 2021 inKharif season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted in the Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental site belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain .For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4–5.6 (Anon., 1989). The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0–15 cm depths were collected from the Sher-e-Bangla Agricultural University (SAU) Farm, field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in Appendix-II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Experimental materials

BARI mash-2,BARI mash-3 and BARI mash-4 were used as experimental materials for this experiment. The important characteristics of thesevarieties was mentioned below:

BARI Mash-2

BARI mash-2 was released in the year of 1996. It was developed by Pulses Research Centre, Ishurdi, Pabna. BARI mash-2 was erect, attains a height of 33 to 35cm, it flowers 35 to 40 days after emergence and reaches physiological maturity at 70 to 75 days after emergence. Leaves are trifoliate, alternate, and green. Leaf pubescence is present. Potioles are short and purple-green The corolla is yellowish green. The raceme position is above the canopy Mature pods are black and have hair Seeds are drum-shaped and blackish.1000 seeds weight 32-36gm crop duration 65-70 days, sowing time last February to mid March (Kharif-I), Mid August to last August

(Kharif-II) and harvesting from Last February to mid March (Kharif-I), Mid August to last August (Kharif-II). The average yield was 1400-1500 kg ha^{-1}.

BARI Mash-3

BARI mash-3 was released in the year of 1996. It was developed by Pulses Research Centre, Ishurdi, Pabna.BARImash-3 has an erect growth habit and attains of 35-37cm. It flowers 35-40 d after emergence and reaches physiological maturity 70-75 days after emergence. Leaves are trifoliate, alternate, and green. Leaf pubescence is present, Petioles are short and purple-green. The corolla is yellowish-green. The raceme position is under the canopy. Mature pods are black with dense pubscence. Seeds are drum-shaped and blackish. Sowing time last February to mid March (Kharif-1), mid August to last August (Kharif-II) and harvesting time from last May (Kharif-I), to last October (Kharif-II).The crop duration of this variety is 65-70 days and average yield is 1500-1600 kg ha^{-1}.

BARI Mash-4

BARI mash-4 was released in the year of 1996.It was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. BARI Mash is a medium statured (45-50cm), semi erect cultivar with basal primary branches, stem pigmentation absent at the seedling stage, but it becomes light green at the late vegetative stage, leaves are dark green with slightly pubescence, leave size is medium with dark green color, short petiole and rachis that forms no tendrils, flowers are white, and pods and leaves turns to straw, seed coat is ash and testa pattern is dotted with smooth seed surface, and cotyledon is yellow. Seed is large, 1000 seeds weight 38-43g compared to 21.5g or less for the local cultivars. Day neutral, for this reason it is cultivated in kharif-1 and kharif-2, cooking time 30-35 min, crop duration 65-70days and average yield is 1400-1500 kg ha^{-1}.

3.4 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. In main plot there was blackgram variety and in sub plot there was sowing method treatments. There are 12 treatment combinations and 36 unit plots. The unit plot size was 5.4 m^2 (2.7 m × 2 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.

3.5 Experimental treatment

There were two factors in the experiment namely blackgram variety and different plant spacing as mentioned below:

Factor A. Blackgram varieties (3):

V_1=BARI Mash 2

V_2=BARI Mash 3

V_3=BARI Mash 4 and

Factor B. Different plant spacing(4) :

S_1 = Broadcasting,

S_2 = 15 cm × 10 cm,

S_3 = 20 cm × 20 cm,

S_4 = 30 cm × 15 cm.

3.6 Land preparation

Initially the field was prepared with the help of tractor drawn disc plough. After giving one deep ploughing the experimental field was cross harrowed and levelled properly to break the clods and bring the soil to the desired tilth. The plots were prepared manually for sowing the subsequent crops of the experimental study.

3.7 Seed collection

For conducting the present experiment the seeds of the test crop *i.e*., BARI Mash-2, BARI Mash-3 and BARI Mash-4 were collected from Pulses Research Centre, Ishurdi, Pabna and Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.8Final land preparation

On March 25th, 2021, a power tiller opened the experimental land. Using a power tiller, cross-plowing and laddering were performed. On March 27, 2021, the land preparation was finished, and it was prepared for seed sowing.

3.9 Fertilizer application

As sources of nitrogen, phosphorus, potassium, zinc, and boron, fertilizers of urea, triple superphosphate (TSP), muriate of potash (Mp), zinc sulphate, and boric acid were utilized. For urea, TSP, MP, gypsum, and boric acid, the fertilizer doses were 45, 90, 40, 55, and 10 kg ha^{-1}, respectively. Urea, TSP, MP, Gypsum, and boric acid were all were treated in total at basal doses during the final land preparation (BARI krishi projukti hatboi-(2019 recommendation). All fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.10 Sowing of seeds

Seeds were sown at the rate of 35 kg ha^{-1} in the furrow on 28March, 2021 and the furrows were covered with the soils soon after seed sowing. Seeds were being treated with bavistin before sowing the seeds to control the seed borne disease. Seed were sown as par treatment requirement.

3.11 Intercultural operation

3.11.1Application of irrigation water

The field was irrigated twice- one at 20 days and the other one at 35 DAS.

3.11.2 Plant protection measures

3.11.2.1 Insect and pest infestation

Early on in its development, the crop was afflicted with insects and pests. Worms (*Agrotis ipsilon*) and virus-carrying jassids attacked the plants at young stage, and at a later stage, the pod borer (*Maruca testulalis*) attacked the plant.

3.11.2.2 Management

Dimacron 50EC (Emulsifiable concentrate) was sprayed at the rate of 1litre ha-^{1} to control worms, virus vectors, and pod borer insects.

3.12 Harvesting

Crops were harvested at complete maturity as judged by visual observations. The border rows were harvested first and kept aside. Thereafter the net plots were harvested and brought to the threshing floor after proper tagging and sun drying.

3.13 Threshing

After properly sun drying of tagged bundle, each bundle was weighted, threshed andcleaned separately and seed yield per plot was recorded. For recording stover yield, seed yield was deducted from the total bundle weight.

3.14 Recording of data

The data were recorded from 15days after sowing and continued untilthe end of recording of yield contributing characters of the characters of the crop after harvest. Dry weights of plant were collected from the inner rows leaving border rows by destructive sampling of 5 plants at hervest. The following data were recorded during the experiment.

i. Plant height (cm)
ii. Leaves plant^{-1} (no.)
iii. Branches plant^{-1} (no.)
iv. Nodules plant^{-1} (no.)
v. Nodules dry weight plant^{-1} (g)
vi. Above ground dry matter weight plant^{-1} (g)
vii. Pods plant^{-1} (no.)
viii. Pod length
ix. Seeds pod^{-1} (no.)
x. 1000 seeds weight (g)
xi. Seed yield (t ha^{-1})
xii. Stover yield (t ha^{-1})
xiii. Biological yield (t ha^{-1})
xiv. Harvest index (%)

3.15 Detailed procedures of recording data

i. Plant height (cm)

Five plants were selected randomly from the inner row of each plot. The height of the plants were measured from the ground level to the tip of the plant at 15, 30, 45 DAS and harvest. The mean value of plant height was recorded in cm.

ii. Leaves plant^{-1} (no.)

The number of leaves plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of leaves of all sampled plants at 15, 30, 45 and harvest and then the average data were recorded.

iii. Branches plant^{-1} (no.)

The number of branchesplant^{-1} was counted from five randomly sampled plants. It was done by counting total number of branches of all sampled plants at 30, 45 and harvest and then the average data were recorded.

iv. Nodules plant^{-1} (no.)

Number of nodules plant^{-1} was counted from each selected plant sample at 45 DAS and at harvest respectively.

v. Dry weight of nodules plant^{-1}

Nodules plant^{-1} was counted from each selected plant sample at 45 DAS and at harvest respectively. After collection and counting the nodules that were oven dried maintaining 70^{0}C temperature for 72 hours for oven dry until attained a constant weight and the mean of dry weight of nodules plant^{-1} was measured.

vi. Above ground dry matter weight plant^{-1}

Five plants were collected randomly from each plot at harvest. The sample plants were oven dried for 72 hours at 70°C and then dry matter content plant^{-1} was determined.

vii. Pods plant^{-1} (no.)

Pods plant^{-1} was counted from the 5 selected plant sample and then the average pod number was calculated.

viii. Pod length

Pod length is measured by scale on five tagged plants and averaged to pod length.

ix. Seeds pod^{-1}(no)

The number of seeds pod^{-1} was counted randomly from selected pods at the time of harvest. Data were recorded as the average of 20 pods from each plot.

x. Weight of 1000-seed

One thousand cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

xi. Seed yield

Seed yield was recorded from 1 m^2 area of each plot were sun dried properly. The weight of seeds was taken and converted the yield in kg ha^{-1}.

xii. Stover yield

After separation of seeds from plant, the straw and shell from harvested area was sun dried and the weight was recorded and then converted into kg ha^{-1}.

xiii. Biological yield

Seed yield and Stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

xiv. Harvest index

Harvest index was calculated from the seed yield and stover yield of blackgram for each plot and expressed in percentage.

Harvest index (HI %) = $\frac{\text{Grain yield}}{\text{Biological yield}} \times 100$

3.16 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistics 10 data analysis software and the mean differences were adjusted by Least

Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

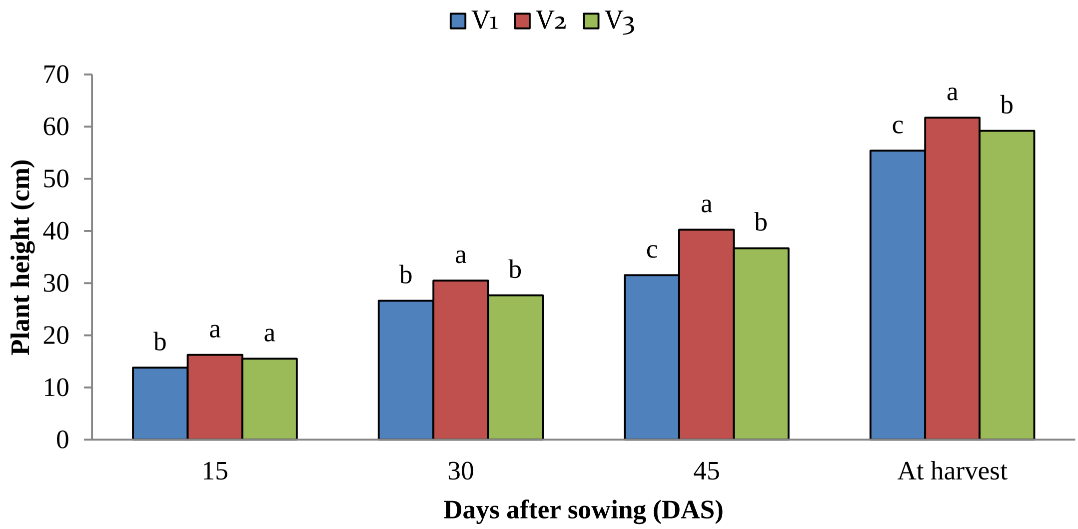
Results obtained from the present study have been presented and discussed in this chapter with a view to study the response of blackgram varieties as affected by different plant spacing. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant growth parameters

4.1.1 Plant height (cm)

Effect of varieties

Plant height is a crucial aspect of the crop plant's vegetative stage that indirectly affects crop plant yield. Blackgram plant height varied greatly depending on the variety at different days after sowing (DAS). Height was observed to grow steadily as the crop aged up to harvest. At maturity, the plant's height achieved its peak value. (Fig. 1). Experimental results revealed that the highest plant height (16.27, 30.52, 40.27 and 61.74 cm) at 15, 30, 45 DAS and at harvest respectively was observed in V_2 treatment (BARI Mash-3) which was statistically similar with V_3 (15.52cm) treatment (BARI Mash-3) at 15 DAS. Whereas the lowest plant height (13.79, 26.64, 31.54 and 55.39 cm) at 15, 30, 45 DAS and at harvest respectively was observed in V_1 treatment (BARI Mash-2) which was statistically similar with V_3 (27.67cm) treatment (BARI Mash-3) at 30 DAS. The variation of plant height is probably due to the genetic make-up of the variety. Siddikee *et al.* (2018) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical makeup.



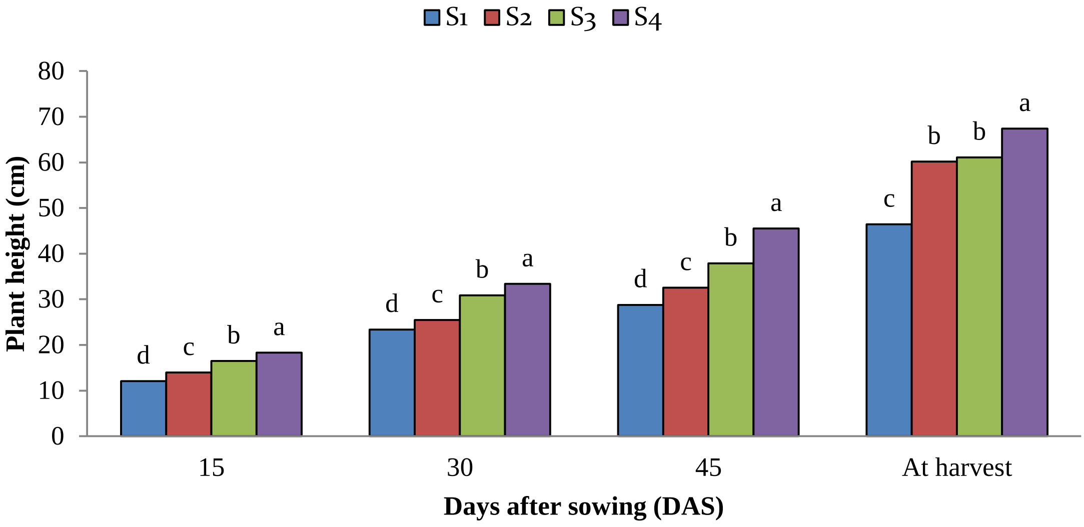
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 1. Effect of varietis on plant height of blackgram at different DAS ($LSD_{(0.05)}$=1.49, 1.21, 2.0 and 1.98 at 15, 30, 45 DAS and harvest respectively).

