GROWTH AND YIELD RESPONSE OF MUNGBEAN VARIETIES TO PLANTING GEOMETRY

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CERTIFICATE

This is to certify that the thesis entitled, " ***GROWTH AND YIELD RESPONSE OF MUNGBEAN VARIETIES TO PLANTING GEOMETRY*** *" 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* ***MAHMUDA AHMED,*** *Registration no.* ***19-10364*** *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.

Date:

Place: Dhaka, Bangladesh

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DEDICATED TO

MY

BELOVED PARENTS

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GROWTH AND YIELD RESPONSE OF MUNGBEAN VARIETIES TO PLANTING GEOMETRY

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from March to June 2021, to study the growth and yield values of mungbean varieties to planting geometry. The experiment comprised of two factors like, (i) varieties (3) *viz*., V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8 and (ii) planting geometry (4) *viz*., P_1= Broadcast, P_2=Paired row (15 cm × 10 cm) cm, P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm) and followed split plot design with three replications. Result showed that, variety, planting geometry and their combination had significant effect on growth, yield contributing parameters and yield of mungbean. Binamoog-8 showed maximum yield (1.76 t ha^{-1}) with pods $plant^{-1}$ (21.37), pod length $plant^{-1}$ (7.09 cm), seeds pod^{-1} (11.98), 1000-seed weight (50.76 g), biological yield (4.34 t ha^{-1}) and harvest index (40.65 %) maximum compared to others varieties. In case of planting geometry results revealed that, the conventional spacing management (30 cm × 10 cm) influenced plant to yielding maximum (1.59 t ha^{-1}) with several yield contributing characters like pods $plant^{-1}$ (21.67), pod length $plant^{-1}$ (7.33 cm), seeds pod^{-1} (12.45) and 1000-seed weight (49.25 g). In case of different planting geometry the lowest seed yield (1.47 t ha^{-1}) was obtained from P_1 (Broadcasting). Binamoog-8 along with spacing 30 cm × 10 cm (V_3P_4) found suitable combination for maximum growth, yield and yield contributing parameters of mungbean. Thus, this management could help farmers to have increased production of mungbean.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agr.
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 Political Science Association	IPSA
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Phosphorus solubilizing bacteria	PSB
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Mungbean (*Vigna radiata* L) is one of the most popular pulse crops, grown on more than six million hectares of land across the globe representing around 8.5 percent of the global pulse cultivated area (Hou *et al*., 2019). The mungbean is extensively cultivated in many Asian countries, primarily India, Bangladesh, China, Pakistan, and some Southeast Asian countries, as well as in dry regions of southern Europe and warmer regions of the USA and Canada, owing to its characteristics such as the short duration crop (around 70 days), low-input crop, and drought tolerance (Di Paola *et al*., 2017). Mungbean serves as a rich source of protein, containing 14.6-33.0 g/100 g protein and 5.9-7.6 mg/100 g iron (Kumar and Pande, 2018). Mungbean is a popular food for low-income people, especially those who cannot afford animal protein, as its production cost is low. Vegetarians also consume it as a good protein in their diet (Sehrawat *et al*., 2020). Mungbean, a plant-based protein, contributes substantially to reducing the effects of climate change, as plant protein generates considerably less greenhouse gas than animal protein. Cultivation of mungbean enhanced soil physical, biological and chemical properties as well as soil fertility status and improved through biological nitrogen fixation with symbiotic association with *rhizobium* from the atmosphere (Diatta *et al*., 2020). Mungbean is a popular pulse crop in Bangladesh and its cultivated area was 54.98 thousand ha with annual production of 34,400 m tons (BBS, 2021). But over the years, pulse production is gradually decreasing. The low yield is attributed to several reasons *viz*., cultivated as rainfed crop, cultivating in marginal lands, poor management practices and low yield potential of varieties.

The release of high yielding varieties has contributed a great deal towards the improvement of mungbean yields. Improved varieties of different pulse crops hold promise to increase productivity by 20-25%, whereas latest technology comprising varieties and integrated nutrients and pests management has shown 25-42% increase productivity (Pandey *et al*., 2022). Several high-yielding varieties was released in this country and distributed throughout the countries for cultivation (Islam *et al.*, 2020).

The yield potential of these high yielding varieties can be further exploited through better agronomic practices. Yield potentiality of mungbean can be fully harnessed with combination of agronomic practices and recommended varieties with suitable zone (Mondal *et al*., 2012). Among the various agronomic practices, planting geometry is the most important factor influencing the yield of mungbean.

The gap between potential and existing yield of greengram can be bridged by using optimized spacing of various greengram varieties to improve its production by achieving optimum plant population (Sathyamoorthi *et al.*, 2012). Optimum spacing requirement depends on type of crop and cultivar, growing season and planting system. Most of short duration pulse varieties need narrow spacing, while long duration varieties perform well under wider spacing. An appropriate planting density in field crops and vegetables lead to better harness of the solar radiation to translate into higher crop yields (Choudhary and Suri, 2014). The significance of using optimum inter and intra row spacing has been recognized by several researchers. Kabir and Sarkar (2008) reported that highest seed yield of greengram was obtained by maintaining 30 × 10 cm spacing between rows and plants, respectively. Plant density of 40 plants per square meter at 25 × 10 cm planting was the optimum for achieving higher productivity (Singh *et al.*, 2013 a). The results of Ahmad (2016) showed a seed rate of 25 kg per hectare is optimum to obtain maximum greengram yield. Seed yield of greengram per unit area tended to increase up to 30 plants per square meter and further increase in density did not result any further in yield per unit area. Jahan and Hamid (2004) reported a decline in seed yield as the density of plants increased to 60 plants per square meter. Gebremariam and Baraki (2018) concluded that the optimum plant population of greengram was 666,667 plants per hectare obtained through the configuration of 30 cm and 10 cm between rows and plants within row, respectively.

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 thus harvested lower yield (Ekanayake *et al*., 2011). Optimum plant density is a primary requirement for a better crop growth in order to minimize intraspecies competition (Widyati *et al*., 2022). So it is required to maintain optimum spacing for obtaining higher yield.

Keeping in view of the above facts, an experiment was carried out on growth and yield response of mungbean varieties to planting geometry with the following objectives:

i. To evaluate varietal difference regarding their growth and yield performance.
ii. To determine the effect of planting geometry on growth and yield of mungbean.
iii. To study the combined effect of variety and planting geometry towards maximum yield of mungbean.

CHAPTER II

REVIEW OF LITERATURE

In this section, an attempt was made to collect and study relevant information available regarding the growth and yield response of mungbean varieties to planting geometry in order to gather knowledge useful in carrying out the current piece of work.

2.1 Effect of variety

Yoseph (2022) carried out a field experiments to study the performance evaluation of mungbean [*Vigna radiata* (L.) Wilczek] varieties in pastoral areas of South OmoZone, Southern Ethiopia. Experimental result revealed that the overall mean values for plant height ranged from 41.33 cm for Shewarobit to 62.00 cm for the local check. The mean values for the number of pods per plant ranged from 19.33 for the local check to 24.44 for NVL-01. The mean value for thousand seeds weight was maximum 59.56 g for N-26, while it was a minimum 48.22 g for Shewarobit. The highest overall mean grain yield of 2483.8 kg ha^{-1} was recorded for N-26 while the minimum 1462.6 kg ha^{-1} was noted for the local check. The grain yield advantages of 41.11, 34.52, and 25.26% were obtained from the improved varieties N-26, NVL-01, and Shewarobit, respectively over the local check. The effect of varieties on grain yield was significant and the best performing mungbean varieties were N-26 2483.8 kg ha^{-1} and NVL-01 2233.6 kg ha^{-1}.

Jnanesha *et al*. (2019) carried out a study on the performance of different cultivar of greengram in Northern transition zone of Karnataka, Ethiopia during the year 201415. The variety SML 668 recorded significantly higher seed yield (985.2 kg ha^{-1}) compared to rest of the cultivars and was followed by PDM 139 (913.2 kg ha^{-1}). Significantly lower seed yield was recorded in DGGV 2 (701.3 kg ha^{-1}). The seed yield in SML 668 was higher to an extent 7.9 per cent, 15.2 per cent, 23.9 per cent and 40.4 per cent respectively over PDM 139, BGS 9, SML 832 and DGGV 2.

Kumar *et al*. (2018) in India observed that number of seeds $plant^{-1}$, seed yield and economics were significantly affected by different mungbean genotypes.

Dash and Rautaray (2017) at Odisha, India observed that maximum number of branches, seed and stover yield were produced by variety Pusa Vishal as compared to local variety of greengram. This could be due to different genetic variability and adaptability to the environment of greengram varieties.

Govardhan *et al.* (2017) conducted a field experiment in India on six mungbean varieties viz., TLM-80, WGG-42, LM-12, LM-5s5, LM-97 and MGG-30 for drought related traits and found that variety MGG-390 produced higher number of leaves plant^{-1}, branches plant^{-1}, specific leaf area index and was resistant to moisture stress condition.

Noorzai *et al*. (2017) from Afghanistan observed that the mungbean genotype Mash2008 produced significantly higher number of pods plant^{-1} (25.8) than the other genotypes but at par with genotype Mai-2008 (24.5).

Palsaniya *et al.* (2016) from India while studying on four mungbean varieties SML 668, Smart, Mehaand and IPM 02-3 observed that variety IPM 02-3 gave more number of pods plant^{-1} as compared to other varieties.

Razzaqe *et al.* (2016) at Gazipur, Bangladesh studied on nitrogen fixing ability of mungbean genotypes under different levels of nitrogen application and found that genotype IPSA 12 at 40 kg nitrogen ha^{-1} produce maximum number of nodules per plant as compared to other genotypes.

Zahan *et al*. (2016) in Bangladesh studied on three mungbean varieties, BARI Mung6, Binamoog-5 and Binamoogg-8 and found that Binamoog-6 give higher grain yield than other varieties.

Buriro *et al.* (2015) conducted a field experiment in Pakistan on two mungbean varieties Mung-06 and NM-92 and reported that variety NM-92 gave more number of branches plant^{-1} as compared to Mung-06.

Malik *et al.* (2015) at Meerut, India studied the effect of Zn, MoP, and urea on mungbean varieties Pant Mung-1 and Narendra-1. Results revealed that significantly higher seed yield and 1000 seed weight of both the varieties were obtained.

Mondal *et al*. (2015) from Bangladesh observed that mungbean genotype BARI Mung-4 produced significantly higher total dry mass per plant (32.63 g) than the other genotypes but statistically similar to the genotype Binamoog-2 (30.63 g) at 65 DAS. They also reported that the 1000-seed weight in mungbean genotype BARI Mung-6 (55.4 g) was significantly higher than the other genotypes but at par with BARI Mung-5 and Binamoog-7.

Ahmed *et al*. (2014) from Pakistan observed significant difference in pod length of some mungbean genotypes with maximum produced by genotype AZRI-2006 (8.91 cm).

Sharma (2014) while working at Bikaner in transitional plain of Luni basin of Rajasthan, India found that mungbean variety RMG 492 gave significantly higher seed yield as compared to other varieties.

Yadav and Singh (2014) at Agra, India reported the effect of different levels of growth regulators on seed vigour and other characters of Pant mung-5, K 851, SML 668 and Pusa-9072 and found that number of pods plant^{-1} and 1000-seed weight of all varieties SML 668 gave superior result in both the years.

Singh *et al.* (2013 b) from India carried out an experiment to study growth and yield behavior of urdbean (*Vigna mungo L.)* genotypes to dates of sowing revealed that among the genotypes, Pant Urd 35 gave the maximum seed yield (1238 kg and 1214 kg ha^{-1}) followed by Pant Urd 19 (1112 kg and 1111 kg ha^{-1}) and NDU 1 (1009 kg and 1048 kg ha^{-1}) during 2004 and 2005, respectively. As far as sowing time is concerned 25th June was the best date resulted into a seed yield of 1231 kg and 1204 kg ha^{-1} during 2004 and 2005, respectively. A delay of 10 and 20 days in sowing reduced the seed yield by 8.4%, 8.8% and 20.3%, 21.0% during 2004 and 2005 respectively. Nodule number and their dry weights primary root length and total dry matter also followed the similar trend as the NPK uptake. The crop took highest days to attain flowering, podding and maturity when sown on June 25th, however, among genotypes Pant-Urd-35 took the largest duration to affecting maturity and NDU-1 the shortest during both the seasons.

Gangwar *et al.* (2012) conducted field experiment in India 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.

Sharma *et al*. (2012) carried out experiment at Department of Plant Breeding and Genetics, Punjab Agriculture University, Ludhiana, India to evaluate the performance and growth analysis in mash bean and revealed that blackgram (*Vigna mungo* L. Hepper.) genotype Mash-1 recorded highest biological yield (8313 kg ha^{-1}) over Mash-338 (6110 kg ha^{-1}).

Rasul *et al*. (2012) reported that NM-98 exhibited the highest yield 727.02 kg ha^{-1} while the lowest seed yield 484.79 kg ha^{-1} was obtained with V_3. The spacing 30 cm showed highest seed yield 675.84 kg ha^{-1} as compared to other spacing treatments in Faisalabad, Pakistan.

Mondal *et al.* (2011) conducted an experiment at Mymensingh, Bangladesh on four genotypes of mungbean (MB-35, MB-45, MB-16 and MB-43) and found the significant differences in pods $plant^{-1}$, yield $plant^{-1}$ and seed index due to varieties.

Singh *et al*. (2011) studied the effect of different genotypes of mungbean in India and Taiwan as well. They used four different genotypes in each location *viz*., Pusa Vishal, SML 668, Pusa 9531 and UPM 98-1 in India and NM 92, NM 94, SML 134 and VC 3890-A in Taiwan. In India, they observed that the plant height of Pusa Vishal and Pusa 9531 was significantly higher than the other two but at par with each other and in Taiwan, SML 134 was the tallest than rest.

Singh and Singh (2010) from India studied three genotype of greengram viz., SMC668, SMC-832 and SMC-843. The result indicated that the genotype SMC-843 recorded highest dry matter, nodule $plant^{-1}$ and plant height compared to rest of genotypes.

Begum *et al*. (2009) from Bangladesh observed that the mungbean genotype Binamoong-2 (55.8 cm) produced significantly taller plants than Binamoong-5 (51.8 cm) and Binamoong-6 (40 cm) genotypes but statistically at par with genotype Binamoong-7 (55.1 cm).

Anurang *et al*. (2009) conducted field experiment at Allahabad, India on different cultivars of greengram *viz*., K-851, HUM-2, Asha and HUM-6. The results revealed that Asha variety was found most promising for all parameters compared to rest of the varieties.

Miah *et al.* (2009) conducted an experiment on four mungbean (*Vigna radiata* L., Wilczek) varieties viz Binamoog-2, Binamoog-5, Binamoog-6 and Binamoog-7 to identify the suitable variety(s) of summer mungbean. Among the varieties, Binamoog7 gave significantly higher pods plant^{-1}, seed plant^{-1} and straw yield than other varieties.

Kabir and Sarkar (2008) conducted a field experiment at the Agronomy field laboratory, Bangladesh Agricultural University during 2002 with five varieties and three spacing of planting. It was observed BARI Mung-2 planted at a spacing of 30 × 10 cm gave the maximum seed yield.

Kotwal and Prakash (2007) studied the effect of row spacing on performance of greengram cultivars. Among the cultivars T-44 was superior in terms of number of branches plant^{-1} (5.64), dry matter accumulation plant^{-1} (37.08 g), number of pods plant^{-1} (17.91), number of seeds pod^{-1} (9.37), 1000-grain weight (35.58 g) and grain yield plant^{-1} (12.56 q ha^{-1}) over other varities of greengram.

Kumar *et al.* (2007) conducted field experiment at Pantnagar, India 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.

Mathur *et al*. (2007) from Jodhpur, India reported that mungbean variety K 851 produced more pods plant^{-1}, seeds pod^{-1}, 1000-seed weight as compared to RMG 62 and RM 268.

Bora *et al*. (2006) conducted a field experiment in India to study the performance of different cultivars of greengram. The results revealed that Pusa 9531 and PDM-11 remained at par and produced significantly more number of pods plant^{-1} and number of grain pod^{-1} over rest of genotypes.

Gupta *et al.* (2006) reported that UG-218 urdbean variety produces significantly higher pods plant^{-1}, 1000-seed weight, seed yield as well as straw yield over other two varieties (Type-9 and Pant-U19).

Siddique *et al*. (2006) from Bangladesh reported that greengram varieties differed significantly among themselves in respect of yield contributing characters and seed yield. Binamoog-7 was ranked first in terms of seed yield (938 kg ha^{-1}) followed by Binamoog-6 (711 kg ha^{-1}), Binamoog- 5 (684 kg ha^{-1}) and Binamoog-2 (547 kg ha^{-1}).

Singh *et al*. (2006 a) studied on mungbean namely IC-39535, IC-39429, IC-39358, IC39447, IC-39283 and IC-3931 and observed significant variations in pods $plant^{-1}$, seeds pod^{-1}, 100-seed weight, seed yield, biological yield and harvest index in India. Genotype IC-39358 followed by IC- 39535 produced significantly higher seed yield than IC-39313 and rest of genotypes.

Tickoo *et al*. (2006) conducted field experiment at India on greengram with 2 varieties (Pusa 105 and Pusa Vishal). The results revealed that the grain yield of Pusa Vishal was significantly higher than Pusa 105.

Kumar and Behera (2002) conducted a field experiment at India to study the response of greengram cultivars. The results revealed that Nayagarh Local variety of greengram recorded higher seed yield over rest of the varieties.

Pramanik *et al*. (2002) studied four varieties of greengram *viz.,* Local, T-44, PDM-54 and Narendramung. They observed that Narendramung variety recorded higher pods $plant^{-1}$, pods length and seeds pod^{-1} over rest of the varieties.

Nayak and Patra (2000) conducted field experiment on greengram cultivars to study the response of greengram varieties to date of sowing. Variety 'Nayagarh Local' gave the maximum seed yield (978 kg ha^{-1}), followed by 'Sujata' (937 kg ha^{-1}) and 'PaM 54' (878 kg ha^{-1}). Sowing on 10^{th} September was the best date with seed yield of 969 kg ha^{-1}. A delay of 10 and 20 days in sowing reduced the seed yield by 14.2 and 30.0 percent (%), respectively. Most yield components varied significantly due to varieties but not due to dates of sowing.

Rakesh *et al*. (2000) conducted an experiment at J.V. College farm, Baraut (U.P.), India during spring season. Among the five different varieties, Pusa Baisakhi recorded significantly higher yield (10.66 q ha^{-1}) than other greengram varieties PS-105, (7.60 q ha^{-1}), PS9032 (5.40 q ha^{-1}), K-851 (9.26 q ha^{-1}) and ML-337 (7.33 q ha^{-1}).

Singh and Singh (2000) conducted a field experiment at Pantnagar (U.P.), India 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.

Thakral *et al*. (2000) conducted field experiment under KVK, Sadalpur, Haryana, India on mungbean varieties. The results revealed that Asha variety recorded 34.6 to 41.6 percent (%) increased yield was observed in demonstration plots over the local check.

Effect of planting geometry

Pandey *et al.* (2022) conducted a field experiment during 2021 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P), India to study the effect of spacing on growth and yield of varieties of greengram (*Vigna mungo* L.). The results of the experiment showed that application of 45 cm x 10 cm + SHEKHAR 2 was recorded significantly higher plant height (44.58 cm), nodules plant^{-1} (9.17), no. of branches plant^{-1} (6.87), plant dry weight (7.08 g plant^{-1}), pods plant^{-1} (64.64), seeds pod^{-1} (8.20), test weight (38.5 g) whereas maximum crop growth rate (4.36 g^{-1}/m^{-2}/day^{-1}) was recorded with treatment 30 cm x 15 cm + T9. However, higher seed yield (1062.86 kg ha^{-1}) were obtained with application of 30 cm x 15 cm + SHEKHAR 2 as compared to other treatments.

Sasidhar *et al*. (2022) carried out a field experiment during 2021 at crop research farm of SHUATS, Prayagraj (U.P), India to study the effect of spacing and biofertilizer on growth and yield of blackgram (*Vigna mungo* L.) The experiment was laid out in randomized block design by keeping three spacing levels, *i.e.* S_1 - (20 × 10 cm), S_2 - (25 × 10 cm) and S_3 - (30 × 10 cm) and Biofertilizers *i.e. PSB* and *Rhizobium* and replicated thrice. Results revealed that spacing of 30 × 10 cm + *Rhizobium,* PSB recorded significantly higher plant height (43.88 cm), number of branches plant^{-1} (6.81), number of nodules plant^{-1} (25.84), number of pods plant^{-1} (37.30), number of seeds pod^{-1} (7.51), test weight (37.73 g), grain yield (836 kg ha^{-1}) and stover yield (2144 kg ha^{-1}) and plant dry weight (6.77 g plant^{-1}). However, net returns (54550.00 INR ha^{-1}) and B:C ratio (2.62) was also obtained with the of spacing 30 cm × 10 cm + *Rhizobium* + PSB.

Bonepally *et al.* (2021) reported that the number of pods plant^{-1} (66.30), number seeds pod^{-1} (7.80), 1000-seed weight (37.33 g), grain yield (854 kg ha^{-1}), stover yield (2072 kg ha^{-1}), biological yield (2926 kg ha^{-1}) and harvest index (29.17%) was found to be maximum in treatment combination of 30 × 10 cm^2 + 40 kg ha^{-1} of phosphorus as compared to rest of the treatments which is beneficial for greengram production.

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

Raman (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 mungbean. The experiment was carried out at four levels of spacing viz. T_1 (30 cm × 5 cm), T_2 (30 cm × 10 cm), T_3 (45 cm × 10 cm) and T_4 (60 cm × 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 mungbean cultivation practices at 0.05 level of significance. The highest plant spacing of 60 cm × 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 cm × 5 cm. Similarly, grain yield and harvest index were found superior at the spacing of 30 cm × 10 cm.

Kabir and Sarkar (2018) from Bangladesh reported that spacing of 30 cm × 10 cm in mungbean cultivation gave the highest number of pods plant^{-1}, the highest grain yield, and the highest stover yield.

Birhanu *et al*. (2018) from Ethiopia observed significantly higher number of branches in mungbean at a spacing of 50cm × 15cm than at spacing of 20cm × 5cm attributed to wider space available for better sun shine interception for photosynthesis which provide more nutrients for translocation toward production of more number of branches.

Gurjar *et al*. (2018) from Gujarat, India observed significantly higher number of pods plant^{-1} (14.18) in semi rabi mungbean at wider row spacing 45 cm × 10 cm due to greater availability of space.

Muchira *et al*. (2018) from Kenya, East Africa found that in mungbean the plant height was positively and significantly higher, at spacing of 50cm × 15cm and 45cm × 15cm, than at spacing 40cm × 15cm.

Ibrahimi *et al*. (2017) in Afghanistan observed that dry matter accumulation in mungbean at 60 DAS was significantly higher at optimum spacing of 30 cm × 10 cm attributed to optimum space for growth and higher photosynthetic efficiency at that spacing.

Khan *et al.* (2017) in Punjab, India reported that at optimum spacing of 30 cm × 10 cm, the pod length was maximum while at wider and narrow spacing than this *i.e.* 35 cm × 10 cm and 25 cm × 10 cm, the pod length was minimum. They also reported highest 1000-seed weight at spacing of 30 cm × 10 cm.

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., seeds pod^{-1}, pods plant^{-1}, seeds 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 recorded significantly highest seed yield 1281 kg ha^{-1} over the other genotypes. 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 seeds pod^{-1} (4.23), pods plant^{-1} (132.00), seeds plant^{-1} (557.27) and 100-seed weight (11.22 g) over rest of the genotypes. Pigeon pea sown with wider geometry of 60cm x 10cm gave maximum seeds pod^{-1} (4.05), pods plant^{-1} (124.50), seeds plant^{-1} (496.67) and 100-seed weight (11.10) compared to narrow spacing of 45 cm × 10 cm. In conclusion, among the genotypes Asha was the best variety in terms of growth and yield in winter season planting of pigeon pea.

Muthu *et al*. (2016) at Bangalore, India observed significantly higher number of nodules in greengram at wider spacing of 60cm × 10cm than at 30cm × 10cm.

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 greengram (*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 plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1}, seed yield ha^{-1} 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 cm × 10 cm recorded higher pods plant^{-1} (18.40), number of seeds pod^{-1} (13.08), seed yield plant^{-1} (6.9 g), seed yield ha^{-1} (8.9 q.) and 1000-seed weight (39g).

Amruta *et al*. (2015) from Karnataka, India found that in blackgram, the number of leaves plant^{-1} (26.53) was higher at wider spacing of 60 cm × 10 cm than at closer spacing of 45cm × 10cm and 30cm × 10cm due to reduced competition for space, sunlight, moisture and nutrients.