Effect of plant spacing

At different days after sowing significant variance in blackgram plant height was observed as a results of various plant spacing (Fig. 2).Experimental result showed that the highest plant height (18.29, 33.37, 45.50 and 67.40 cm)at 15, 30, 45 DAS and at harvest, respectively were observed in S_4 (30 cm × 15 cm) treatment. While the S_1 (Broadcasting) treatment had the lowest plant height (12.06, 23.38, 28.78 and 46.43 cm) at 15, 30, 45 DAS and at harvest respectively. In general, height was increased as the plant spacing was increased indicating tendency of plant to grow tall under adequate space which might be due to less competition for light and CO_2 between plants. The result obtained from the present study was similar with the findings of Ihsanullah *et al.* (2002) who reported that the highest plant height (47.50cm) was observed in 43 cm × 7 cm spacing in blackgram.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure. 2.Effect of plant spacingon plant height of blackgram at different DAS ($LSD_{(0.05)}$=1.17, 1.25, 2.00 and 2.57at 15, 30, 45 DAS and harvest respectively).

Combined effect of varietis and plant spacing

Variety and plant spacinghad shown significant effect on blackgramplant height at different days after sowing. (Table 1). The results of the experiment showed that the V_2S_4treatment combination showed taller plants in V_3S_4 (19.00, 34.32, 46.56 and 68.60 cm) at 15, 30, 45 DAS and at harvest respectively and with V_2S_3 (67.40 cm) treatment combination at harvest respectively had the highest plant height (19.60, 34.60, 49.73 and 71.12 cm) at 15, 30, 45 DAS and harvest respectively. While V_1S_1 treatment combination showed the lowest plant height (10.34,20.13,22.10 and 41.13 cm)15, 30, 45 DAS and at harvest respectively which was statistically comparable to V_3S_1(12.52 cm), V_3S_2(12.55 cm) treatment combination at 15DAS and with V_2S_1(44.60 cm)treatment combination at harvest respectively.

Table 1. Combined effect of varietis and plant spacingon plant height of blackgram at different DAS.

Treatment combinations	Plant height (cm)			
	15	30	45	At harvest
V_1S_1	10.34 f	20.13 g	22.10 e	41.13 g
V_1S_2	13.43 de	26.34 e	31.60 cd	59.17 de
V_1S_3	15.13 cd	28.90 d	32.24 cd	58.78 de
V_1S_4	16.27 bc	31.19 c	40.20 b	62.49 cd
V_2S_1	13.33 de	27.57 de	34.17 c	44.60 g
V_2S_2	15.83 bc	27.52 de	34.72 c	63.83 bc
V_2S_3	16.32 bc	32.40 bc	42.45 b	67.40 ab
V_2S_4	19.60 a	34.60 a	49.73 a	71.12 a
V_3S_1	12.52 ef	22.44 f	30.07 d	53.57 f
V_3S_2	12.56 ef	22.60 f	31.30 cd	57.52 ef
V_3S_3	18.00 ab	31.32 c	38.98 b	57.11 ef
V_3S_4	19.00 a	34.32 ab	46.56 a	68.60 a
$LSD_{(0.05)}$	2.29	2.22	3.57	4.32
CV(%)	7.83	4.48	5.59	4.42

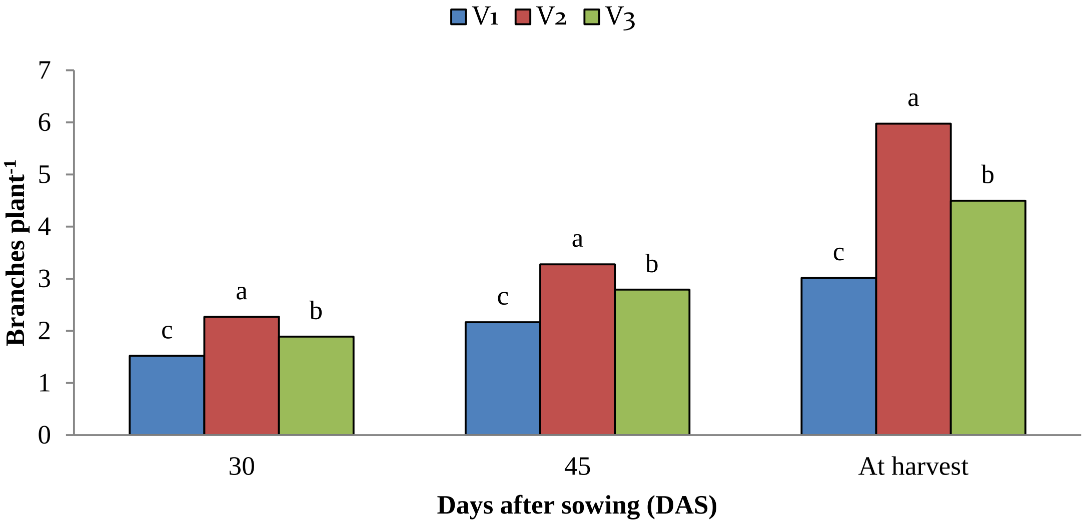
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here,V_1 =BARI Mash-2, V_2 = BARI Mash-3, V_3 = BARI Mash-4, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm and S_4 = 30 cm × 15 cm.

4.1.2 Branches plant^{-1}

Effect of varietis

Depending on the variety blackgram branches plant^{-1}varied significantly at different days after sowing (DAS).According to the experimental results, the V_2 (BARI Mash-3) treatment had the highest number of branches plant^{-1} (2.27, 3.28 and 5.98)at 30, 45 DAS and harvest respectively. While the V_1(BARI Mash-2) treatment, had the lowest number of branches plant^{-1}(1.52, 2.17 and 3.02) at 30, 45 DAS and harvest respectively (Fig. 3). The reason of difference in number of branches plant^{-1}is the genetic makeup of the variety, which is primarily influenced by heredity. Sunil *et al.* (2020)found similar results which supported the present finding and reported that among the varieties tested, the check LBG 791 substantially recorded more branches (4.92) than KU 14-8 (1.68). The probable reason for this may be the genetical potential of the genotype that has helped in producing more number branches on blackgram variety.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

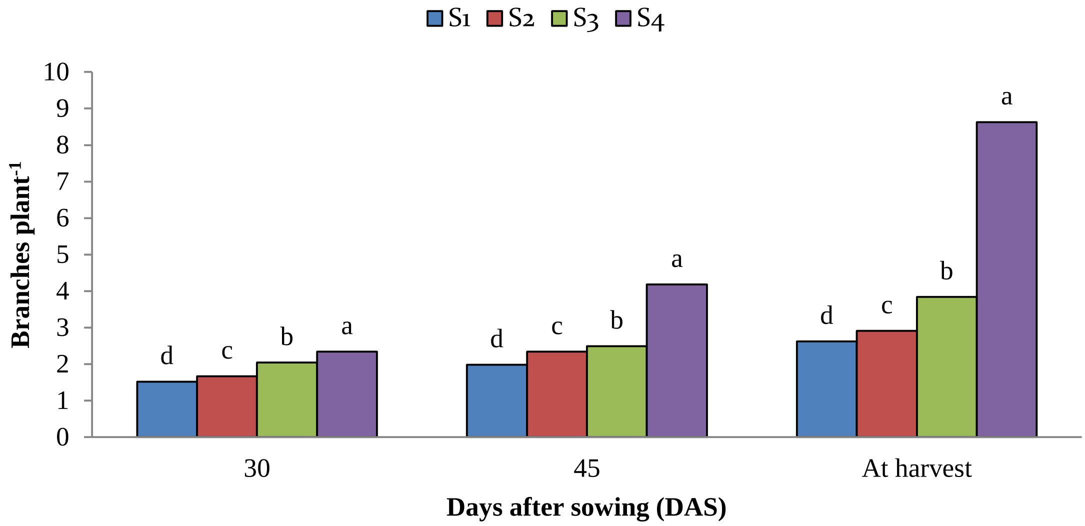
Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 3. Effect of varietis on branches plant^{-1}of blackgram at different DAS ($LSD_{(0.05)}$=0.08, 0.09 and 0.26 at 30, 45 DAS and harvest respectively).

Effect of plant spacing

Different plant spacing had shown significant effect in respect of number of branches plant^{-1} of blackgram at various days after sowing (Fig. 3). According to the experimental results, the S_4 (30 cm × 15 cm) treatment had the highest number of branches plant^{-1}(2.34, 4.18 and 8.63) at 30, 45 DAS and harvest respectively (Fig. 3). While the lowest number of branches plant^{-1}(1.52, 1.98 and 2.62) at 30, 45 DAS and harvest respectively was found inS_1 treatment (Fig. 3). Lower plant spacing increases of plant density which decreased the number of branches plant^{-1} due to plants higher densities accumulate less carbon which is not sufficient to support more branching. Increase in number of branches plant^{-1} might due to availability of nutrient in adequate amount at appropriate spacing resulted in formation of photosynthesis, which promote metabolic activity, increase the cell division, ultimately increase the number of branches plant^{-1}. Similar finding was also observed Result *et al.* (2012)

who discovered that blackgram plants with 30 cm rows spacing had the largest number of branches per plant (6.24).



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability

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Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure. 4. Effect of plant spacingon branches plant^{-1}of blackgram at different DAS (LSD$_{(0.05)}$=0.10, 0.09 and 0.25 at 30, 45 DAS and harvest respectively).

Combined effect of varietis and plant spacing

At various days after sowing, the treatment combination of variety and plant spacing had shown significant variation in respect of the number of branches plant^{-1} of blackgram (Table 2). The experiment findings showed that the V_2S_4 treatment combination, had the highest number of branches plant^{-1} (3.00, 6.30 and 12.30) at 30, 45 DAS and harvest respectively. While the lowest number of branches plant^{-1} of blackgram (1.33, 1.80 and 2.47) at 30, 45 DAS and harvest respectively was found in V_1S_1 treatment combination which was statistically similar with V_1S_2 (1.47) treatment combination at 30 DAS and with V_1S_2 (2.60) and V_1S_3 (2.87) treatment combination and harvest respectively.

Table 2. Combined effect of varietis and plant spacingon branches plant^{-1} of blackgram at different DAS.

Treatment combinations	Branches plant^{-1}(no)		
	30	**45**	**At harvest**
V_1S_1	1.33 h	1.80 g	2.47 g
V_1S_2	1.47 gh	2.14 ef	2.60 g
V_1S_3	1.53 g	2.27 e	2.87 fg
V_1S_4	1.74 ef	2.47 d	4.14 d
V_2S_1	1.63 e-g	2.07 f	2.86 g
V_2S_2	1.80 de	2.14 ef	3.46 e
V_2S_3	2.66 b	2.60 cd	5.30 c
V_2S_4	3.00 a	6.30 a	12.30 a
V_3S_1	1.60 fg	2.07 f	2.54 g
V_3S_2	1.74 ef	2.73 c	2.67 g
V_3S_3	1.94 d	2.60 cd	3.34 ef
V_3S_4	2.27 c	3.76 b	9.46 b
$LSD_{(0.05)}$	0.17	0.16	0.47
CV(%)	5.50	3.48	5.91

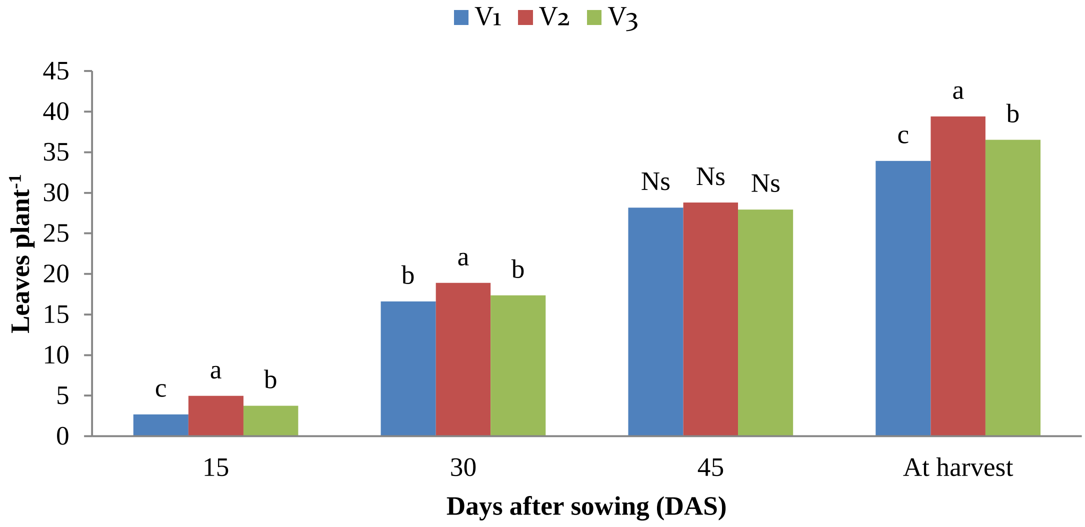
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here,V_1 =BARI Mash-2, V_2 = BARI Mash-3, V_3 = BARI Mash-4, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

4.1.3 Leaves plant^{-1}(no)

Effect of varietis

The number of leaves plant^{-1}of blackgram at various days after sowing varied greatly, depending on the varieties (Fig. 5). The V_2 (BARI Mash-3) treatment had the highest number of leaves plant^{-1}(4.96, 18.89, 28.79 and 39.41) at 15, 30, 45 DAS and harvest respectively. While at 15, 30, 45 DAS and harvest respectively the V_1 (BARI Mash-2) treatment had the lowest number of leaves plant^{-1}. The reason of difference in number of leaves plant^{-1}is the genetic makeup of the variety, which is primarily influenced by heredity. Gangwar *et al*. (2012) reported that the variety PU-19 of urdbean had maximum number of trifoliate leaves and dry matter weight than the other varieties, and this variation may be the result of varietal differences.



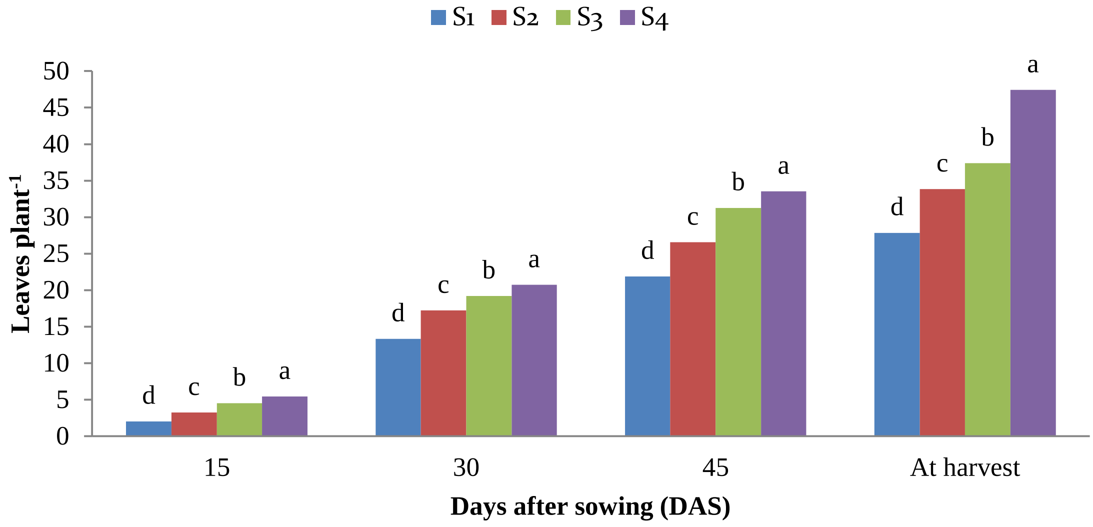
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 5. Effect of variety on leaves plant^{-1}of blackgram at different DAS ($LSD_{(0.05)}$= 0.14, 0.86, Ns and 1.42 at 15, 30, 45 DAS and harvest respectively).

Effect of plant spacing

Depending on the sowing methods, the number of leaves plant^{-1} of the blackgram at different days after sowing varied substantially (Fig. 6). The S_4 (30 cm × 15 cm) treatment had the number of leaves plant^{-1} (5.44, 20.73, 33.53 and 47.42) at 15, 30, 45 DAS and harvest respectively. On the other hand the S_1 (Broadcasting) treatment had the fewest leaves on plant^{-1}(2.04, 13.33, 21.88 and 27.86) at 15, 30, 45 DAS and harvest respectively. Due to greater in the plant competition, closer spacing resulted in fewer leaves being produced. In order to decrease in the plant competition, which eventually has an impact on the plant's leaf number, as a result optimum spacing must be maintained. The outcome of the following experiment was quite similar to that of Sathe and Patil (2012), who discovered that the average number of pigeon pea leaves per plant varied significantly depending on the spacing, and with 60 cm × 30 cm spacing recording the highest number leaves plant^{-1}of pigeon pea in comparison to other treatments.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure. 6.Effect of plant spacingon leaves plant^{-1}of blackgram at different DAS ($LSD_{(0.05)}$= 0.14, 0.86, Ns and 1.42 at 15, 30, 45 DAS and harvest respectively).

Combined effect of varietis andplant spacing

The treatment combination of varietis and plant spacinghad demonstrated a substantial difference in the number of leaves plant^{-1} of blackgram at different days after sowing (Table 3). The V_2S_4 treatment combination had the highest number of leaves plant^{-1} (7.40, 22.40, 36.13 and 49.66) at 15, 30, 45 DAS and harvest respectively which was statistically comparable to V_3S_4 (48.27) treatment combination at harvest respectively. While the lowest number of leaves plant^{-1} of blackgram (1.33, 9.00, 19.52 and 25.40) at 15, 30, 45 DAS and harvest respectively was reported in the V_1S_1 treatment combination.

Table 3. Combined effect of variety and plant spacingleaves plant^{-1}of blackgram at different DAS.

Treatment combinations	Leaves plant^{-1}			
	15	30	45	At harvest
V_1S_1	1.33 i	9.00 g	19.52 f	25.40 h
V_1S_2	1.86 h	18.00 de	29.00 c	31.87 f
V_1S_3	3.73 ef	19.27 b-d	31.94 b	34.20 e
V_1S_4	3.90 e	20.20 b	32.27 b	44.34 b
V_2S_1	3.00 g	16.60 e	22.20 e	29.50 g
V_2S_2	4.27 d	16.86 e	26.46 d	37.26 d
V_2S_3	5.20 b	19.73 bc	30.40 bc	41.20 c
V_2S_4	7.40 a	22.40 a	36.13 a	49.66 a
V_3S_1	1.80 h	14.40 f	23.93 e	28.67 g
V_3S_2	3.59 f	16.80 e	24.20 e	32.40 ef
V_3S_3	4.62 c	18.60 cd	31.47 b	36.74 d
V_3S_4	5.03 b	19.60 bc	32.20 b	48.27 a
$LSD_{(0.05)}$	0.26	1.59	2.21	2.25
CV(%)	4.08	5.18	4.56	3.25

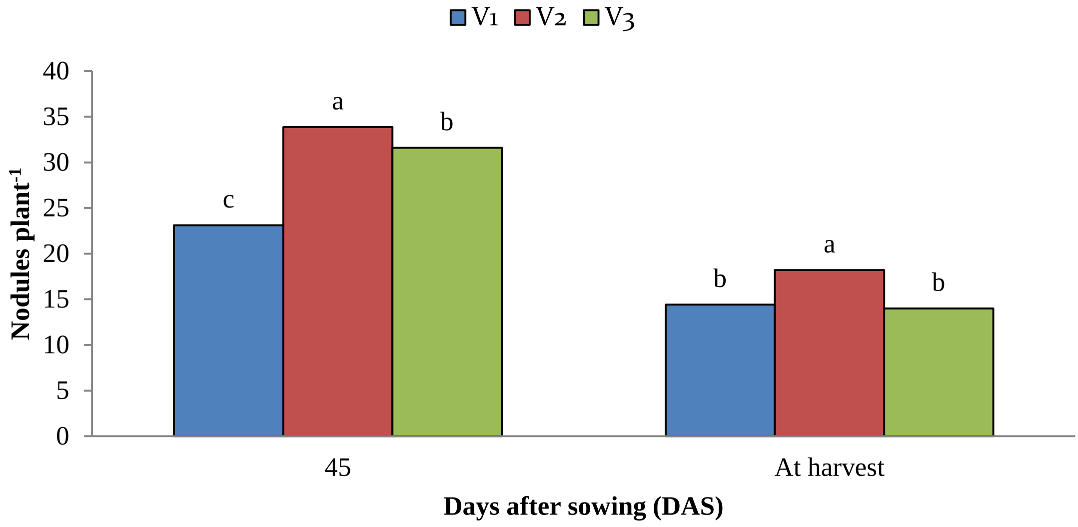
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here,V_1 =BARI Mash-2, V_2 = BARI Mash-3, V_3 = BARI Mash-4, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

4.1.4 Nodules plant^{-1}

Effect of varieties

Different variety had shown significant effect on number of nodules plant^{-1} of blackgram at different days after sowing (Fig. 7). Experimental results revealed that the highest number of nodules plant^{-1} (33.87 and 18.20) at 45 DAS and harvest respectively was observed in V_2 (BARI Mash-3) treatment. Whereas the lowest number of nodules plant^{-1} (9.00) at 45 DAS was observed in V_1 treatment. At harvest respectively the lowest number of nodules plant^{-1} (14.00) was observed in V_3 treatment which was statistically comparable to V_1 (14.42) treatment. The probable reason for this is that the genetic potential of the variety which has helped to increase the number of nodules in the blackgram variety. Singh *et al.* (2013) reported that the number of nodules plant^{-1} significantly varied amount different cultivars of urdbean.



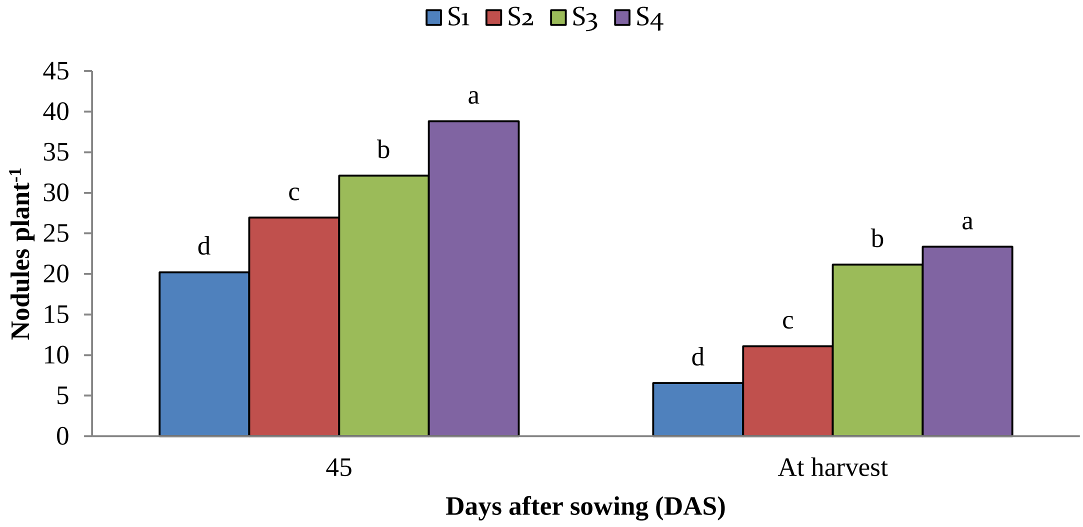
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 7. Effect of variety on nodules plant^{-1} of blackgram at different DAS ($LSD_{(0.05)}$= 1.49 and 0.93 at 45 DAS and harvest respectively).

Effect of plant spacing

The number of nodules on plant^{-1}blackgram had significantly changed depending on the sowing methods used at different days after sowing (Fig. 8).The results of the experiment showed that at 45 DAS and harvest respectively, the S_4 treatment had the highest number of nodules plant^{-1} (38.82 and 23.34).While the S_1 treatment had the lowest number of nodules plant^{-1} (20.22 and 6.56) at 45 DAS and at harvest respectively. The result obtained from the present study was similar with the findings of Result *et al*. (2012) who reported that the highest nodules per plant (11.34) of blackgram was found with 30 cm row spacing.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 8. Effect of plant spacingon nodules plant^{-1} of blackgram at different DAS (LSD$_{(0.05)}$= 1.45 and 0.86 at 45 DAS and harvest respectively).

Combined effect of varietis and plant spacing

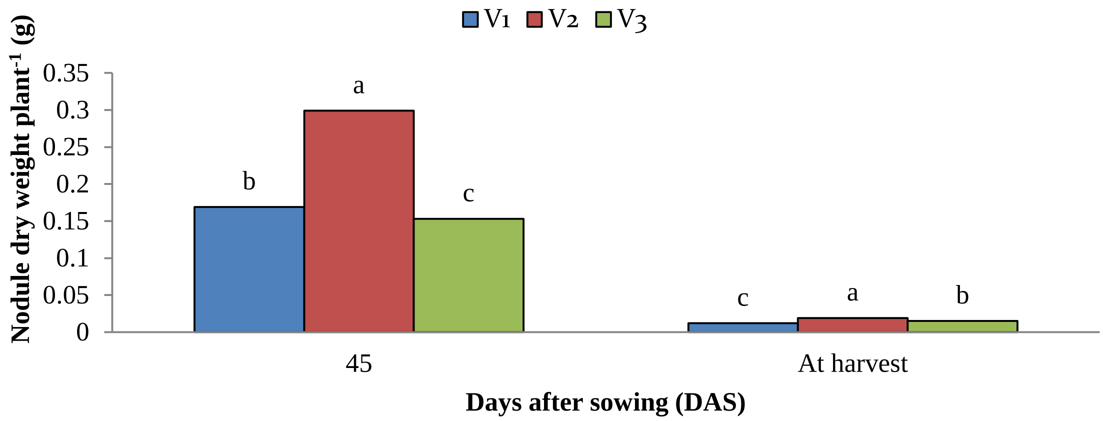
Combination of variety and plant spacinghad shown significant difference in the number of nodule plant^{-1} of blackgram at various days after sowing (Table 4). The highest number of nodules plant^{-1} (40.12 and 25.34) at 45 DAS and harvest respectively was found in the V_2S_4 treatment combination, which was statistically comparable with the V_3S_4 (38.34) and V_1S_4 (38.00) treatment combination at 45 DAS and with V_2S_3 (25.12) treatment combination at harvest respectively. While the lowest number of nodule plant^{-1} (10.00 and 4.34) at 45 DAS and at harvest respectively was found in the V_2S_4 treatment combination.

4.1.5 Nodule dry weight plant^{-1} (g)

Effect of varieties

The nodule dry weight plant^{-1} of blackgram at various days after sowing varied significantly depending on the variety (Fig. 9). The experimental results revealed that the V_2 (BARI Mash-3) had the highest nodule dry weight plant^{-1} (0.299 and 0.019 g) at 45 DAS and harvest, respectively. However, at 45 DAS, the V_3 treatment had the lowest nodule dry weight plant^{-1} (0.153 g). While at harvest respectively the V_1

treatment had the least nodule dry weight plant^{-1}(0.012 g).The significant variations in nodule dry weight plant^{-1}among the varieties may be due to their genetic variability and the influence of environmental factors might be the least.