Tanya *et al.* (2015) carried out an investigation at Experimentation Centre and Research Field of School of Forestry and Environment, SHIATS, Allahabad, India to study the effect of spacing on the growth and yield of different varieties of blackgram (*Vigna radiata* L.) under Subabul (Leucaena leucocephala) based agro silviculture system. The maximum plant height (36.73cm), absolute growth rate (0.79g day^{-1}), number of pods (15.63 plant^{-1}), number of grains (8.6 pod^{-1}) and straw yield (14.23 q ha^{-1}) was recorded in treatment T_6 (30 cm × 15 cm with T_9 variety). Whereas, maximum number of branches (7.26 plant^{-1}), leaves (21.73 plant^{-1}), nodules (16.75 plant^{-1}), dry weight plant^{-}

^{1} (23.96 g), pod length (8.11 cm) and test weight (4.53 g) was recorded in treatment T_9 (40 cm × 15 cm) with T_9 variety. Grain yield (8.13 q ha^{-1}) and harvest index (37.87 %) recorded in treatment T_3 (20 cm × 15 cm) with T_9 variety and treatment T_8 (40 cm ×15 cm) with Shekhar 2 variety respectively.

Kadam and Khanvilkar (2015) at Dapoli, Maharashtra, India reported maximum number of leaves $plant^{-1}$ in summer greengram, when planted at a spacing of 45 cm × 15 cm, than at 30 cm × 15 cm and 22.5 cm × 15 cm.

Singh and Yadav (2013) carried a field investigation out at the research farm area of R.A.K. College of Agriculture, Sehore (M.P.), India during the Kharif season of 2012, reported that the experiment was laid out in a randomized block design with three replications and 10 treatment combinations of five greengram 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 greengram 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 $plant^{-1}$ (11.34), nodule dry weight $plant^{-1}$ (0.39 g), branches $plant^{-1}$ (6.24), pod $plant^{-1}$ and seed yield (675.84 kg ha^{-1}) of mungbean with 30cm row spacing.

Sathe and Patil (2012) conducted a field trial on green gram at Nagpur, India during semi rabi season of 2009-10 and they recorded higher plant height under 45cm × 15cm spacing at 90 and 120 DAS, and harvest. Number of branches $plant^{-1}$, number of leaves $plant^{-1}$ and dry matter accumulation $plant^{-1}$ at 60, 90 and 120 DAS, and harvest recorded maximum at spacing of 60 cm × 30 cm.

Singh *et al*. (2012) from Ludhiana, Punjab, India noted that when mungbean was sown at spacing of 30cm × 15cm resulted in higher plant height, number of branches $plant^{-1}$, pods $plant^{-1}$ and 100-seed weight as compared to spacing of 45cm × 15cm.

Bhise *et al*. (2011) from Prabhani, Maharashtra, India observed highly significant difference in harvest index of summer mungbean at different spacing.

A field trial was undertaken during summer season of 2009 at Navsari, Gujarat, India by Tekale *et al*. (2011). They found higher plant height (56.67 cm), seed yield (11.01 q ha^{-1}) and haulm yield (21.67 q ha^{-1}) of greengram cultivated at 30 cm spacing.

Asaduzzaman *et al.* (2010) carried out an experiment at the Research Field of Sher-eBangla 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 30cm × 10cm showed its advantages by producing 7.96-16.19 % higher yield compared to other spacings.

Kachare *et al*. (2009) conducted a field trial at Mahatma Phule Krishi Vidyapeeth, Rahuri, India during *Kharif* season on greengram and concluded that 30 cm × 11.25 cm spacing recorded highest number of pods $plant^{-1}$ (22.77), higher number of seeds pod^{-1} (9.47), 100-seed weight (3.33 g) and seed yield $plant^{-1}$ (6.27 g).

Bavalgave *et al.* (2008) conducted a field trial at Latur, Maharashtra, India during *rabi* season on greengram and reported that 30cm x 10cm produced the highest grain yield while number of pods $plant^{-1}$ and pods weight $plant^{-1}$ were higher in 45cm × 15cm 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 that is statistically at par with four other spacing *viz;* 20, 25, 30 and 35 cm. Results further revealed that number of pods $plant^{-1}$ (0.744) and grain yield $plant^{-1}$ (0.888) were highly significant and positively correlated with grain yield.

Singh *et al.* (2006 b) carried out a field trial at Pantnagar, India during 2000-2001 in urd bean. They revealed that wider spacing (30 cm) produced higher number of pods $plant^{-1}$ (43.1), number of grains pod^{-1} (7.6) and grain yield $plant^{-1}$ (6.7 g).

Patel *et al.* (2005) reported that in greengram, planting geometry had significant effects on growth and seed yield. Planting geometry of 40cm×15cm recorded the highest plant height, root length, number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and biomass $plant^{-1}$ than rest of the planting geometries. They also reported that planting geometry of 30cm×10cm and 30 cm ×15 cm gave higher seed yield over the rest of the planting geometries.

Ihsanullah *et al.* (2002) reported that highest plant height (47.50 cm) 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 and reported that yield difference due to row spacing variations was significant. Row spacing of 30 cm and 40 cm gave comparable yield (351.8 kg and 374.0 kg ha^{-1}, respectively) and significantly higher than closure row spacing.

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

It understands from the above literature review that the yield of mungbean can be optimized with appropriate variety along with spacing management.

CHAPTER III

MATERIALS AND METHODS

A field experiment entitled "Growth and yield response of mungbean varieties to planting geometry" was conducted during the *kharif* season of 2021. The predominant edaphic and climatic conditions during the crop-growing 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.

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 (Anon., 1988 b). 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 was collected from Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Experimental materials

Mungbean varieties of BARI Mung-5, BARI Mung-6 and Binamoog-8 were used as experimental materials for this experiment. The important characteristics of these varieties was mentioned below:

BARI Mung-5

BARI Mung-5 is developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. The origin of this seed is from Asian Vegetable Research and Development Center and released in the year of 1997. It is a high yielding variety; leaves, pods and seeds are larger. Plant height 40-45 cm, photo-insensitive and can be grown in kharif-I, kharif-II and late rabi. Seed color deep green, large shaped with smooth seed coat, pods matured at a same stage, 1000 seed weight 40-42 g, cooking time 17-20 min, crop duration 60-65 days. Last February to mid March (kharif-1); First August to last September (kharif-II) are the planting season of this variety, and give an yield of 1.2-1.5 t/ha^{-1}. It is tolerant to Cercospora leaf spot and Yellow mosaic virus and protein 20-22%.

BARI Mung-6

BARI Mung-6 is developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. The origin of this seed is from Asian Vegetable Research and Development Center and released in the year of 2003. Its plant height range between 40-45 cm, photo insensitive and can be grown in Kharif-I, Kharif-II and late Rabi, after flowering stage plant growth become stunted, leaf and seed color deep green and leaf broad, seed large shaped with smooth seed coat, pods matured at a same stage. Large grain, 1000 seed weight 51-52 g, after wheat harvest sowing up to April first week, It is sowing also Kharif-2 and Rabi season , crop duration 55-58 days. Last February to mid-March (Kharif-1); First August to last September (KharifII) are the planting season of this variety, and give an yield of 1.5 t/ha^{-1}. It is tolerant to Cercospora leaf spot and Yellow mosaic virus.

Binamoog-8

Binamoog-8 is developed by Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh and released in the year of 2010. It is obtained from seeds of MB-149 which were irradiated with 400 Gy dose of gamma ray. Binamoog-8 is a summer mungbean variety, seed is medium size with green shiny color. This variety is suitable for cultivation in pulse growing areas of Bangladesh. Maturity period ranges from 64-67 days. Plants are short and tolerant to yellow mosaic virus (YMV) disease. Seed contains higher protein (23 %).

3.4 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. In main plot, there was mungbean variety and in sub plot, there was planting geometry 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

The experiment comprised of two factors namely variety and different planting geometry as mentioned below:

Factor A. Mungbean varieties (3) *viz*.,

V_1 = BARI Mung-5

V_2 = BARI Mung-6

V_3 = Binamoog-8

Factor B. Different planting geometry (4) *viz*.,

P_1= Broadcast

P_2=Paired row (15 cm × 10 cm)

P_3= Square planting (20 cm × 20 cm)

P_4= Row sowing (30 cm × 10 cm)

3.6 Land preparation

Initially the field was prepared with the help of tractor drawn implement. 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 Mung-5, BARI Mung-6 and Binamoog-8 were collected from Pulses Research Centre, Ishwardi, Pabna.

3.8 Land preparation for seed sowing

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

3.9 Fertilizer application

As sources of nitrogen, phosphorus, potassium, zinc, and boron, fertilizers urea, triple superphosphate (TSP), muriate of potash (MoP), zinc sulphate, and boric acid were used. For urea, TSP, MoP, gypsum, and boric acid, the fertilizer doses were 45, 90, 40, 55, and 10 kg ha^{-1}, respectively. Urea, TSP, MoP, Gypsum, and boric acid were all treated in total at basal doses during the last stage of land preparation (BARI, 2019). 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 broadcasting and furrow on 28th March, 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 according with par treatment requirement.

3.11 Intercultural operation

3.11.1 Application of irrigation water

The field was irrigated twice- one at 20 days and the other one at 35 DAS as rainfall was not enough in this season.

3.11.2 Plant protection measures

3.11.2.1 Insect and pest infestation

Early on in its development, the plant 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 1 litre ha^{-1} to control worms, virus vectors, and pod borer insects.

3.12 Harvesting

Crops were harvested at 75% maturity (first installment) 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 and cleaned 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 15 DAS and continued until the 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 different dates. 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 plant^{-1} (cm)
ix. Seeds pod^{-1} (no.)
x. 1000-seed 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 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 branches plant^{-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} (g)

Nodules plant^{-1} was counted from each selected plant sample at 45 DAS and at harvest respectively. After collected and counted nodules were oven-dried oven maintaining 70^{0}C 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} (g)

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 plant^{-1} (cm)

Pod length was 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 (g)

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 (t ha^{-1})

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

xii. Stover yield (t ha^{-1})

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 t ha^{-1}.

xiii. Biological yield (t ha^{-1})

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 mungbean 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 Statistix 10 and the mean differences were Least Significant Difference (LSD) test at 5% level of probability wherever 'F' values were significant (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

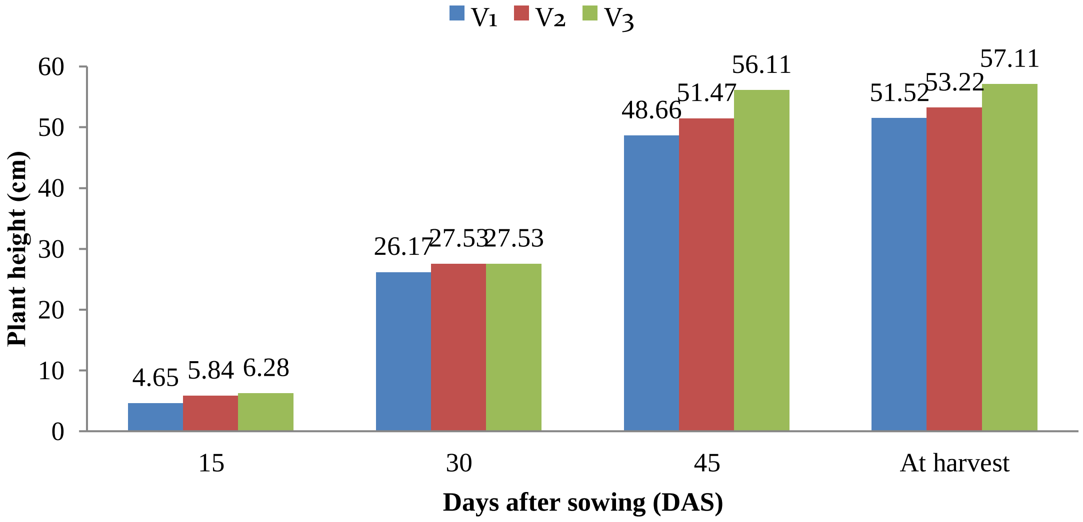
Results obtained from the present study have been presented and discussed in this chapter with a view to study the growth and yield response of mungbean varieties to planting geometry. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant growth parameters

4.1.1 Plant height (cm)

Effect of variety

Plant height is a crucial aspect of the crop plant's vegetative stage that indirectly affects crop plant yield. Mungbean plant height varied greatly depending on the variety at different day after sowing (DAS). Height was observed to increase steadily as the crop aged up to harvest. At maturity, the plant's height achieved its peak value (Fig. 1). Experimental result revealed that the highest plant height 6.28, 27.53, 56.11 and 57.11 cm at 15, 30, 45 DAS, and harvest, respectively was observed in V_3 variety (Binamoog-8) which was statistically similar with V_2 (27.53 cm) variety (BARI Mung-6) at 30 DAS. Whereas the lowest plant height 4.65, 26.17, 48.66 and 51.52 cm at 15, 30, 45 DAS, and harvest respectively was observed in V_1 variety (BARI Mung-5) which was statistically similar with V_2 (53.22 cm) variety (BARI Mung-6) at harvest. The variation of plant height is probably due to the genetic make-up of the variety. Gangwar *et al.* (2012) reported that the height of a plant was determined by genetical character, and different varieties will acquire their height based on their genetical makeup under a given set of environmental conditions.