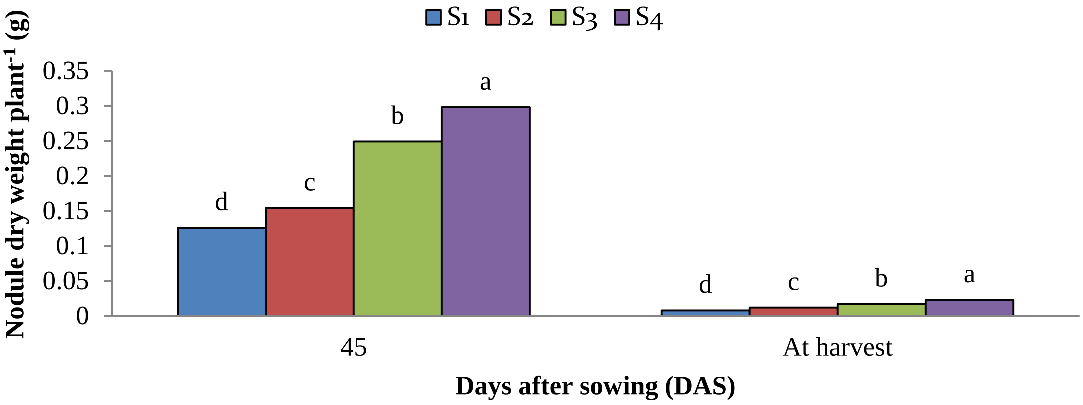
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure.9. Effect of variety on nodules dry weight plant^{-1} of blackgram at different DAS ($LSD_{(0.05)}$= 0.014 and 0.001 at 45 DAS and harvest, respectively).

Effect of plant spacing

Different plant spacinghad shown significant effect onthe nodule dry weight plant^{-1}of blackgram at different days after sowing (Fig. 10). The experimental results revealed that the S_4 treatment had the highest nodule dry weight plant^{-1} (0.298 and 0.023g) at 45 DAS and harvest, respectively. While the S_1 treatment had the lowest nodule dry weight plant^{-1}(0.126 and 0.008 g)at 45 DAS and harvest, respectively. The mean total nodules produced per plant decreased with increase in number of plants per pot which were found inS_1. Nodulation reduces or ceases when there is stress on the activity of the host plant as a result of competition for nutrients, water and light. These stresses that negatively affect the micro symbiont in free-living conditions as well as during the symbiotic relationship can lead to a delay in infection and nodule formation, development of non-fixing nodules or even to failure ofthe nodulation process result in decreased nodule number and nodule dry weight with increased inplant population. The result obtained from the present study was similar with the findings of Singh *et al*. (2007) who revealed that the highest number and dry weight of nodules per plant were obtained with 30 cm × 10 cm spacing.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure. 10. Effect of plant spacingon nodules dry weight plant^{-1} of blackgram at different DAS ($LSD_{(0.05)}$= 0.01 and 0.0009 at 45 DAS and harvest respectively).

Combined effect of varieties and plant spacing

The nodule dry weight plant^{-1} of blackgram had significantly varied due to the combined effect variety and plant spacingat different days after sowing (Table 4). The V_2S_4 treatment combination had the highest nodule dry weight plant^{-1} (0.497 and 0.034 g) at 45 DAS and harvest, respectively. While the V_1S_1 treatment combination had the lowest nodule dry weight plant^{-1} (0.098 and 0.007 g) at 45 DAS and harvest, respectively.

Table 4. Combined effect of varieties and plant spacingon number of nodules and nodules dry weight plant^{-1}of blackgram at different DAS.

Treatment combinations	Nodule plant^{-1}(no)		Nodules dry weight plant^{-1}(g)	
	45 DAS	At harvest	45 DAS	At harvest
V_1S_1	10.00 h	4.34 g	0.098 e	0.007 f
V_1S_2	19.12 g	12.67 d	0.179 c	0.013 d
V_1S_3	25.34 ef	19.00 c	0.199 c	0.014 d
V_1S_4	38.00 ab	21.67 b	0.199 c	0.014 d
V_2S_1	27.00 e	10.34 e	0.150 d	0.009 e
V_2S_2	34.00 d	12.00 d	0.150 d	0.010 e
V_2S_3	34.34 cd	25.12 a	0.398 b	0.021 b
V_2S_4	40.12 a	25.34 a	0.497 a	0.034 a
V_3S_1	23.67 f	5.00 g	0.130 d	0.009 e
V_3S_2	27.67 e	8.67 f	0.133 d	0.014 d
V_3S_3	36.67 bc	19.34 c	0.149 d	0.016 c
V_3S_4	38.34 ab	23.00 b	0.199 c	0.022 b
$LSD_{(0.05)}$	2.62	1.58	0.02	0.001
CV(%)	4.98	5.60	5.32	5.99

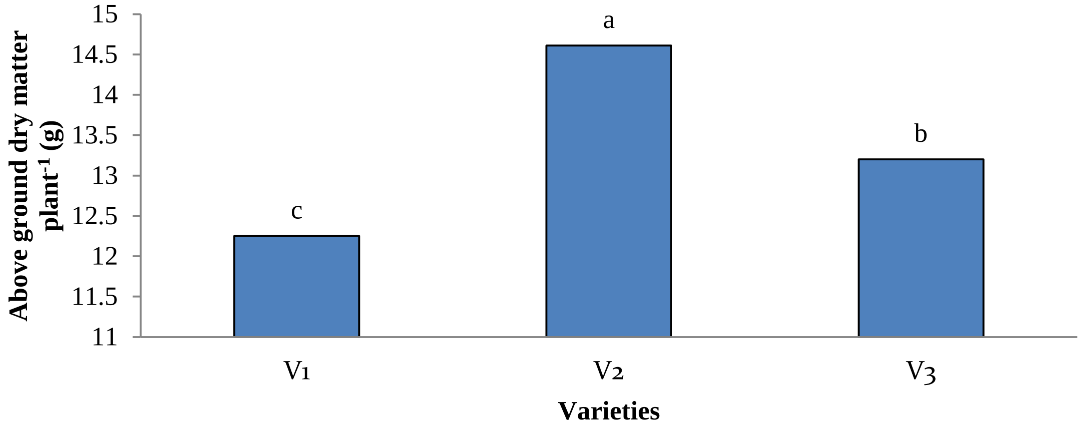
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1 =BARI Mash-2, V_2 = BARI Mash-3, V_3 = BARI Mash-4, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

4.1.6 Above ground dry matter plant^{-1}(g)

Effect of varieties

The result of the experiment shown that different varieties had significant effect on the above ground dry matter weight plant^{-1} of blackgram at harvest. (Fig. 11). According to the experimental result it was revealed that, the highest above ground dry matter weight plant^{-1} (14.61 g) at harvest was found in V_2 (BARI Mash-3) treatment. Whereas the lowest above ground dry matter weight plant^{-1} of blackgram (12.25g) at harvest was found in V_1 (BARI Mash-2) treatment. The reason why the dry weight plant^{-1} varies between different varieties is because each variety has a unique growth pattren and makes use of resources from its environment differently.

Jadhav *et al.* (2014) reported that the mean total dry matter per plant was influenced due to blackgram varieties. Variety BDU-1 Produce significantly more dry matter as compared to TAU-1 and TPU-4 at all growth stages. This might be due to higher biomass potential of the variety such differential dry matter production in different blackgram variety and BDU-1 produced significantly more dry matter as compared to TAU-1 and TPU-4 at all growth stages.

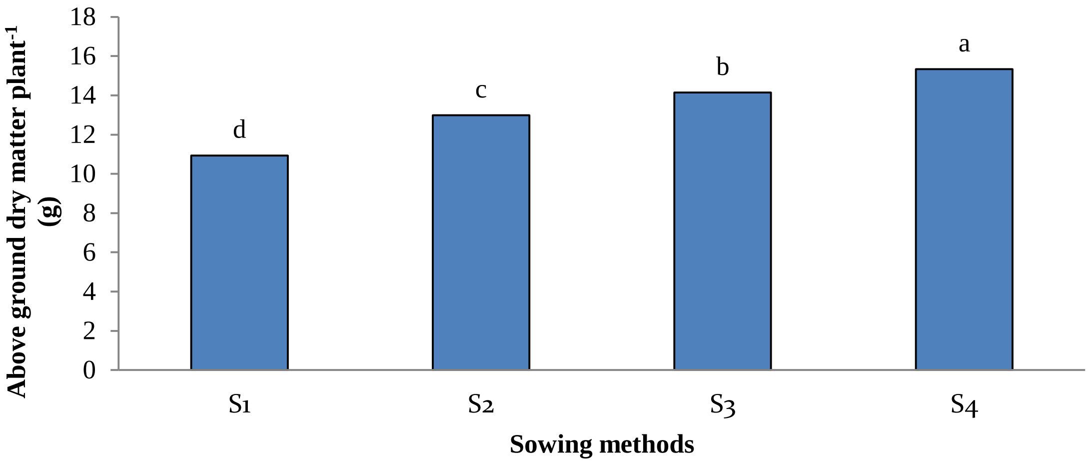


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability. Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 11. Effect of variety on above ground dry matter plant^{-1} of blackgram at harvest ($LSD_{(0.05)}$= 0.38).

Effect of plant spacing

Different plant spacing had shown significant effect on above ground dry matter weight plant^{-1} of blackgram at harvest (Fig. 12). According to the findings it was measured that, the S_4 treatment had the highest above ground dry matter weight plant^{-1} (15.34 g) at harvest. However, the S_1 (Broadcasting) treatment, was found to had the lowest above ground dry weight matter plant^{-1} (10.94 g) at harvest respectively. The variation of above ground dry matter weight plant^{-1} of blackgram among different treatment due to availability of more space for plant spread, getting more sunlight and CO_2 for better growth and development of the plant. Tanya *et al.* (2015) reported that in blackgram wider spacing gave highest above ground dry matter weight plant^{-1} than narrow spacing.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure. 12. Effect of plant spacingon above ground dry matter plant^{-1} of blackgram at harvest ($LSD_{(0.05)}$= 0.40).

Combined effect of varieties and plant spacing

The above ground dry matter weight plant^{-1} of blackgram at harvest was significantly influenced as a result of the variety and plant spacing treatment combination. (Table 5). The experiment's findings revealed that the V_2S_4 treatment combination had the highest above ground dry matter weight plant^{-1} of blackgram (16.52 g)at harvest. While the V_1S_1 treatment combination had the lowest above ground dry matter weight plant^{-1} of blackgram (9.59 g) at harvest.

Table 5. Combined effect of varieties and plant spacingon above ground dry matter weight plant^{-1} at harvest.

Treatment combinations	Above ground dry matter weight plant^{1}(g)at harvest
V_1S_1	9.59 h
V_1S_2	11.97 fg
V_1S_3	13.01 e
V_1S_4	14.45 cd
V_2S_1	11.88 fg
V_2S_2	14.63 cd
V_2S_3	15.44 b
V_2S_4	16.52 a
V_3S_1	11.34 g
V_3S_2	12.38 ef
V_3S_3	13.99 d
V_3S_4	15.08 bc
$LSD_{(0.05)}$	0.72
CV(%)	3.08

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here,V_1 =BARI Mash-2, V_2 = BARI Mash-3, V_3 = BARI Mash-4, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

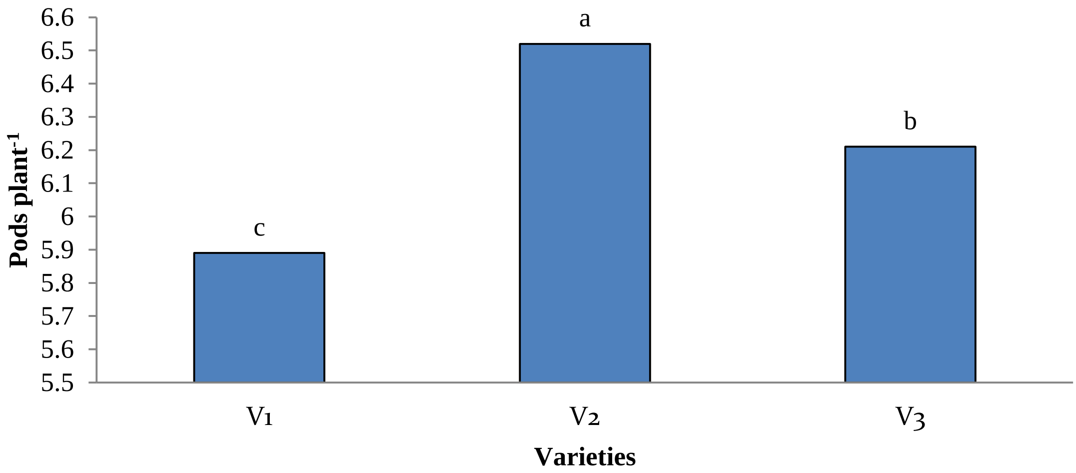
4.2 Yield contributing characters

4.2.1 Pods plant^{-1}

Effect of varieties

The number of pods plant^{-1} of blackgram was significantly influenced by different varieties (Fig. 13). Experimental results revealed that the highest number of pods plant^{-1} of blackgram (6.52) was found in V_2 (BARI Mash-3) treatment. Whereas the lowest number of pods plant^{-1} of blackgram (5.89) was found in V_1 (BARI Mash-2) treatment. Different blackgram varieties had different number of pods plant^{-1} was due to the genetic makeup of the variety and maximum number of pods plant^{-1} was obtained from high yielding varieties comparable to low yielding blackgram varieties.

The result obtained from the present study was similar with the findings of Mane *et al.* (2018) who reported that the blackgram variety BDU-1 was found to be highly productive as compared to TAU-1 and AKU-15. Variety BDU-1 produced maximum pods plant^{-1} i.e. (24.54) was significantly superior over variety TAU-1 i.e.23.77, and variety AKU-15 i.e. (21.83).



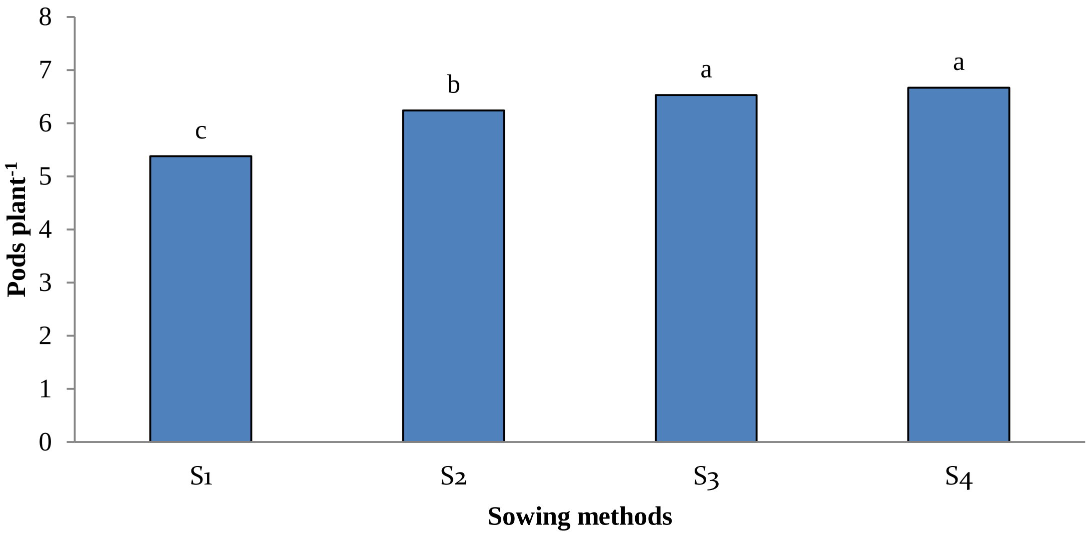
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 13. Effect of varieties on pods plant^{-1}of blackgram (LSD$_{(0.05)}$= 0.19).

Effect of plant spacing

The different plant spacing had shown significant effect on the number of pods plant^{-1} of blackgram (Fig. 14). According to the experimental results, the highest number of pods plant^{-1} of blackgram (6.67) was observed in the S_4 (30 cm × 15 cm) treatment which was statistically similar with S_3 (6.53) treatment. However the S_1 (Broadcasting) treatment had the lowest number of pods plant^{-1} of blackgram (5.38). This could be due to the fact that at high plant density or at closer spacing leads to competition for air, light, and nutrients, forcing plants to go through less reproductive growth and, as a result, reducing the number of pods plant^{-1}. Similar result also observed by Bonepally *et al.* (2021) who reported that the number of pods per plant (66.30) was found to be maximum in treatment combination with 30 × 10 cm^2 + 40 kg/ha of phosphorus as compared to rest of the treatments which is beneficial for blackgram production.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure. 14. Effect of sowing methods on pods plant^{-1}of blackgram(LSD$_{(0.05)}$= 0.25).

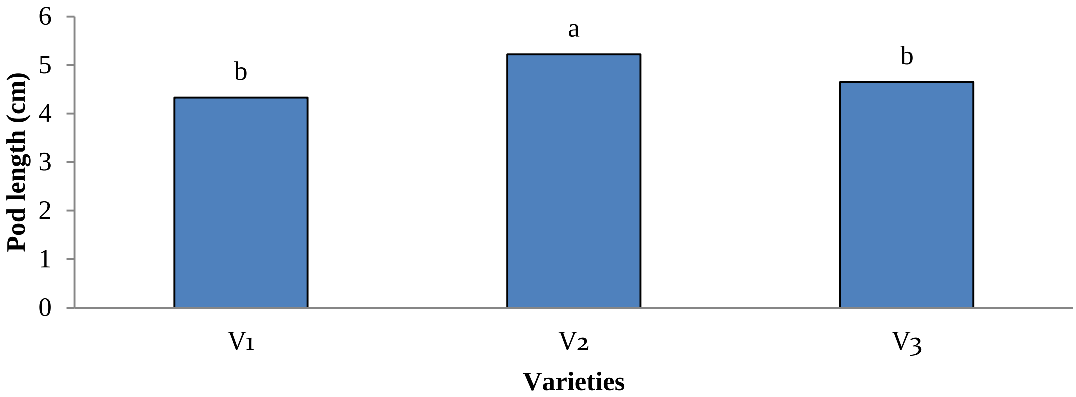
Combined effect of variety and plant spacing

Blackgram pods plant^{-1} was significantly influenced by variety andplant spacingcombination. (Table 6).Experimental result revealed that the highest number of pods plant^{-1} of blackgram (6.94) was observed in V_2S_4 treatment combination which was statistically similar with V_3S_4(6.60)treatment combination. While the lowest number of pods plant^{-1} of blackgram (4.54) was observed in V_1S_1 treatment combination.

4.2.2Pod length(cm)

Effect of varieties

The length of pods of blackgram was significantly influenced by various blackgram varieties (Fig. 15). The highest pod length was observed in the V_2(BARI Mash-3) treatment. While the V_1 treatment (BARIMash-2) had the lowest pod length of blackgram (4.33 cm) which was statistically similar to V_3 (4.65 cm)treatment. The pod length varies between blackgram varieties because of the variety's genetic makeup. Patra *et al.* (2001) who reported that the variation of pod length of the different blackgram cultivars differed significantly due to the genetic characters of the varieties.



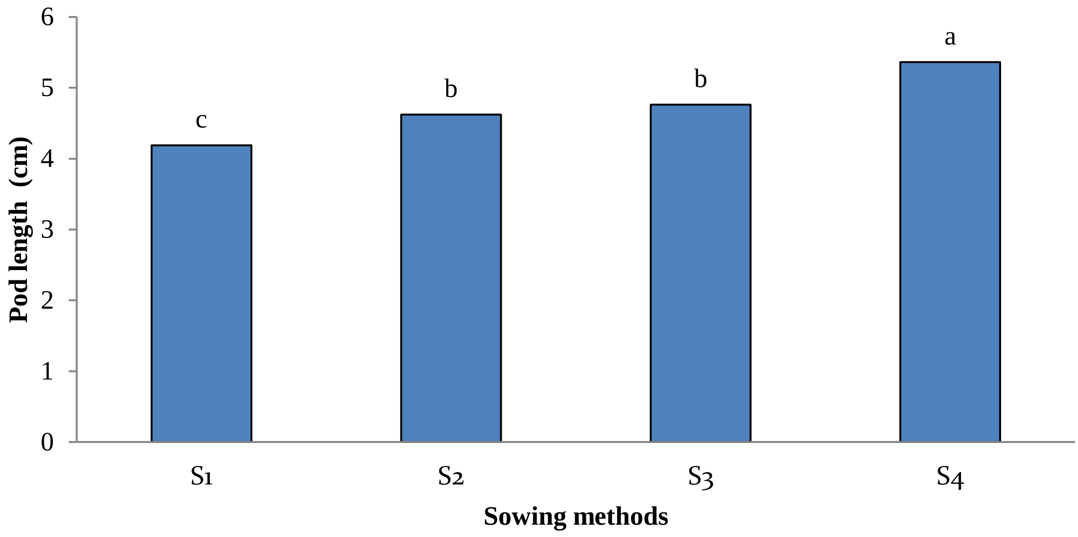
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 15. Effect of varieties on pod length of blackgram ($LSD_{(1)}$= 0.37).

Effect of plant spacing

Different plant spacing performed in the experiment field showed significant effect on the pod length of blackgram (Fig. 16). Experimental results showed that the highest pod length of blackgram (5.36 cm) was observed in the S_4 (30 cm × 15 cm) treatment. While the S_1 treatment (Broadcasting) had the lowest pod length of blackgram (8.56 cm). Increase in pod length might due to less competition between plant at optimum spacing and also availability of nutrient in adequate amount resulted in formation of photosynthesis, which promotes metabolic activity, increase the cell division, ultimately increase the pods length. Patel *et al*. (2005) reported that pod length increasing with increasing plant spacing.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure.16.Effect of sowing methods on pod length of blackgram ($LSD_{(0.05)}$= 0.32).

Combined effect of varieties and plant spacing

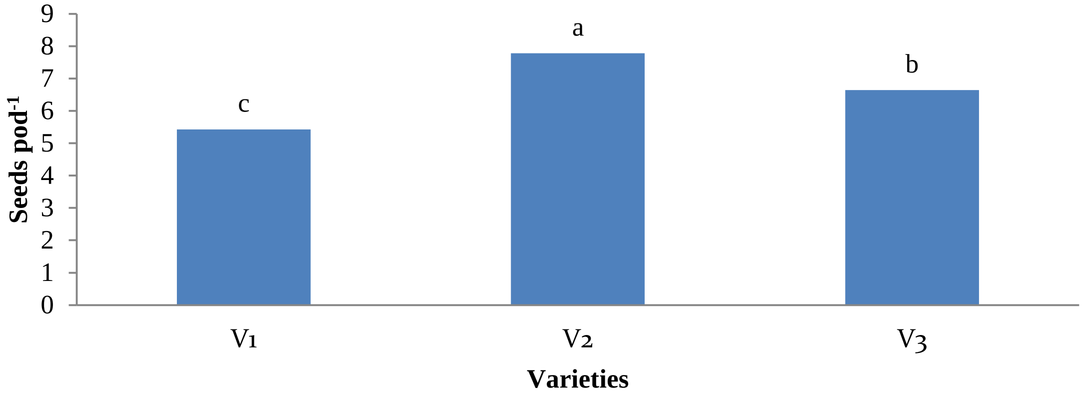
Combination of cultivar and plant spacing has shown significant effect on the pod length of blackgram (Table 6). The results of the experiment showed that the V_2S_4 treatment combination, had the largest pod length of blackgram (6.10). While the V_1S_1 treatment combination had the lowest pod length of blackgram (3.42).

4.2.3Seeds pod^{-1}

Effect of varieties

The number of seeds pod^{-1}of blackgram varied significantly depending on the variety (Fig. 17). According to the experimental findings the V_2 (BARI Mash-3) treatment had the highest number of seeds pod^{-1}of blackgram (7.78). On the other hand the V_1 (BARI Mash-2) treatment had the lowest seeds pod^{-1}of blackgram (5.43).The differences of number of seeds was due to the genetic characters of the varieties. Similar result observed by Vishnu *et al.* (2022) who reported that, the variances in the genetic make-up of the variety, which is mostly controlled by inheritance, are the cause of variations in the number of seeds pod^{-1} among different varieties of blackgram. Eswari and Rao (2007) also reported that the genotypes LBG-709, LBG-

693, LBG-712 and MBG-207 of black gram were found to be the most desirable genotypes for high seed yield, pods plant^{-1}, earliness, seeds pod^{-1} and seed weight.



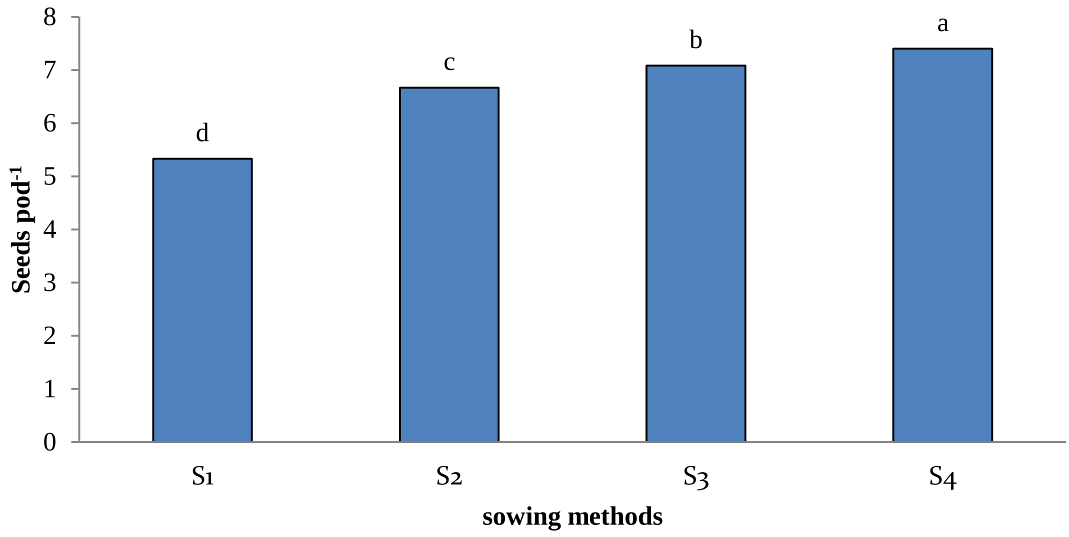
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 17. Effect of varieties on seeds pod^{-1}of blackgram (LSD$_{(0.05)}$= 0.33).

Effect of plant spacing

The number of seeds pod^{-1}of blackgram was significantly affected by the various plant spacing (Fig. 18). The results of the experiment showed that the S_4 treatment (30 cm × 15 cm) had the highest number of seeds pod^{-1}of blackgram (7.40). While the S_1 (Broadcasting) treatment had the lowest number of seeds pod^{-1}of blackgram (5.33).Similar findings were made by Bonepally *et al.*(2021) who claimed that the combination of 30 ×10 cm^2 + 40 kg/ha of phosphorus produced the maximum number seeds pod^{-1} (7.80), as compared to rest of the treatments which is beneficial for blackgram production.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure. 18. Effect of sowing methods on seeds pod^{-1}of blackgram(LSD$_{(0.05)}$= 0.28).