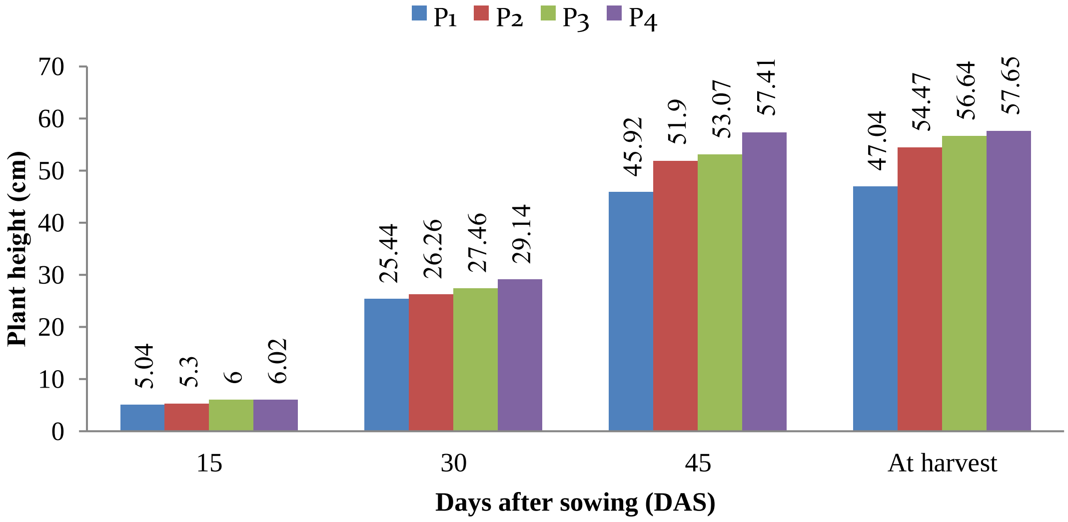


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 1. Effect of variety on plant height of mungbean at different DAS ($LSD_{(0.05)}$ = 0.38, 0.86, 2.80 and 2.26 at 15, 30, 45 DAS and harvest respectively).

Effect of planting geometry

Significant variation in mungbean plant height was observed on different days after sowing because of different planting geometry (Fig. 2). Experimental results showed that P_1 (Broadcasting) treatment had the lowest plant height 5.04, 25.44, 45.92 and 47.04 cm at 15, 30, 45 DAS and harvest, respectively which was statistically similar with P_2 treatment (5.30 cm) at 15 DAS. The highest plant height 6.02, 29.14, 57.41 and 57.65 cm at 15, 30, 45 DAS, and harvest, respectively was observed in P_4 (30 cm × 10 cm) treatment which was statistically similar with P_3 treatment (6.00 and 56.64 cm) at 15 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) that highest plant height (47.50 cm) was observed in 43 cm × 7 cm spacing in mungbean.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 2. Effect of planting geometry on plant height of mungbean at different DAS ($LSD_{(0.05)}$= 0.29, 0.64, 2.31 and 1.78 at 15, 30, 45 DAS and at harvest respectively).

Combined effect of variety and planting geometry

Combination of variety and planting geometry had shown significant effect on mungbean plant height at different days after sowing (Table 1). The results of the experiment showed that V_1P_1 treatment combination showed the lowest plant height 4.26, 23.44, 39.46 and 42.83 cm at 15, 30, 45 DAS, and harvest, respectively which was statistically comparable to V_1P_2 4.54 and 24.53 cm at 15 and 30 DAS and with V_2P_1 (45.03 cm) at harvest, respectively. While the V_3P_4 treatment combination had the highest plant height 7.08, 29.55, 58.85 and 58.85 cm at 15, 30, 45 DAS and harvest, respectively which was statistically similar with V_3P_3 7.03, 56.83 and 58.83 cm at 15, 45 DAS and harvest, respectively with V_1P_4 28.53 and 55.42 cm treatment combination at 30 and 45 DAS; with V_2P_4 (29.33 cm) at 30 DAS and with V_3P_3 (55.47 and 57.47 cm) at 45 DAS and harvest, respectively.

Table 1. Combined effect of variety and planting geometry on plant height of mungbean at different DAS

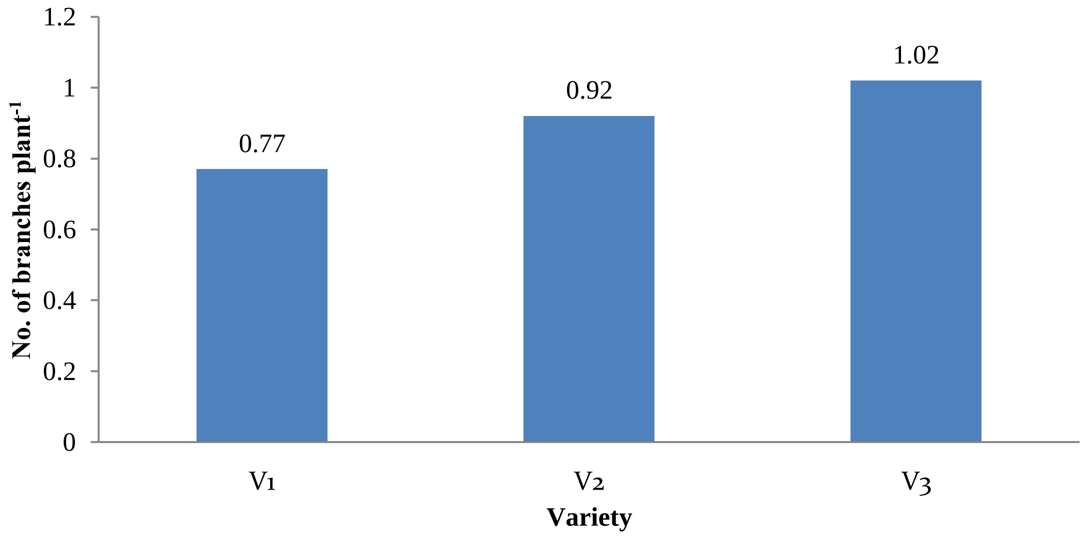
Treatment combinations	Plant height (cm) at			
	15 DAS	30 DAS	45 DAS	Harvest
V_1P_1	4.26 f	23.44 e	39.46 f	42.83 e
V_1P_2	4.54 ef	24.53 e	49.67 d	52.37 d
V_1P_3	4.89 de	28.19 bc	50.07 d	54.77 b-d
V_1P_4	4.89 de	28.53 ab	55.42 a-c	56.12 a-c
V_2P_1	5.46 cd	26.64 d	45.03 e	45.03 e
V_2P_2	5.74 bc	27.03 cd	50.57 d	53.57 cd
V_2P_3	6.09 b	27.11 cd	52.32 cd	56.32 a-c
V_2P_4	6.09 b	29.33 ab	57.97 a	57.97 ab
V_3P_1	5.41 cd	26.23 d	53.27 b-d	53.27 cd
V_3P_2	5.61 bc	27.22 cd	55.47 a-c	57.47 ab
V_3P_3	7.03 a	27.07 cd	56.83 ab	58.83 a
V_3P_4	7.08 a	29.55 a	58.85 a	58.85 a
$LSD_{(0.05)}$	**0.58**	**1.28**	**4.42**	**3.47**
CV(%)	**5.39**	**2.28**	**4.48**	**3.34**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

4.1.2 Branches plant^{-1}

Effect of variety

Cultivation of different varieties had shown significant effect on branches plant^{-1} of mungbean at harvest. According to the experimental results, the V_3 (Binamoog-8) variety had the highest number of branches plant^{-1} (1.02) at harvest. While the V_1 (BARI Mung-5) variety, had the lowest number (0.77) (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. Dash and Rautaray (2017) observed that maximum number of branches, was produced by variety Pusa Vishal as compared to local variety of greengram. This could be due to different genetic variability and adaptability to the environment of greengram varieties.

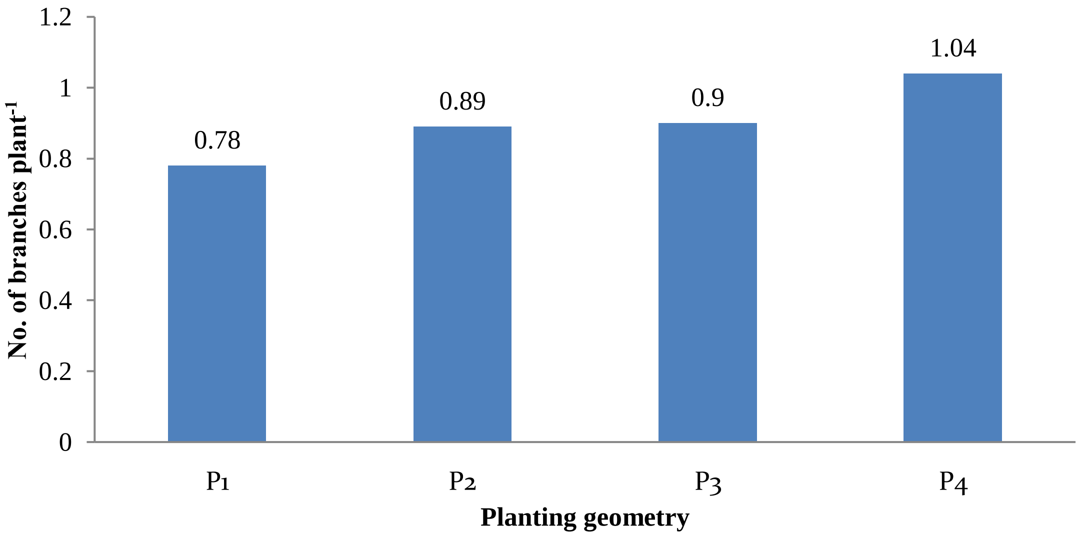


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 3. Effect of variety on number of branches plant^{-1} of mungbean at harvest ($LSD_{(0.05)}$= 0.02).

Effect of planting geometry

Different planting geometry had shown significant effect in respect of number of branches plant^{-1} of mungbean at different days after sowing (DAS) (Fig. 4). According to the experimental results, the P_4 (30 cm × 10 cm) treatment had the highest number of branches plant^{-1} (1.04) at harvest (Fig. 4). While the lowest number of branches plant^{-1} (0.78) at harvest, was found in P_1 treatment (Fig. 4). 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 promotes metabolic activity, increase the cell division, ultimately increase the number of branches plant^{-1}. The result obtained from the present study was similar with the findings of Birhanu *et al*. (2018).They found significantly higher number of branches in mungbean at a spacing of 50 cm × 15 cm than spacing of 20 cm × 5 cm attributed to wider space available for better sun shine interception for photosynthesis which provide more nutrients for translocation toward production of more number of branches.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 4. Effect of planting geometry on branches plant^{-1} of mungbean at harvest (LSD$_{(0.05)}$= 0.03).

Combined effect of variety and planting geometry

At different days after sowing, the treatment combination of variety and planting geometry had shown significant variation in respect of the number of branches plant^{-1} of mungbean (Table 2). The experimental findings revealed that the V_3P_4 treatment combination had the highest number of branches plant^{-1} (1.20) at harvest. While the lowest number of branches plant^{-1} of mungbean (0.60) at harvest was found in V_1P_1 treatment combination.