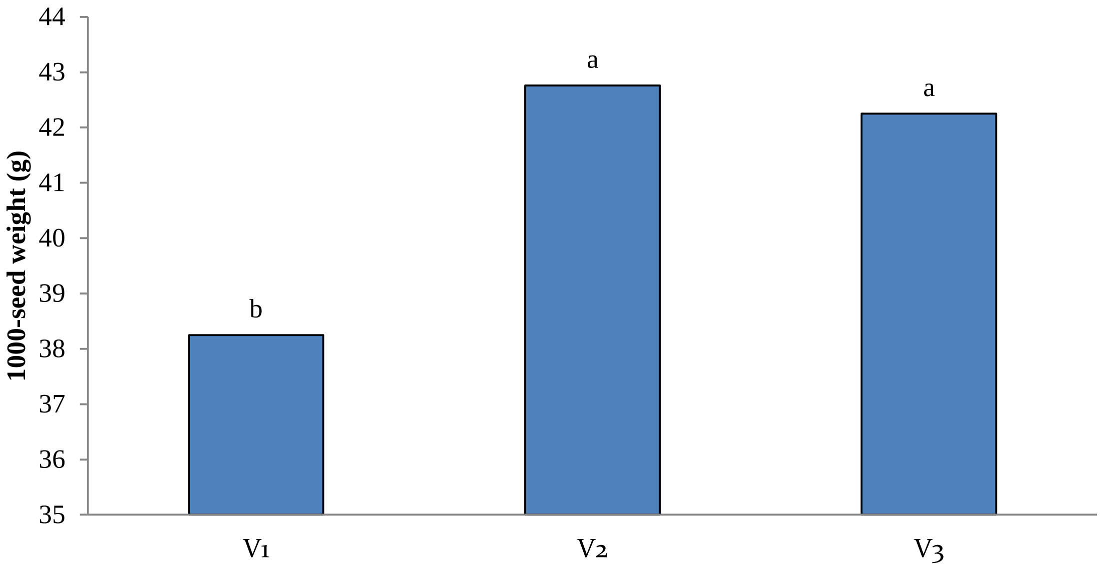
Combined effect of varieties and plant spacing

The number of seeds pod^{-1}of blackgram had been significantly affected by different varieties and plant spacing. (Table 6). According to the experimental findings, the V_2S_4 treatment combination had the highest number of seeds pod^{-1}of blackgram (8.80). While the lowest number of seeds pod^{-1}(3.27) of blackgram were seen with the V_1S_1 treatment combination.

4.2.4 1000-seed weight (g)

Effect of varieties

The 1000 seeds weight of blackgram was significantly affected by different varieties. (Fig. 19). The results of the experiment showed that the V_2 (BARI Mash-3) treatment had highest 1000-seed weight of blackgram (42.76 g) which was statistically similar with V_3 (42.25 g) treatment. While the V_1 (BARI Mash-2) treatment, had the lowest 1000-seed weight of blackgram (38.25 g). The differences in 1000 seeds weight among the various blackgram varieties could be attributed to the traits of the blackgram varieties and their genetic makeup. Gupta *et al.* (2006) reported that UG-218 urdbean variety produces significantly higher pods/plant, 1000 seed weight, seed yield as well as straw yield over other two varieties (Type-9 and Pant-U19).



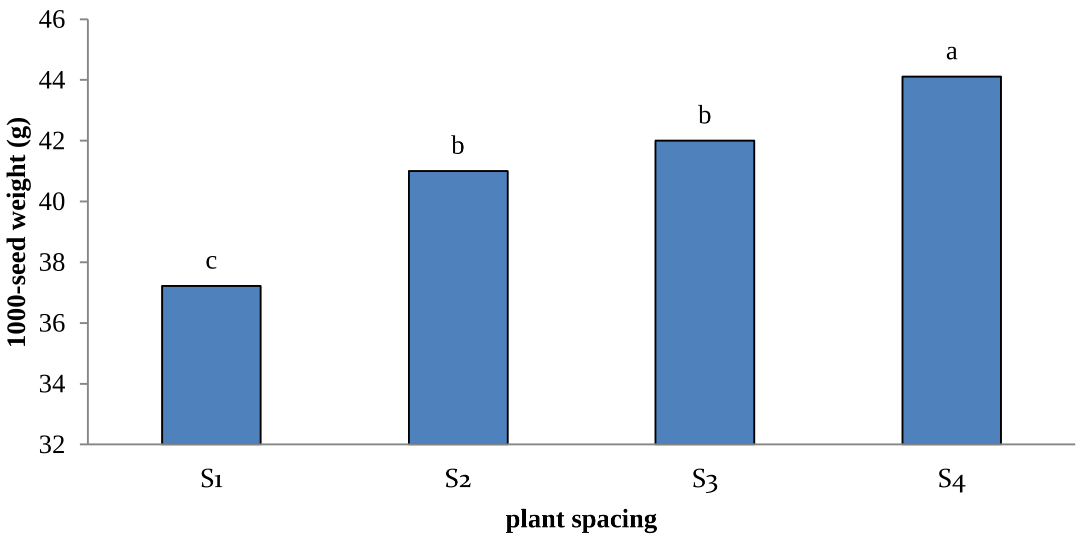
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 19. Effect of variety on 1000-seed weight of blackgram ($LSD_{(0.05)}$= 0.73).

Effect of plant spacing

The plant spacing had significant effect on the1000 seed weight of blackgram (Fig. 20). The experiment's findings revealed that the S4 treatment (*30 cm × 15 cm*)had the highest 1000-seed weight of blackgram (44.11 g).While the S1 (Broadcasting) treatment, had the lowest1000-seed weight of blackgram (37.22 g). Kumar and Rajput (2020) reported that crop geometry 30×10 (cm2) recorded significantly higher *1000* seed weight comparable to other treatments.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure.20. Effect of sowing methods on 1000-seed weight of blackgram ($LSD_{(0.05)}$= 1.26).

Combined effect of varietis and plant spacing

The 1000 seeds weight of blackgram varied significantly depending on the variety and sowing methods. (Table 6). According to the experimental findings, the highest 1000 seeds weight of blackgram (46.67 g)was found in V_2S_4 treatment combination. However, the lowest 1000 seed weight was indicated by the V_1S_1 treatment combination (33.34 g).

Table 6. Combined effect of varietis and plant spacing on pods plant^{-1}, pod length, seeds pod^{-1} and 1000-seed weight of blackgram.

Treatment combinations	Pods plant^{-1}(no)	Pod length(no)	Seeds pod^{-1}(no)	1000-seed weight(g)
V_1S_1	4.54 g	3.42 e	3.27 h	33.34 g
V_1S_2	6.14 de	4.43 d	5.73 g	39.00 f
V_1S_3	6.40 b-d	4.64 b-d	6.33 ef	39.00 f
V_1S_4	6.47 b-d	4.81 b-d	6.40 ef	41.67 cd
V_2S_1	5.94 ef	4.80 b-d	6.80 de	39.34 ef
V_2S_2	6.40 b-d	4.82 b-d	7.40 c	41.34 de
V_2S_3	6.80 ab	5.16 bc	8.13 b	43.67 bc
V_2S_4	6.94 a	6.10 a	8.80 a	46.67 a
V_3S_1	5.67 f	4.34 d	5.93 fg	38.99 f
V_3S_2	6.17 c-e	4.60 cd	6.87 c-e	42.67 b-d
V_3S_3	6.40 b-d	4.49 d	6.77 de	43.34 b-d
V_3S_4	6.60 a-c	5.18 b	7.00 cd	44.00 b
$LSD_{(0.05)}$	0.43	0.60	0.54	2.03
CV(%)	4.13	7.03	4.52	3.11

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

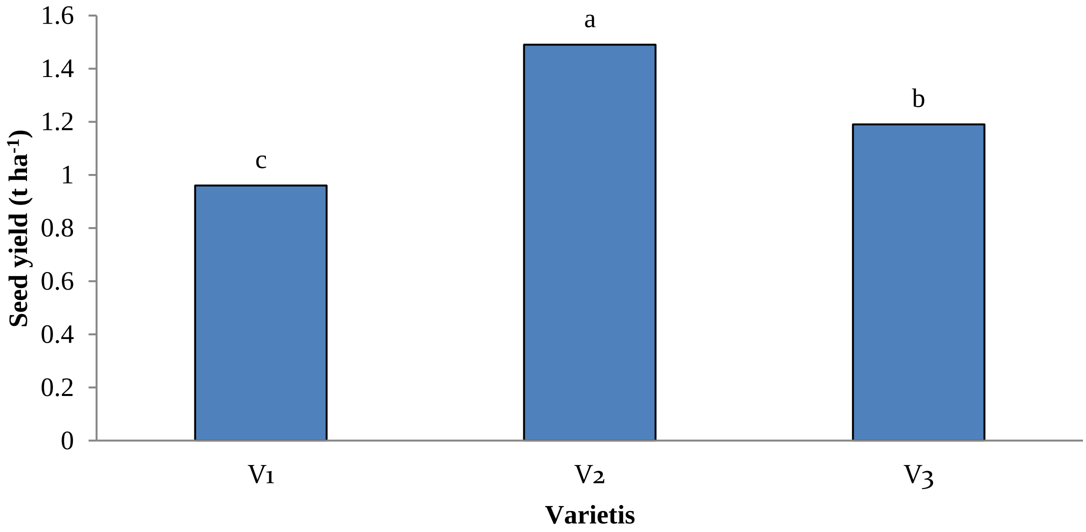
.Here,V_1 =BARI Mash-2, V_2 = BARI Mash-3, V_3 = BARI Mash-4, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

4.3 Yield characters

4.3.1 Seed yield (t ha^{-1})

Effect of varietis

Blackgram seed yield was significantly influenced by different varieties. (Fig. 21). In this experiment result revealed that the V_2 (BARI Mash-3) treatment recorded the highest seed yield of blackgram (1.49 t ha^{-1}). While V_1 (BARI Mash-2) treatment had the lowest seed yield (0.96 t ha^{-1}).The differences of seed yield among different varieties might be due to the inherent variation in the genetic makeup for photosynthesis and translocation of dry matter to grain yield production. Rathore *et al.* (2010) reported that yield varies among different varieties and the maximum seed yield of urdbean (1103 kg ha^{-1}) was observed by the variety Barkha which had lower maturity period than other varieties so as to gave higher seed yield as compared to T-9 and TAU-1.



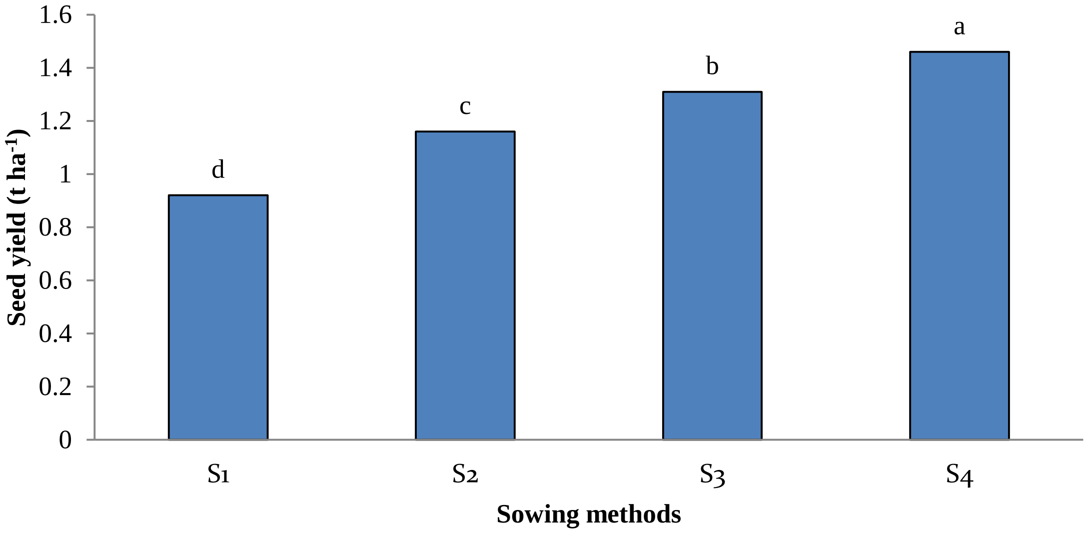
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 21. Effect of variety on seed yield of blackgram ($LSD_{(0.05)}$= 0.08).

Effect of plant spacing

The seed yield of blackgram was significantly affected by the various plant spacings (Fig. 22). The results of the experiment showed that the S_4 treatment (30 cm × 15 cm) had the highest seed yield of blackgram (1.46 t ha^{-1}). Whereas the lowest seed yield of blackgram (0.92 t ha^{-1}) was found in the S_1 (Broadcasting) treatment. The optimum spacing 30 cm × 15 cm helped plant to receive sufficient amount of heat, water and nutrients from soil which increased number of pods plant^{-1}, seeds pod^{-1} and 1000-seed weight which directly helped in increase of seed yield in blackgram. The results were similar to that found by Singh and Yadav (2013) who reported that the seed yield of blackgram was maximum with 30 cm spacing (641 kg ha^{-1}). However, the grain yield with 30 cm spacing was significantly superior over 45 cm spacing. Rasul *et al*. (2012) reported that the highest seed yield (675.84 kg ha^{-1}) of blackgram was found with 30 cm row spacing.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 22. Effect of sowing methods on seed yield of blackgram ($LSD_{(0.05)}$= 0.06).