Table 2. Combined effect of variety and planting geometry on number of branches plant^{-1} of mungbean at harvest

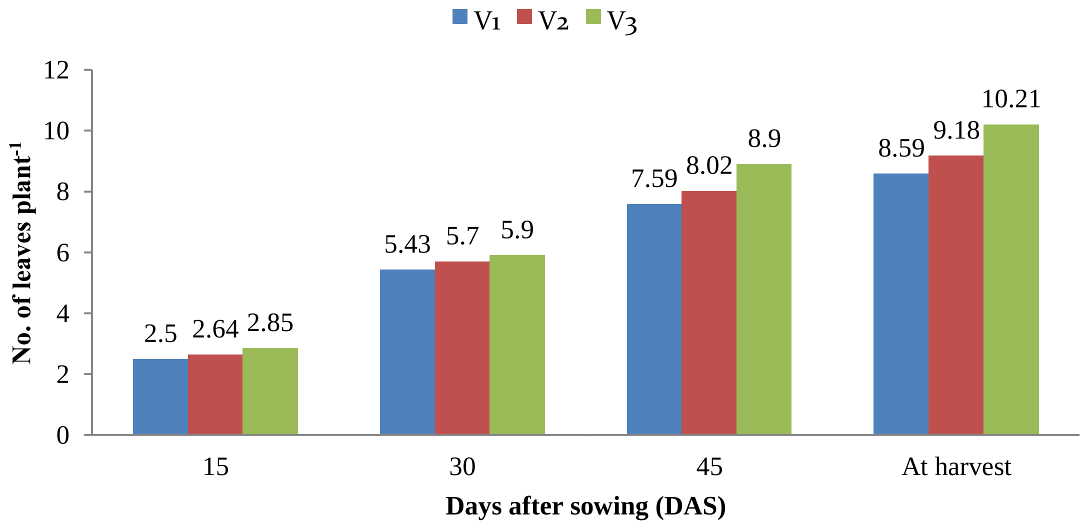
Treatment combinations	No. of branches plant^{-1}
V_1P_1	0.60 g
V_1P_2	0.73 f
V_1P_3	0.83 de
V_1P_4	0.93 c
V_2P_1	0.80 e
V_2P_2	1.00 b
V_2P_3	0.87 d
V_2P_4	1.00 b
V_3P_1	0.93 c
V_3P_2	0.93 c
V_3P_3	1.00 b
V_3P_4	1.20 a
$LSD_{(0.05)}$	0.05
CV(%)	3.64

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm) cm, P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

4.1.3 Leaves plant^{-1}

Effect of variety

The number of leaves plant^{-1} of mungbean at different days after sowing varied significantly, depending on the varieties (Fig. 5). The V_3 (Binamoog-8) variety had the highest number of leaves plant^{-1} of 2.85, 5.90, 8.90 and 10.21 at 15, 30, 45 DAS, and harvest, respectively which was statistically similar with V_2 (5.70) variety at 30 DAS. While V_1 (BARI Mung-5) variety had the lowest number of leaves plant^{-1} of 2.50, 5.43, 7.59 and 8.59 at 15, 30, 45 DAS and harvest, respectively. The reason of difference in number of leaves plant^{-1} is the genetic makeup of the variety, which is primarily influenced by heredity. Govardhan *et al.* (2017) found that mungbean variety MGG-390 produced higher number of leaves plant^{-1} comparable to other varieties of mungbean.

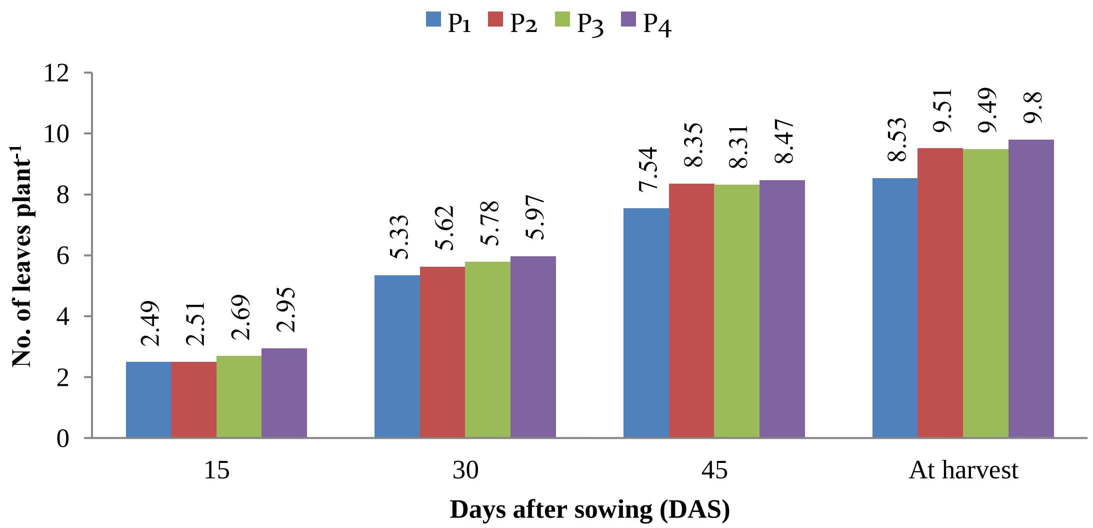


In the bar graphs, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 5. Effect of variety on number of leaves plant^{-1}of mungbean at different DAS ($LSD_{(0.05)}$= 0.11, 0.21, 0.33 and 0.36 at 15, 30, 45 DAS and harvest respectively).

Effect of planting geometry

The number of leaves plant^{-1} of mungbean at different days after sowing varied significantly due to different planting geometry (Fig. 6). Experimental results showed that the P_4 (30 cm × 10 cm) treatment had the highest number of leaves plant^{-1} of 2.95, 5.97, 8.47 and 9.80 at 15, 30, 45 DAS and harvest, respectively which was statistically similar with P_3 (8.31 and 9.49) and P_2 (8.35 and 9.51) at 45 DAS and harvest, respectively. On the other hand, the P_1 (Broadcast) treatment had the lowest number of leaves plant^{-1} of 2.49, 5.33, 7.54 and 8.53 at 15, 30, 45 DAS and harvest, respectively. Due to greater intra plant competition, closer spacing resulted in fewer leaves being produced. In order to decrease intra plant competition, which eventually has an impact on the plant's leaf number, as a result optimum spacing must be maintained. Amruta *et al*. (2015) found that in greengram, the number of leaves per plant was higher at wider spacing than at closer spacing due to reduced competition for space, sunlight, moisture and nutrients.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1 = Broadcast, P_2 = Paired row (15 cm × 10 cm), P_3 = Square planting (20 cm × 20 cm) and P_4 = Row sowing (30 cm × 10 cm)

Figure 6. Effect of planting geometry on leaves plant^{-1} of mungbean at different DAS ($LSD_{(0.05)}$= 0.11, 0.21, 0.33 and 0.36 at 15, 30, 45 DAS and harvest respectively).

Combined effect of variety and planting geometry

The treatment combination of variety and planting geometry had demonstrated a significant difference in the number of leaves plant^{-1} of mungbean at different days after sowing (DAS) (Table 3). The V_3P_4 treatment combination had the highest number of leaves plant^{-1} of 3.33, 6.33, 9.07 and 11.13 at 15, 30, 45 DAS and harvest, respectively which was statistically comparable to V_3P_3 (8.93), V_3P_2 (8.93), V_3P_1 (8.67) and V_2P_2 (8.73) treatment combination at 45 DAS. While the lowest number of leaves plant^{-1} of mungbean of 2.40, 4.93, 6.47 and 7.27 at 15, 30, 45 DAS, and harvest, respectively observed in V_1P_1 treatment combination which was statistically similar with V_1P_2 (2.40) and V_1P_4 (2.53) at 15 DAS.

Table 3. Combined effect of variety and planting geometry on number of leaves plant^{-1} of mungbean at different DAS

Treatment combinations	Number of leaves plant^{-1} at			
	15 DAS	**30 DAS**	**45 DAS**	**Harvest**
V_1P_1	2.40 e	4.93 d	6.47 e	7.27 e
V_1P_2	2.40 e	5.40 c	7.40 d	8.80 d
V_1P_3	2.67 cd	5.67 bc	8.07 c	9.20 cd
V_1P_4	2.53 c-e	5.73 bc	8.40 bc	9.13 cd
V_2P_1	2.40 e	5.40 c	7.47 d	8.60 d
V_2P_2	2.47 de	5.73 bc	8.73 ab	9.80 bc
V_2P_3	2.67 cd	5.80 b	7.93 cd	9.20 cd
V_2P_4	3.00 b	5.87 b	7.93 cd	9.13 cd
V_3P_1	2.67 cd	5.67 bc	8.67 ab	9.73 bc
V_3P_2	2.67 cd	5.73 bc	8.93 ab	9.93 b
V_3P_3	2.73 c	5.87 b	8.93 ab	10.07 b
V_3P_4	3.33 a	6.33 a	9.07 a	11.13 a
$LSD_{(0.05)}$	**0.22**	**0.35**	**0.54**	**0.73**
CV(%)	**4.85**	**3.41**	**3.54**	**4.59**

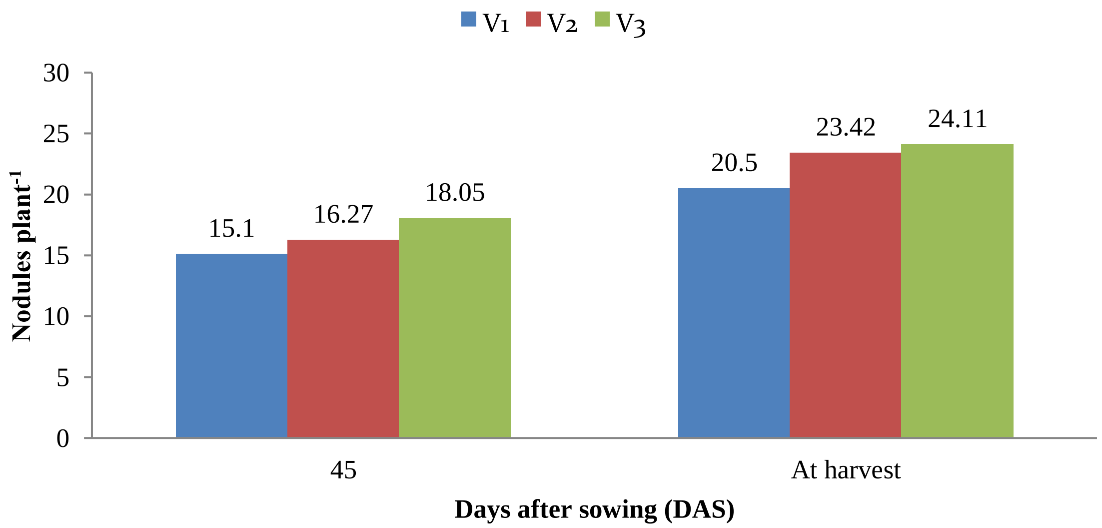
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

4.1.4 Nodules plant^{-1}

Effect of variety

Different variety had shown significant effect on number of nodules plant^{-1} of mungbean at different days after sowing (Fig. 7). Experimental result revealed that the lowest number of nodules plant^{-1} of 15.10 and 20.50 at 45 DAS and harvest respectively was observed in V_1 (BARI Mung-5) variety. Whereas the highest number of nodules plant^{-1} of 18.05 and 24.11 at 45 DAS and harvest, respectively was observed in V_3 (Binamoog-8) variety which was statistically similar with V_2 (23.42) variety at harvest. The probable reason for this is that the genetic potential of the variety which has helped to increase the number of nodules in the mungbean variety.

Razzaqe *et al.* (2016) reported that mungbean genotype IPSA 12 at 40 kg nitrogen ha[1] produce maximum number of nodules plant^{-1} as compared to other genotypes.

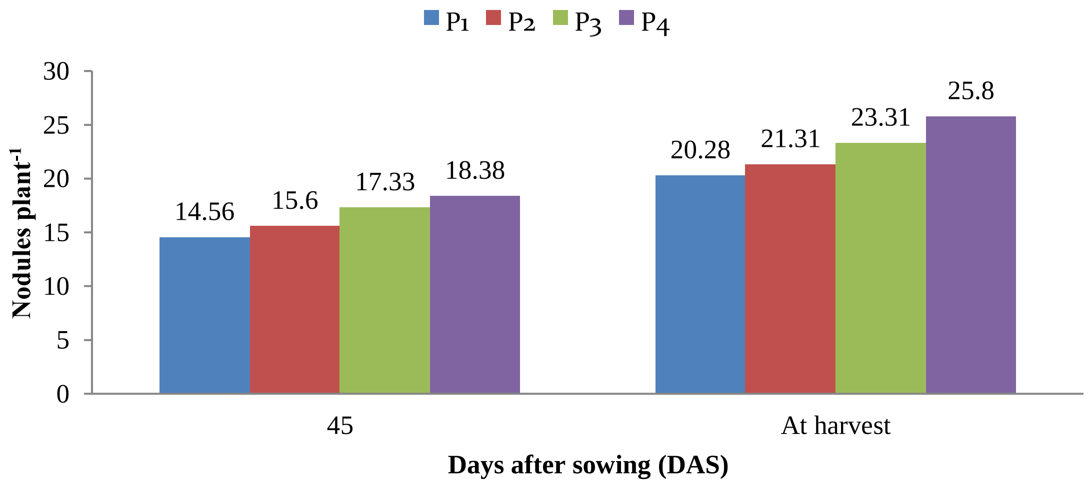


In the bar graphs, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure. 7. Effect of variety on nodules plant^{-1} of mungbean at different DAS ($LSD_{(0.05)}$= 0.64 and 0.91 at 45 DAS and harvest, respectively).

Effect of planting geometry

At different days after sowing (DAS) the number of nodules plant^{-1} of mungbean had significantly changed depending on the planting geometry (Fig. 8). The results of the experiment showed that at 45 DAS and harvest, respectively, the P_4 treatment had the highest number of nodules plant^{-1} (18.38 and 25.80). While the P_1 treatment had the lowest number of nodules plant^{-1} (14.56 and 20.28) at 45 DAS and harvest, respectively. The result obtained from the present study was similar with the findings of Muthu *et al.* (2016) who observed significantly higher number of nodules in greengram at wider spacing than at narrow spacing.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 8. Effect of planting geometry on number of nodules plant^{-1} of mungbean at different DAS ($LSD_{(0.05)}$= 0.64 and 0.91 at 45 DAS and harvest, respectively).