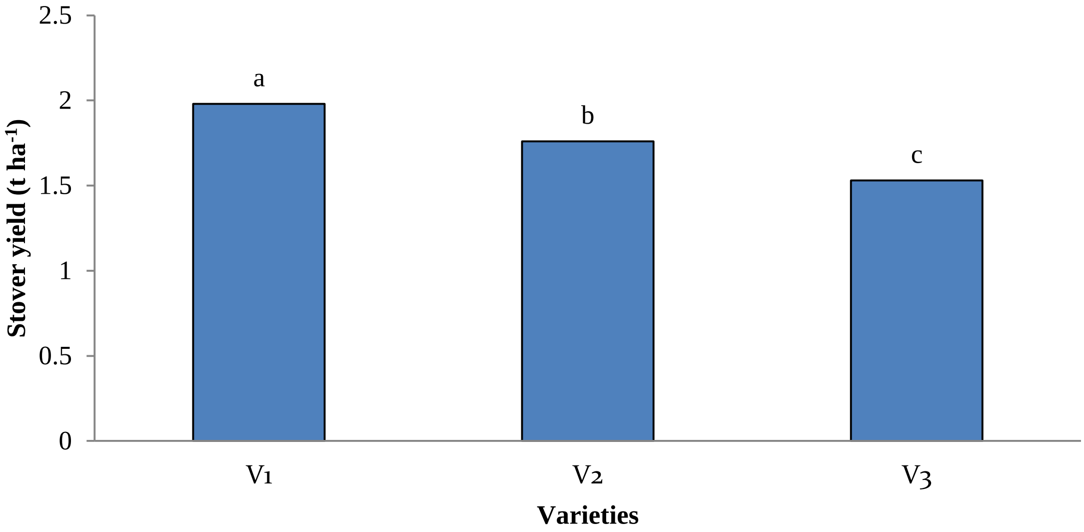
Combined effect of varietis and plant spacing

Depending on the varietis and plant spacing, blackgram seed yield varied significantly. (Table 7). According to the experimental results, the V_2S_4 treatment combination (1.80 t ha^{-1}) treatment combination had the highest seed yield. While theV_1S_1 treatment combination indicated the lowest seed yield(0.78 t ha^{-1}) which was statistically similar to the V_1S_2 (0.87 t ha^{-1}) and V_2S_4 (1.80 t ha^{-1})treatment combination.

4.3.2 Stover yield(t ha^{-1})

Effect of varietis

The stover yield was significantly influenced by different blackgram varieties (Fig. 17). The results of the experiment indicated that the V_1(BARI Mash-2) treatment had the highest stover yield (1.98 t ha^{-1}). While V_3(BARI Mash-4) treatment had the lowest stover yield(1.53 t ha^{-1}).Sharma (2015) also found similar result with present study and reported that stover yield of blackgram was varied with different varieties.



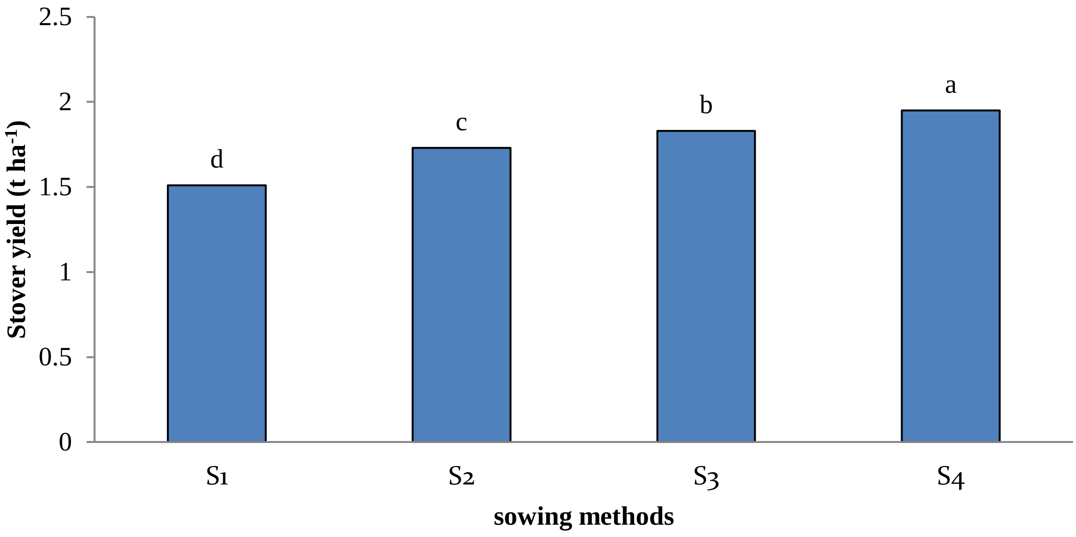
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Fig. 23. Effect of varieties on stover yield of blackgram ($LSD_{(0.05)}$= 0.05).

Effect of plant spacing

The different plant spacing had shown significant effect on the stover yield of blackgram (Fig. 24).The experiment showed that the S_4 (30 cm × 15 cm)treatment recorded the highest stover yield (1.95 t ha^{-1}). While the lowest stover yield was achieved with the S_1 treatment (1.51 t ha^{-1}). Stover yield is chiefly a product of growth parameters like plant height, number of branches and dry matter accumulation. So the increase in these characters as a result of adequate spacing resulted in increase of straw yield of blackgram. Khan and Asif (2001) reported that the plant spacing significantly affected the stover yield (kg ha^{-1}) of blackgram.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

Figure.24. Effect of plant spacing on stover yield of blackgram ($LSD_{(0.05)}$= 0.07).

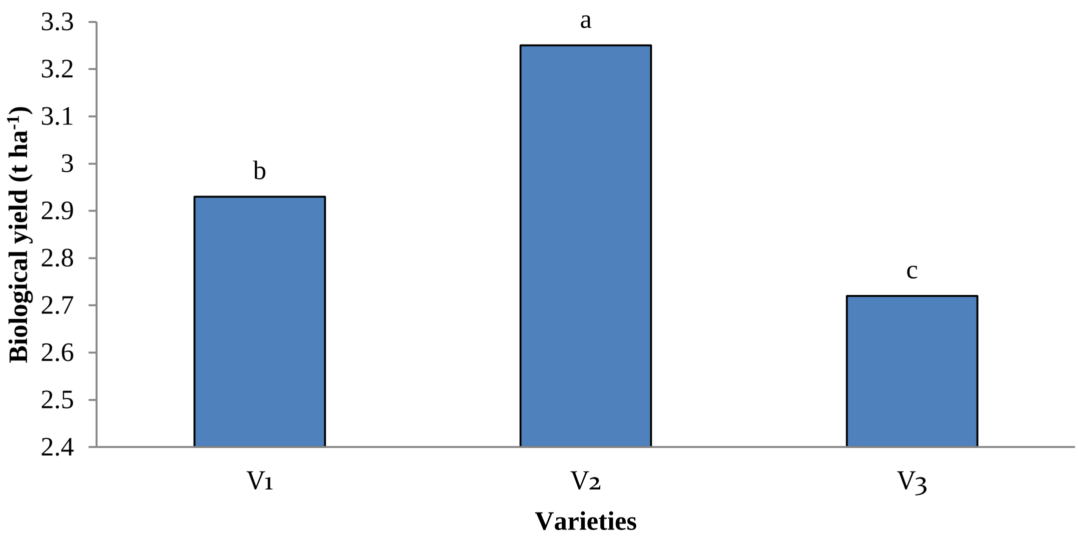
Combined effect of varieties and plant spacing

The stover yield of blackgram varied significantly according on the combined effect of different varieties and plant spacing. (Table 7). The highest stover yield (2.23 t ha^{-1}) was observed in V_1S_4 treatment combination. Whereas the lowest stover yield (1.23 tha^{-1}) was revealed by the V_3S_1 treatment combination.

4.3.3 Biological yield

Effect of varieties(t ha^{-1})

Different blackgram varieties had significant effect on the biological yield (Fig. 25). The experiment showed that the V_2(BARI Mash-3) treatment recorded the highest biological (3.25 t ha^{-1}). While the least biological yield was found in V_3(BARI Mash-4) treatment (2.72 t ha^{-1}).The variation of biological yield by different varieties might be due to the contribution of cumulative favourable effects of the crop characteristics viz., seed and stover yield of the crop. Sharma *et al*. (2012) found similar result which supported the present finding and reported that the variation in biological yield differ among genotype of blackgrams and among different genotype blackgram genotype Mash-1 recorded the highest biological yield (8313 kg ha^{-1}) over Mash338 (6110 kg ha^{-1}).



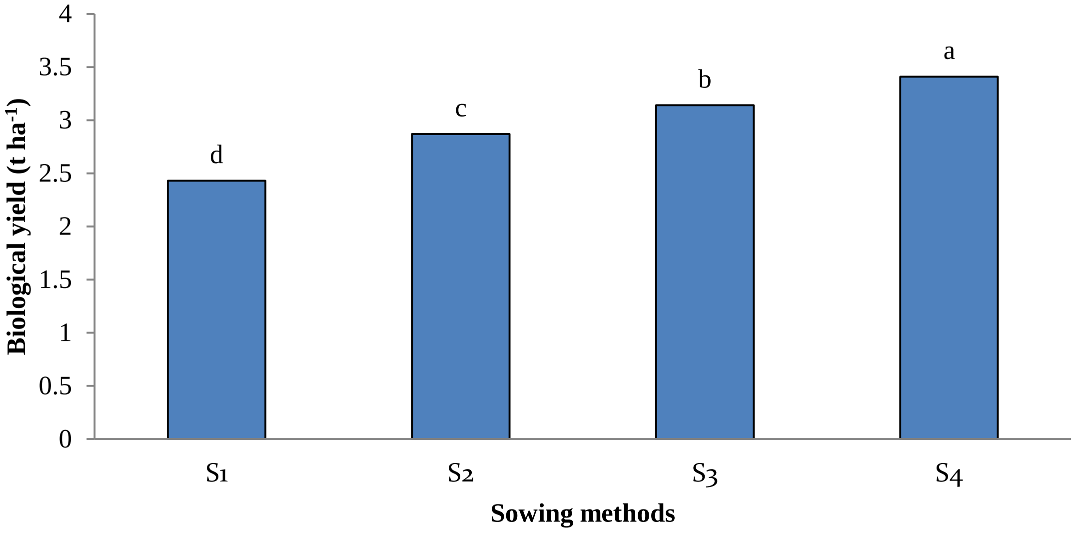
In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 25. Effect of varieties on biological yield of blackgram ($LSD_{(0.05)}$= 0.08).

Effect of plant spacing

The biological yield of blackgram was significantly affected by the various sowing methods technique (Fig. 26). The results of the experiment demonstrated that the highest biological yield (3.41 t ha^{-1}) was obtained by the S_4 (30 cm × 15 cm) treatment. While the S_1 (Broadcasting) treatment resulted in the lowest biological yield (2.43 t ha^{-1}). Higher biological yield might be observed in adequate spacing due to more vigour and strength attained by the plants as a result of better photosynthetic activities with sufficient availability of light, and supply of nutrients in balanced quantity of the plants at growing stages".Bonepally *et al.* (2021) reported that the biological yield (2926 kg ha^{-1}) was found to be maximum in treatment combination with 30 × 10 cm^2 + 40 kg/ha of phosphorus as compared to rest of the treatments which is beneficial for blackgram production.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm and S_4 = 30 cm × 15 cm.

Figure.26. Effect of plant spacing on biological yield of blackgram ($LSD_{(0.05)}$= 0.08).

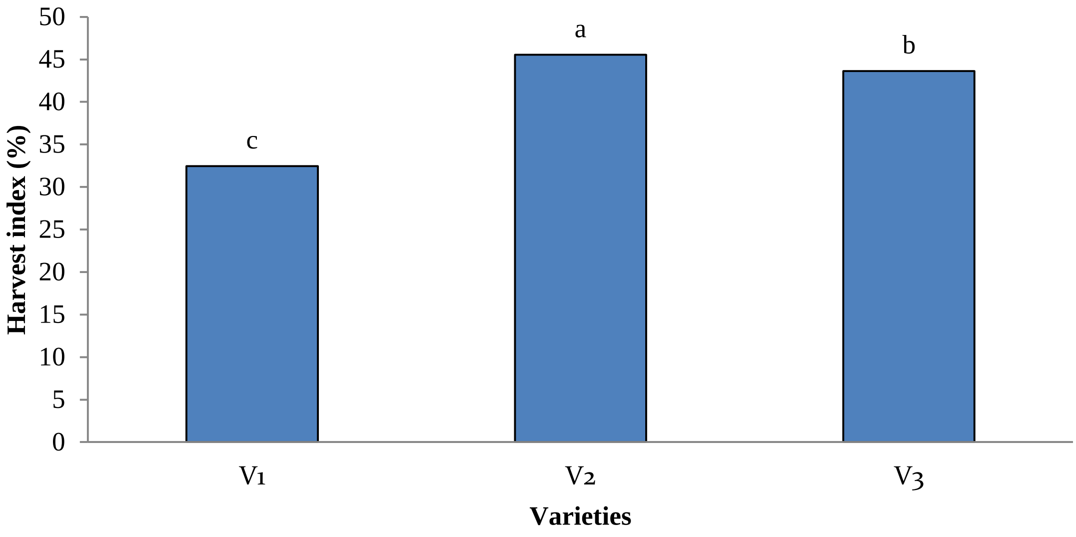
Combined effect of varieties and plant spacing

Different varieties along with plant spacing had shown significant effect on the biological yield of blackgram. (Table 7). The V_2S_4 treatment combination had the highest biological yield (3.67 t ha^{-1}).Whereas the V_3S_1 treatment combination recorded the lowest biological yield (2.13 t ha^{-1}).