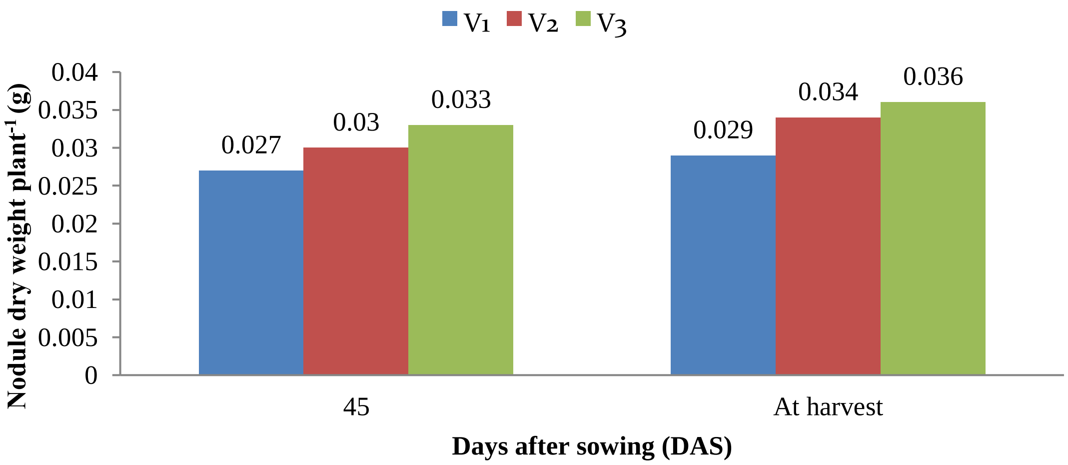
Combined effect of variety and planting geometry

Combination of variety and planting geometry had shown significant difference in respect of number of nodules plant^{-1} of mungbean at various days after sowing (Table 4). The highest number of nodule plant^{-1} of 21.67 and 27.40 at 45 DAS and harvest, respectively was found in the V_3P_4 treatment combination, which was statistically comparable with the V_2P_4 (26.73) treatment combination at harvest, respectively. While the lowest number of nodule plant^{-1} of 12.67 and 17.14 at 45 DAS and harvest, respectively was found in the V_1P_4 treatment combination.

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

Effect of variety

The nodule dry weight plant^{-1} of mungbean at different days after sowing varied significantly depending on the variety grown (Fig. 9). The experimental findings revealed that the V_3 (Binamoog-8) variety had the highest nodule dry weight plant^{-1} of 0.033 and 0.036 g at 45 DAS and harvest, respectively. However, at 45 DAS and harvest, the V_1 variety had the lowest nodule dry weight plant^{-1} (0.027 and 0.029 g, respectively). 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 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

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

Effect of planting geometry

Planting geometry had shown significant effect on the nodule dry weight plant^{-1} mungbean at different days after sowing (Fig. 10). The experimental findings revealed that the P_4 treatment had the highest nodule dry weight plant^{-1} of 0.033 and 0.035 g at 45 DAS and harvest respectively. While at 45 DAS and harvest, respectively the P_1 treatment had the lowest nodule dry weight plant^{-1} of 0.026 and 0.028 g at 45 DAS and harvest respectively. The result obtained from the present study was similar with the findings of Rasul *et al*. (2012) who revealed that the highest number and dry weight of nodules plant^{-1} were obtained with 30 cm row spacing.

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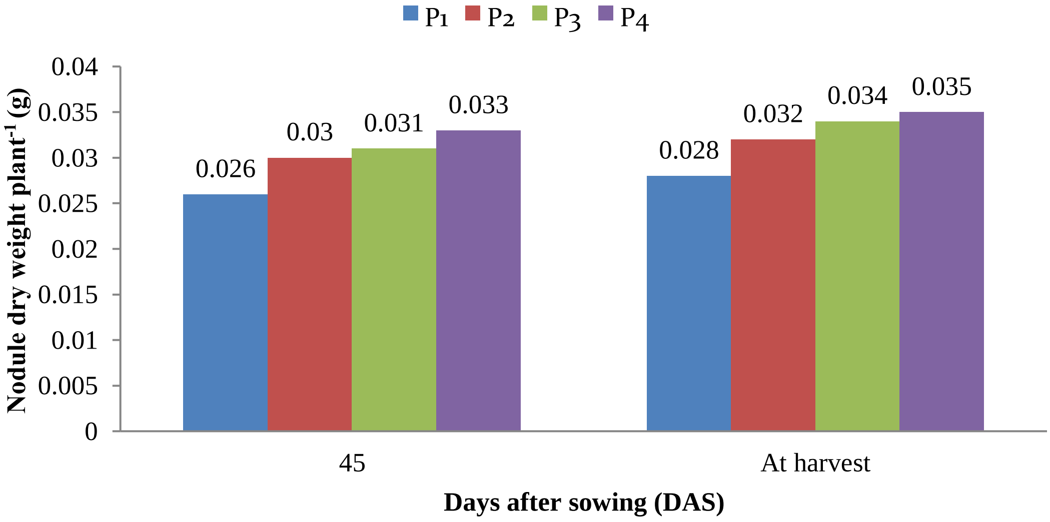


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 10. Effect of planting geometry on nodules dry weight plant^{-1} of mungbean at different DAS ($LSD_{(0.05)}$= 0.001 and 0.001 at 45 DAS and harvest, respectively).

Combined effect of variety and planting geometry

At different days after sowing the nodule dry weight plant^{-1} of mungbean was significantly varied due to the combined effect of variety and planting geometry (Table 4). The V_3P_4 treatment combination had the highest nodule dry weight plant^{-1} of 0.037 and 0.039 g at 45 DAS and harvest, respectively which was statistically similar with V_3P_3 (0.037 g) and V_2P_4 (0.038 g) treatment combination at harvest. While the V_1P_1 treatment combination had the lowest nodule dry weight plant^{-1} of 0.019 and 0.023 g at 45 DAS and harvest, respectively.

Table 4. Combined effect of variety and planting geometry on number of nodules and nodules dry weight plant^{-1} of mungbean at different DAS

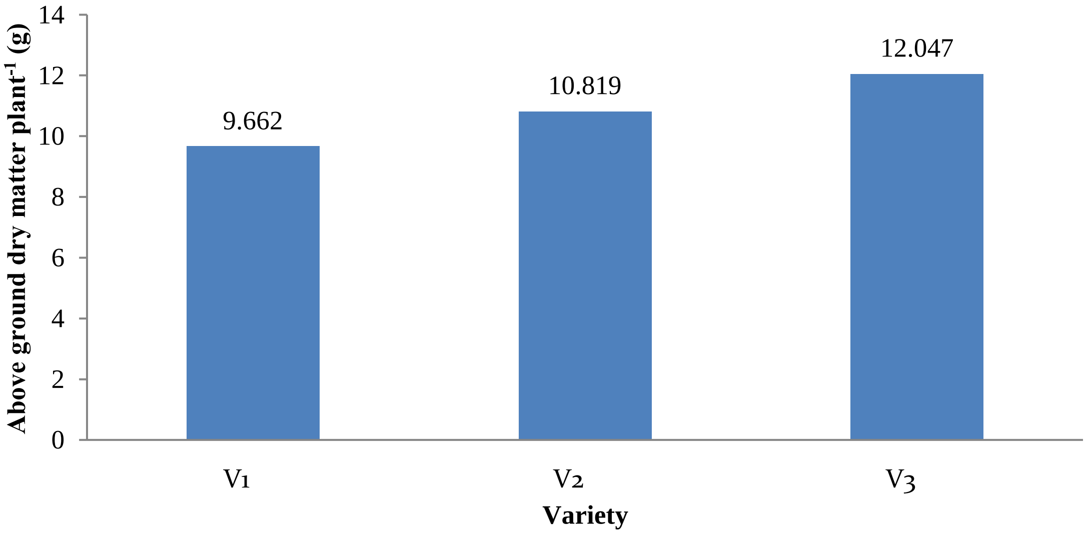
Treatment combinations	No. of nodules plant^{-1} at		Nodules dry weight plant^{-1} (g) at	
	45 DAS	Harvest	45 DAS	Harvest
V_1P_1	12.67 f	17.14 g	0.019 f	0.023 f
V_1P_2	15.67 de	19.60 f	0.028 e	0.030 de
V_1P_3	15.73 de	22.00 c-e	0.030 c-e	0.031 de
V_1P_4	16.33 c-e	23.27 bc	0.031 b-d	0.030 de
V_2P_1	15.73 de	21.07 ef	0.029 de	0.029 e
V_2P_2	15.60 e	21.47 de	0.030 c-e	0.032 d
V_2P_3	16.60 cd	24.40 b	0.031 b-d	0.036 bc
V_2P_4	17.13 c	26.73 a	0.031 b-d	0.038 ab
V_3P_1	15.33 e	22.63 c-e	0.029 de	0.032 d
V_3P_2	15.53 e	22.87 b-d	0.032 bc	0.035 c
V_3P_3	19.67 b	23.53 bc	0.033 b	0.037 a-c
V_3P_4	21.67 a	27.40 a	0.037 a	0.039 a
$LSD_{(0.05)}$	**1.06**	**1.58**	**0.002**	**0.002**
CV(%)	**3.51**	**3.89**	**4.91**	**4.42**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm) cm, P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

4.1.6 Above ground dry matter plant^{-1}

Effect of variety

The experiment results showed that different varieties had a significant influence on the above ground dry matter weight plant^{-1} of mungbean at harvest (Fig. 11). The highest above ground dry matter weight plant^{-1} (12.04 g) at harvest, was found in V_3 (Binamoog-8) variety. Whereas the lowest above ground dry matter weight plant^{-1} of mungbean (9.66 g) at harvest, was found in V_1 (BARI Mung-5) variety. The reason why the dry weight plant^{-1} varies between different varieties is that each variety has a unique growth stage and makes use of resources from its environment differently. Gangwar *et al.* (2012) reported that in urdbean U-31 variety produced significantly higher dry matter than rest of the varieties.

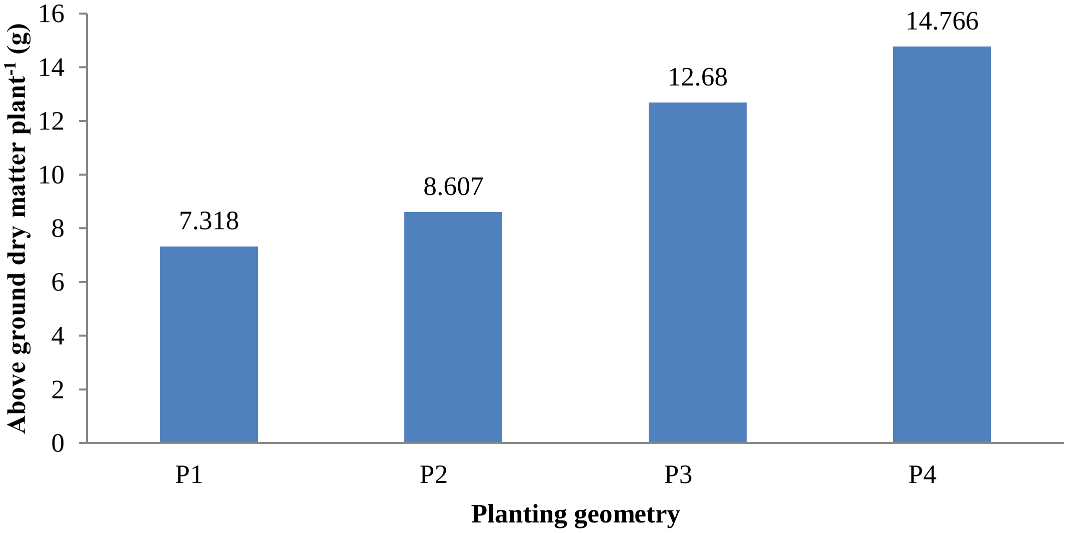


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 11. Effect of variety on above ground dry matter plant^{-1} of mungbean at harvest ($LSD_{(0.05)}$= 1.08).