4.3.4 Harvest index

Effect of varieties

Blackgram varieties significantly influenced on harvest index (Fig. 27). The results of the investigation showed that the V_2 (BARI Mash-3) treatment recorded the highest harvest index (45.53 %) over other varieties might be due to the higher production efficiency that has been reflected through improvement in different yield attributing characters. While V_1 (BARI Mash-2) treatment had the lowest harvest index (32.45 %).Due to genetic diversity, the harvest index varied greatly between varieties. Mondal *et al.* (2011) reported that harvest index of blackgram significantly influenced due to varieties.

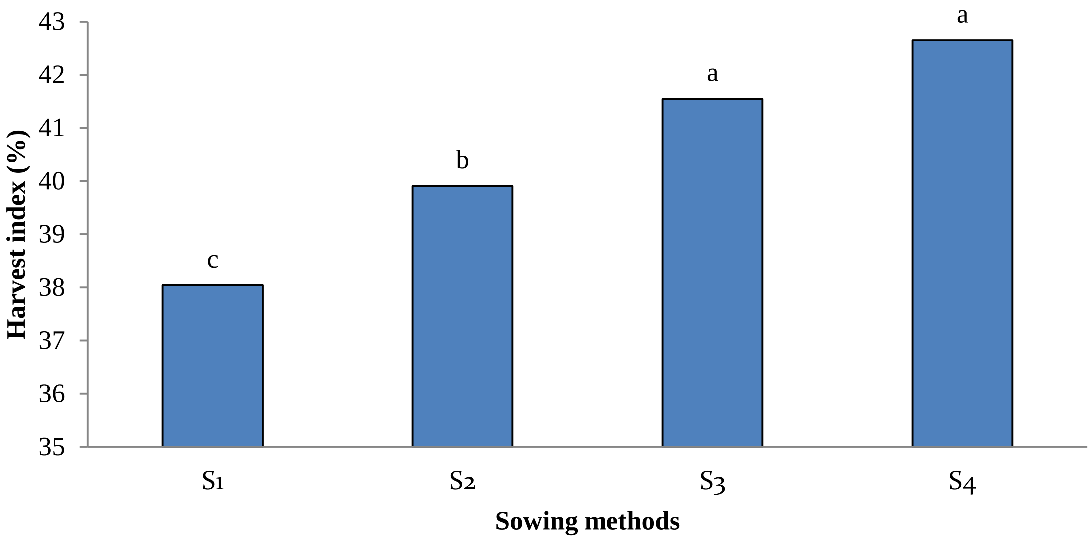


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability. Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 27. Effect of variety on harvest index of blackgram ($LSD_{(0.05)}$= 0.58).

Effect of plant spacing

The different plant spacing had shown significant effect on the harvest index of blackgram (Fig. 28). The experiment showed that the S_4 (30 cm × 15 cm) treatment, which was statistically equal to the S_3 (41.55 %) treatment, had the highest harvest index (42.65 %). Whereas the S_1 (Broadcasting) treatment recorded the lowest harvest index (38.04 %). Achakzai and Panizai (2007) reported that the maximum harvest index of blackgram (61.44%) was obtained in row spacing of 40 cm which is statistically at par with four other spacing *viz;* 20, 25, 30 and 35 cm. Achakzai and Panizai (2007) stated that maximum harvest index of0.61 was got in row spacing of 40 cm, which is statistically at parwith four other spacing *viz*; 20, 25, 30 and 35 cm.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5.0 % level of probability.

Here, V_1 =BARI Mash-2, V_2 = BARI Mash-3 and V_3 = BARI Mash-4.

Figure. 28. Effect of plant spacing plant spacing on harvest index of blackgram ($LSD_{(0.05)}$= 1.38)

Combined effect of varieties and plant spacing

The harvest index of blackgram was significantly influenced by different varieties and plant spacing. (Table 7). The highest index yield (49.05 %) was recorded by the V_2S_4 treatment combination, which was statistically equal to the V_2S_3 (46.94 %) treatment combination. The lowest harvest index (30.95 %) was recorded by the V_1S_1 treatment combination, which was statistically similar to the V_1S_2 (31.64 %) treatment combination.

Table 7. Combined effect of varieties and so plant spacing on seed, stover, biological yield and harvest index of blackgram.

Treatment combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1S_1	0.78 f	1.74 d	2.52 g	30.95 g
V_1S_2	0.87 f	1.88 c	2.75 ef	31.64 fg
V_1S_3	1.05 e	2.06 b	3.11 d	33.76 f
V_1S_4	1.12 e	2.23 a	3.35 bc	33.43 f
V_2S_1	1.08 e	1.56 e	2.64 fg	40.91 e
V_2S_2	1.47 c	1.78 cd	3.25 cd	45.23 bc
V_2S_3	1.61 b	1.82 cd	3.43 b	46.94 ab
V_2S_4	1.80 a	1.87 c	3.67 a	49.05 a
V_3S_1	0.90 f	1.23 f	2.13 h	42.25 de
V_3S_2	1.14 de	1.52 e	2.66 fg	42.86 de
V_3S_3	1.27 d	1.62 e	2.89 e	43.94 cd
V_3S_4	1.46 c	1.75 d	3.21 cd	45.48 bc
$LSD_{(0.05)}$	0.13	0.11	0.16	2.16
CV(%)	5.14	3.79	3.08	3.45

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

V_1 =BARI Mash-2, V_2 = BARI Mash-3, V_3 = BARI Mash-4, S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm.

CHAPTER-V

SUMMERY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from March to June 2021 in Kharif I season, to study the response of blackgram varieties as affected by different plant spacing. The experiment consisted of two factors, and followed split plot design with three replications. Factor A:Blackgram varieties (3)*viz*:V_1=BARI Mash 2, V_2=BARI Mash 3, V_3=BARI Mash 4 and Factor B: Different plant spacing(4) *viz*: S_1 = Broadcasting, S_2 = 15 cm × 10 cm, S_3 = 20 cm × 20 cm, and S_4 = 30 cm × 15 cm. For the purpose of evaluating the experiment's outcomes, data on various parameters were evaluated. These data revealed significant variance in blackgram's growth, yield, and yield-contributing traits as a result of variety, plant spacing, and combination of these factors.

In case of variety, the highest growth parameters *i.e*. plant height, leaves plant^{-1}, branches plant^{-1}, nodulesplant^{-1}nodules dry weight plant^{-1} and aboveground dry matter weight were observed by V_2 (BARI Mash-3) treatment. However this treatment also recorded the highest pods plant^{-1} (6.52),pod length (5.22 cm),seeds pod^{-1}(7.78),1000-seed weight(42.76 g),seed yield (1.49 t ha^{-1}),biological (3.25 t ha^{-1}) and harvest index (45.53 %) comparable to other treatments. Whereas the lowest yield contributing characterizes and yield *viz*, pods plant^{-1} (5.89),pod length (4.33cm),seeds pod^{-1}(5.43),1000-seed weight(38.25g),seed yield (0.96 t ha^{-1}) and harvest index (32.45) were observed in V_1 (BARI Mash-2) treatment.

In terms of different plant spacingS_4 (30 cm × 15 cm) treatment showed the highest growth characteristics, including plant height, leaves plant^{-1}, branches plant^{-1}, nodulesplant^{-1},nodulesplant$^{-1,}$dry weight plant^{-1}, and aboveground dry matter weight. However, in comparison to other treatments, this treatment also had the highest pods plant^{-1} (6.67),pod length (5.36cm),seeds pod^{-1}(7.40),1000-seed weight(44.11g),seed yield (1.46 t ha^{-1}), stover yield (1.95 t ha^{-1}) biological (3.41t ha^{-1}) and harvest index (42.65 %). While the S_1 (Broadcasting) treatment showed the lowest seed yield (0.92 t ha^{-1}) with pods plant^{-1} (5.38),pod length (4.19cm),seeds pod^{-1}(5.33) and 1000-seed weight(37.22g).

In case of combination, the V_2S_4 treatment combination demonstrated the best growth traits in terms of plant height, leaves plant^{-1}, branches plant^{-1}, nodules, nodules dry weight plant^{-1}, and aboveground dry matter weight. The treatment combination, however, also produced the highest pods plant^{-1} (6.94),pod length (6.10cm),seeds pod^{-1}(8.80),1000-seed weight(46.67g),seed yield (1.80 t ha^{-1}),biological (3.67t ha^{-1}) and harvest index (49.05 %)when compared to all treatment combination. With pods plant^{-1} (4.54),pod length (3.42cm),seeds pod^{-1}(3.27),1000-seed weight(33.34g) the V_1S_1 treatment combination had the lowest seed yield (0.78 t ha^{-1}) and harvest index (30.95 %) comparable to other treatment combinations.

Conclusion

Based on the above findings, the experimental results revealed that different varieties and plant spacing significantly influenced the growth, yield contributing characteristics and seed yield of blackgram, so it may be concluded that In case of combination, cultivation of BARI Mash-3 along with 30 cm × 15 cm spacing affected plant growth and yield-contributing characteristics, leading to the maximum seed yield (1.80 t ha^{-1}) than compared to other treatment combination. Also helps to plant growth and increase its ability to enhanced better yield production of blackgram.

Recommendation

This research may be conducted at different blackgram sowing areas of Bangladesh and it is very important that the treatment variables could be tested in a different blackgram areas for farther confirming present findings.

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APPENDICES

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	**Characteristics**
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0-15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. Monthly meteorological information during the period from March to June, 2021.

Year	**Month**	**Air temperature (^{0}C)**		**Relative humidity (%)**	**Total rainfall (mm)**
		Maximum	**Minimum**		
2021	March	32.9°C	20.1°C	61%	54 mm
	April	34.1°C	23.6°C	67%	138 mm
	May	33.4°C	24.7°C	76%	269 mm
	June	34°C	27.3°C	76%	134 mm

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data of plant height of blackgram at different DAS

Source	**DF**	Mean square of plant height at			
		15 DAS	30 DAS	45 DAS	At harvest
Replication (R)	2	0.7500	3.308	10.083	14.083
Variety (V)	2	19.3695*	48.543*	231.500*	122.390*
Error	4	1.7500	1.158	3.083	3.083
Sowing method (S)	3	67.8636*	193.338*	473.202*	702.331*
V×S	6	4.0328*	11.714*	14.595*	61.311*
Error	18	1.4167	1.607	4.083	6.750

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of branches plant^{-1}of blackgram at different DAS

Source	**DF**	Mean square of branches plant^{-1}		
		30 DAS	45 DAS	At harvest
Replication (R)	2	0.02083	0.01613	0.1008
Variety (V)	2	1.71030*	3.69722*	26.2848*
Error	4	0.00583	0.00563	0.0558
Sowing method (S)	3	1.22489*	8.59996*	70.7233*
V×S	6	0.21557*	2.74166*	10.3299*
Error	18	0.01083	0.00913	0.0708

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data ofleaves plant^{-1}of blackgram at different DAS

Source	**DF**	Mean square of leaves plant^{-1}			
		15 DAS	30 DAS	45 DAS	At harvest
Replication (R)	2	0.0408	1.3333	3.000	1.083
Variety (V)	2	15.3800*	16.2594*	2.301^{Ns}	89.290*
Error	4	0.0158	0.5833	1.000	1.583
Sowing method (S)	3	19.8395*	92.1742*	241.298*	605.386*
V×S	6	0.8977*	12.8270*	15.618*	3.931*
Error	18	0.0242	0.8333	1.667	1.417

Ns: Non significant

*Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of nodule number and nodule dry weight plant^{-1}of blackgram at different DAS

Source	**DF**	Mean square of			
		Nodules plant^{-1}		Nodules dry weight plant^{-1}	
		45 DAS	At harvest	45 DAS	At harvest
Replication (R)	2	0.00015	3.333E-07	3.101	0.908
Variety (V)	2	0.07694*	1.268E-04*	385.066*	64.163*
Error	4	0.00015	1.083E-06	1.726	0.683
Sowing method (S)	3	0.05834*	3.743E-04*	559.106*	577.600*
V×S	6	0.02253*	7.775E-05*	45.665*	9.309*
Error	18	0.00012	8.333E-07	2.162	0.758

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix VII1. Analysis of variance of the data of above ground dry matter weight plant^{-1}of blackgram at different DAS

Source	**DF**	Mean square of stem above ground dry matter weight plant^{-1}at harvest
Replication (R)	2	0.2700
Variety (V)	2	16.9675*
Error	4	0.1181
Sowing method (S)	3	31.7215*
V×S	6	0.4489*
Error	18	0.1688

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of number of pods plant^{-1}, pod length seeds pod^{-1} and 1000-seed weight of blackgram

Source	**DF**	Mean square of stem dry weight plant^{-1}			
		Pods plant^{-1}	Pod length	Seed pod^{-1}	1000-seed weight
Replication (R)	2	0.03000	0.08333	0.0758	0.6603
Variety (V)	2	1.20033*	2.46068*	16.5724*	73.0434*
Error	4	0.03000	0.11083	0.0896	0.4228
Sowing method (S)	3	3.00049*	2.13076*	7.4239*	74.8256*
V×S	6	0.28399*	0.27661*	1.0269*	3.5101*
Error	18	0.06556	0.10167	0.0850	1.6353

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data of number of seed yield, stover yield, biological yield and harvest index of blackgram

Source	**DF**	Mean square of stem dry weight plant^{-1}			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication (R)	2	0.01333	0.00653	0.01333	0.270
Variety (V)	2	0.86228*	0.60082*	0.83790*	600.106*
Error	4	0.00583	0.00203	0.00583	0.270
Sowing method (S)	3	0.47723*	0.31497*	1.56649*	36.429*
V×S	6	0.02088*	0.01209*	0.02217*	5.491*
Error	18	0.00389	0.00442	0.00833	1.959

Ns: Non significant

*: Significant at 0.05 level of probability