Effect of planting geometry

Different planting geometry had shown significant effect on the above ground dry matter weight plant^{-1} of mungbean at harvest (Fig. 12). Experimental results showed that P_4 treatment had the highest above ground dry matter weight plant^{-1} (14.77 g) at harvest. However, the P_1 treatment was found to have the lowest above ground dry matter weight matter plant^{-1} (7.32 g) at harvest. The variation of above ground dry matter weight plant^{-1} among different treatments due to availability of more space for getting more sunlight and CO_2 for better growth and development of the plant. Similar result also observed by Ibrahimi *et al*. (2017) who reported that dry matter accumulation in mungbean was significantly higher at optimum spacing of 30 cm × 10 cm attributed to optimum space for growth and higher photosynthetic efficiency.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 12. Effect of planting geometry on above ground dry matter plant^{-1} of mungbean at harvest ($LSD_{(0.05)}$= 1.00).

Combined effect of variety and planting geometry

The above ground dry matter weight plant^{-1} of mungbean at harvest was significantly influenced by the combination treatments of variety and planting geometry (Table 5). The experimental findings revealed that the V_3P_4 treatment combination had the highest above ground dry matter weight plant^{-1} (17.15g) at harvest. While the V_1P_1 treatment combination had the lowest above ground dry matter weight plant^{-1} (5.99 g) at harvest, which was statistically similar with V_1P_2 (7.63 g) and V_2P_1 (7.75 g) treatment combinations.

Table 5. Combined effect of variety and planting geometry on above ground dry matter weight plant^{-1} at harvest

Treatment combinations	Above ground dry matter weight plant^{-1} (g)
V_1P_1	5.99 e
V_1P_2	7.63 de
V_1P_3	11.79 c
V_1P_4	13.24 bc
V_2P_1	7.75 de
V_2P_2	8.75 d
V_2P_3	12.87 bc
V_2P_4	13.91 b
V_3P_1	8.21 d
V_3P_2	9.45 d
V_3P_3	13.38 bc
V_3P_4	17.15 a
$LSD_{(0.05)}$	1.85
CV(%)	5.48

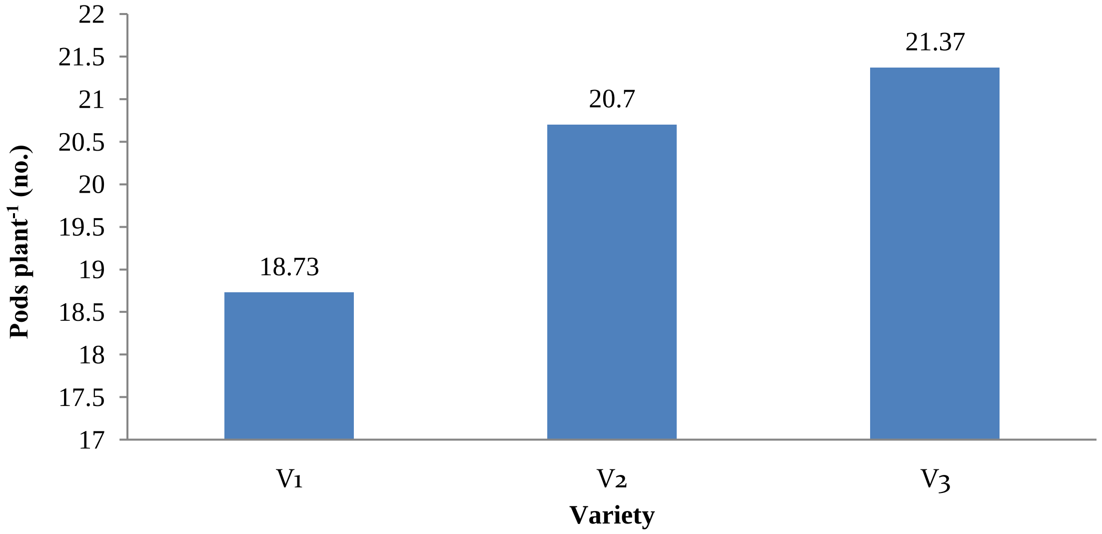
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

4.2 Yield contributing characters

4.2.1 Pods plant^{-1}

Effect of variety

The number of pods plant^{-1} of mungbean was significantly influenced by different varieties (Fig. 13). The experimental results revealed that the highest number of pods plant^{-1} (21.37) was found in V_3 (Binamoog-8) variety which was statistically similar with V_2 (BARI Mung-6) variety (20.70). The lowest number of pods plant^{-1} (18.73) was found in V_1 (BARI Mung-5) variety. Different mungbean varieties had different number of pods plant^{-1} was due to the genetic variation of the variety and maximum number of pods plant^{-1} was obtained from high yielding varieties comparable to low yielding mungbean varieties. The result obtained from the present study was similar with the findings of Noorzai *et al*. (2017) who reported that the mungbean genotype Mash-2008 produced significantly higher number of pods plant^{-1} (25.8) than the other genotypes but at par with genotype Mai-2008 (24.5).

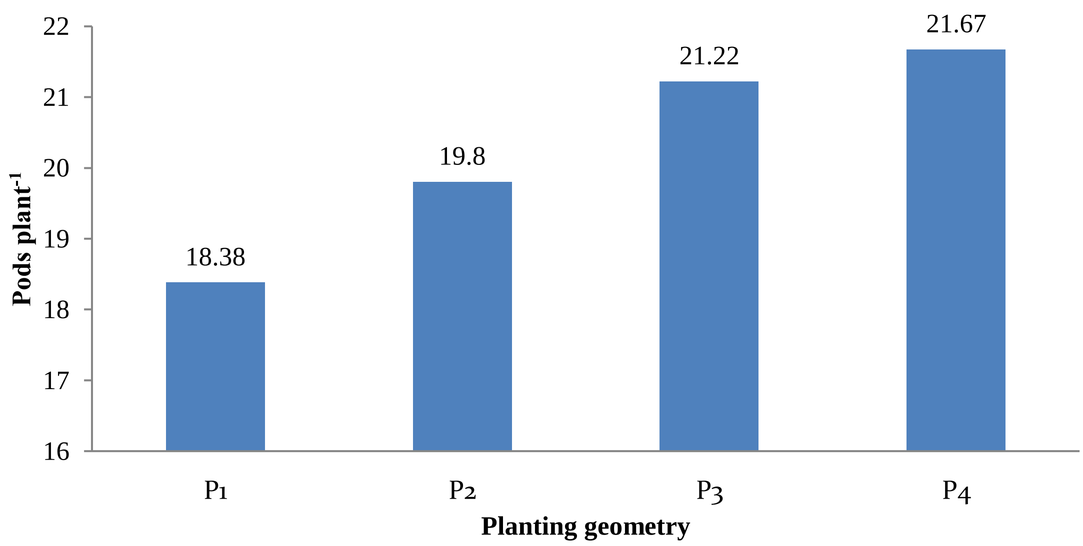


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Fig. 13. Effect of variety on pods plant^{-}1 of mungbean (LSD$_{(0.05)}$= 0.88).

Effect of planting geometry

Planting geometry had shown significant effect on the number of pods plant^{-1} of mungbean (Fig. 14). According to the experimental results, the highest number of pods plant^{-1} of mungbean (21.67) was observed in the P_4 (30 cm × 10 cm) treatment which was statistically similar with P_3 (21.22) treatment. However, the P_1 treatment had the lowest number of pods plant^{-1} of mungbean (18.38). 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 Kabir and Sarkar (2018) who reported that spacing of 30 cm × 10 cm gave the highest number of pods plant^{-1} of mungbean.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 14. Effect of planting geometry on pods plant^{-1} of mungbean ($LSD_{(0.05)}$= 0.66).

Combined effect of variety and planting geometry

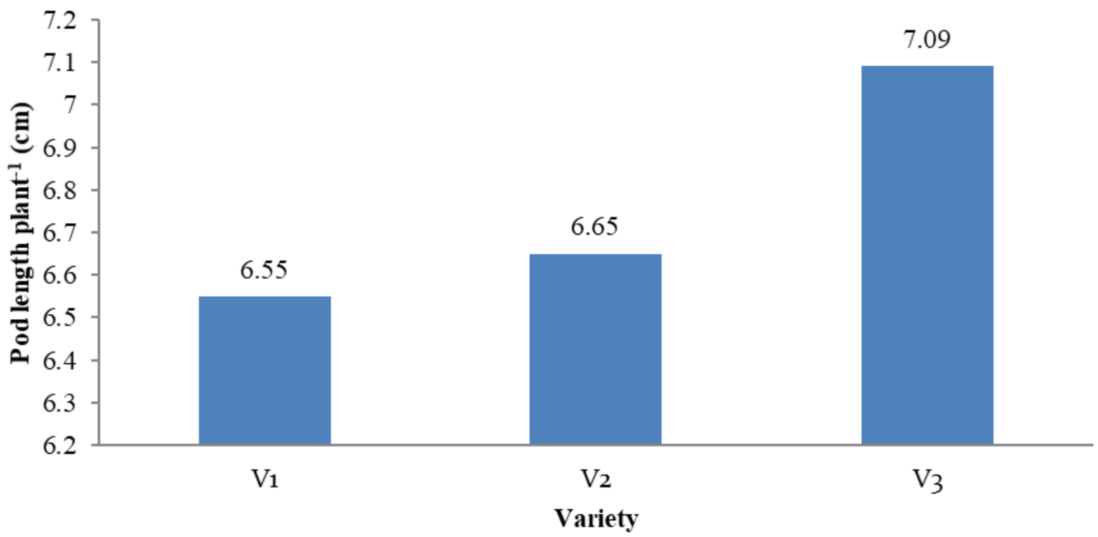
Mungbean pods plant^{-1} was significantly influenced by variety and planting geometry combination (Table 6). Experimental result revealed that the highest number of pods plant^{-1} of mungbean (22.40) was observed in V_3P_4 treatment combination which was statistically similar with V_3P_3 (22.00), V_2P_4 (22.07) and V_2P_3 (21.40) treatment combinations. While the lowest number of pods plant^{-1} of mungbean (15.40) was observed in V_1P_1 treatment combination.

4.2.2 Pod length plant^{-1}

Effect of variety

The length of pods plant^{-1} of mungbean was significantly influenced by different varieties (Fig. 15). The highest pod length plant^{-1} of mungbean (7.09 cm) was observed in the V_3 (Binamoog-8) variety. While the V_1 (BARI Mung-5) variety had the lowest pod length plant^{-1} of mungbean (6.55 cm) which was statistically comparable to V_2 (6.65 cm) variety. The pod length plant^{-1} varies between mungbean varieties because of the varieties genetic makeup. The result was similar with the findings of Ahmed *et al*.

(2014) who observed significant difference in pod length of some mungbean genotypes with maximum produced by genotype AZRI-2006 (8.91 cm).

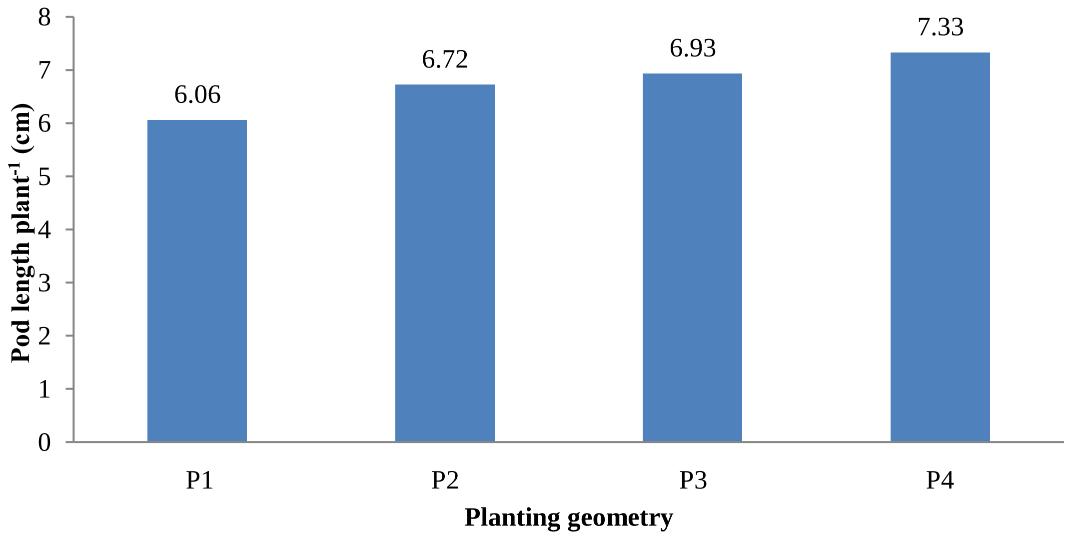


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 15. Effect of variety on pod length plant^{-1} of mungbean ($LSD_{(0.05)}$= 0.29).

Effect of planting geometry

Different planting geometry performed in the experiment field showed significant effect on the pod length plant^{-1} of mungbean (Fig. 16). Experimental results showed that the highest pod length plant^{-1} of mungbean (7.33 cm) was observed in the P_4 (30 cm × 10 cm) treatment. While the P_1 (broadcasting) treatment had the lowest pod length plant^{-1} of mungbean (6.06 cm). Increase in pod length plant^{-1} might due to less competition between plant at optimum spacing and also availability of nutrient use in adequate amount resulted in formation of photosynthesis, which promote metabolic activity, increase the cell division, ultimately increase the pods length plant^{-1}. Khan *et al.* (2017) in Punjab, India reported that at optimum spacing of 30 cm × 10 cm, the pods length was maximum while at wider and narrow spacing than this 35 cm × 10 cm and 25 cm × 10 cm, the pod length was minimum.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 16. Effect of planting geometry on pod length plant^{-1} of mungbean ($LSD_{(0.05)}$= 0.33).

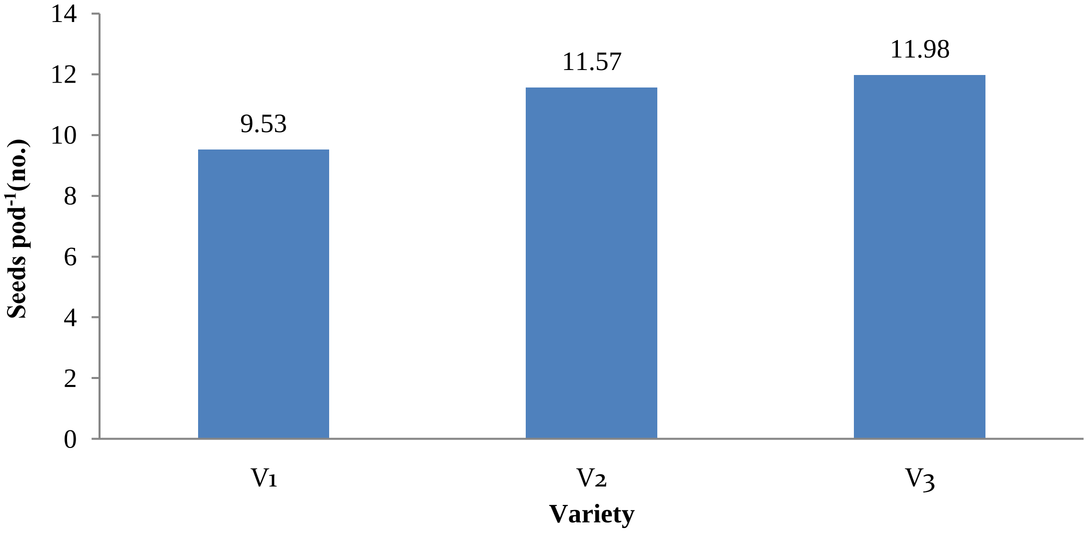
Combined effect of variety and planting geometry

The combination of variety and planting geometry had a significant effect on mungbean pod length plant^{-1} (Table 6). The results of the experiment showed that the V_3P_4 treatment combination, had the highest pod length plant^{-1} of mungbean (7.82 cm) which was statistically similar with V_3P_3 (7.26 cm) treatment combination. While the V_1P_1 treatment combination had the lowest pod length plant^{-1} of mungbean (5.18 cm).

4.2.3 Seeds pod^{-1}

Effect of variety

The number of seeds pod^{-1} of mungbean varied significantly depending on the varietal difference (Fig. 17). According to the experimental findings the V_3 (Binamoog-8) variety had the highest number of seeds pod^{-1} (11.98) which was statistically similar with V_2 (11.57) variety. While the V_1 (BARI Mung-5) variety had the lowest number of seeds pod^{-1} (9.53). The differences of number of seeds pod^{-1} was due to the genetic makeup of the varieties. Kotwal and Prakash (2007) reported that among the cultivars T-44 was superior in terms of number of seeds pod^{-1} (9.37) over other varieties of greengram. Mathur *et al*. (2007) reported that mungbean variety K 851 produced more seeds pod^{-1} as compared to RMG 62 and RM 268.

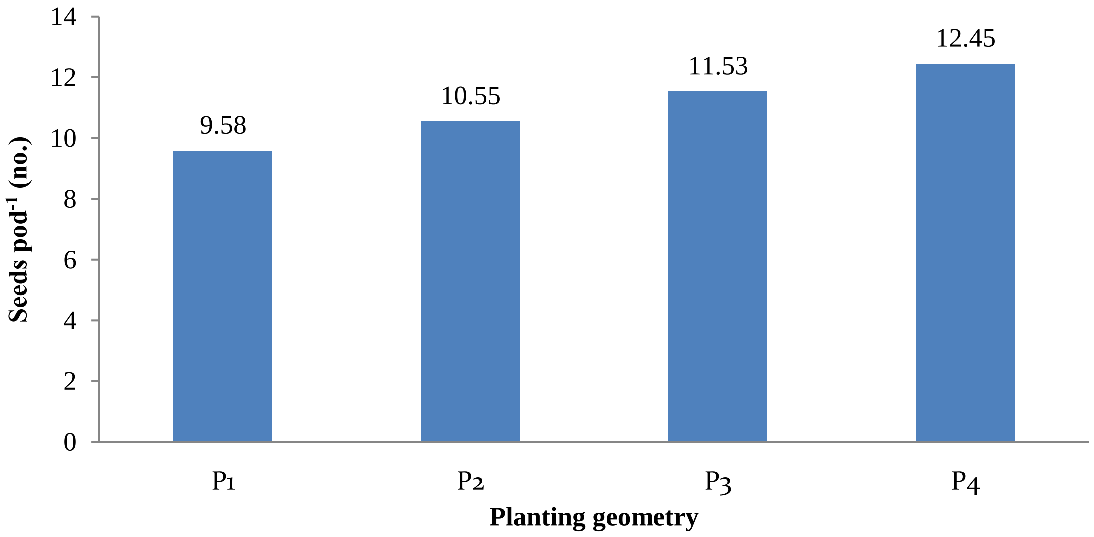


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 17. Effect of variety on seeds pod^{-1}of mungbean (LSD$_{(0.05)}$= 0.56).

Effect of planting geometry

Mungbean cultivated at different planting geometry significantly influenced the number of seeds pod^{-1} (Fig. 18). The results of the experiment showed that the P_4 treatment (30 cm × 10 cm) had the highest number of seeds pod^{-1} (12.45). While the P_1 treatment had the lowest number of seeds pod^{-1} (9.58). Similar findings were made by Tigga *et al*. (2017) who reported that the genotype Asha gave maximum seed pod^{-1} (4.23) with wider geometry compared to narrow spacing.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 18. Effect of planting geometry on seeds pod^{-1} of mungbean (LSD$_{(0.05)}$= 0.43).

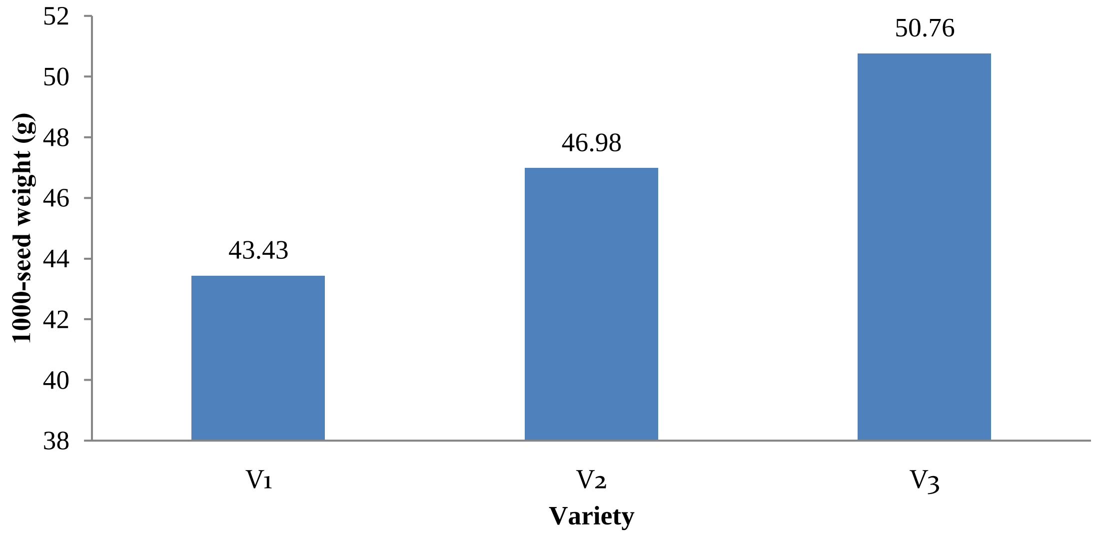
Combined effect of variety and planting geometry

Combinations of different varieties and planting geometry had a significant effect on the number of seeds pod^{-1} of mungbean (Table 6). According to the experimental findings, the V_3P_4 treatment combination had the highest number of seeds pod^{-1} (13.87). While the lowest number of seeds pod^{-1} (7.06) were seen with the V_1P_1 treatment combination.

4.2.4 1000-seed weight (g)

Effect of variety

The 1000-seed weight of mungbean was significantly influenced by different varieties (Fig. 19). The results showed that the V_3 (Binamoog-8) variety had highest 1000-seed weight of mungbean (50.76 g). While the V_1 (BARI Mung-5) variety had the lowest 1000-seed weight (43.43 g). The differences in 1000-seed weight among the various mungbean varieties could be attributed to the traits of the blackgram varieties and their genetic makeup. Mondal *et al*. (2015) reported that 1000-seed weight in mungbean genotype BARI Mung-6 (55.4 g) was significantly higher than the other genotypes but at par with BARI Mung-5 and BINA Mung-7. Mathur *et al*. (2007) reported that mungbean variety K 851 produced more 1000-seed weight as compared to RMG 62 and RM 268.

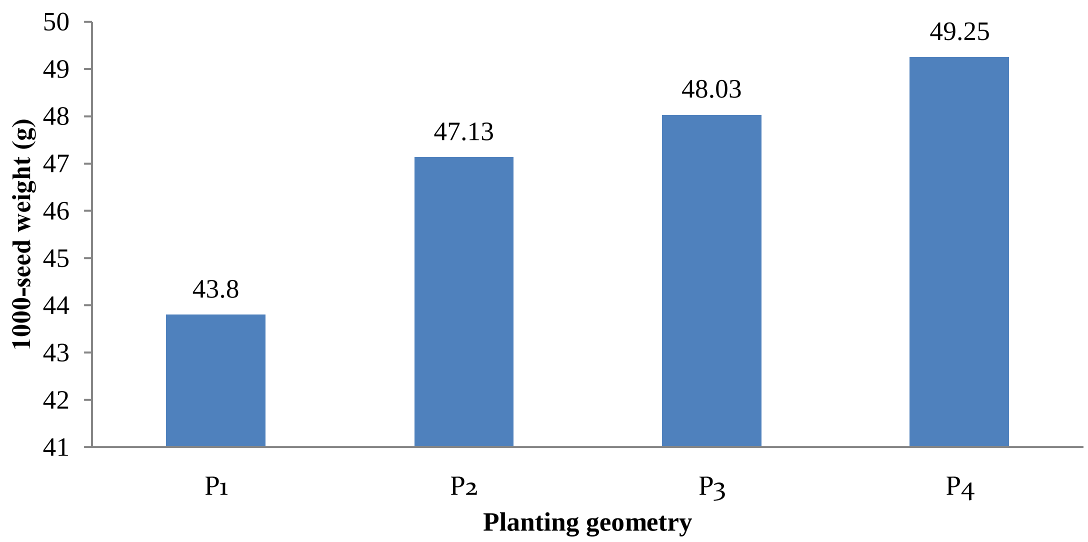


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 19. Effect of variety on 1000-seed weight of mungbean ($LSD_{(0.05)}$= 1.61).

Effect of planting geometry

Mungbean cultivation at different planting geometry had a significant influence on 1000-seed weight (Fig. 20). The experimental findings revealed that the P_4 treatment (30 cm × 10 cm) had the highest 1000-seed weight (49.25 g) which was statistically similar with P_3 (48.03 g) treatment. While the P_1 treatment, had the lowest 1000-seed weight (43.80 g). Similar result also observed by Khan *et al.* (2017) who reported that crop geometry 30×10 (cm^2) recorded significantly higher 1000-seed weight of mungbean.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 20. Effect of planting geometry on 1000-seed weight of mungbean ($LSD_{(0.05)}$= 1.28).

Combined effect of variety and planting geometry

Mungbean 1000-seed weight varied significantly depending on variety and planting geometry combinations (Table 6). According to the experimental findings, the highest 1000-seed weight (52.90 g) was found in V_3P_4 treatment combination which was statistically similar with V_3P_3 (51.67 g) and V_3P_2 (50.90 g) treatment combinations. However, the lowest 1000-seed weight of mungbean (38.26 g) was found in V_1P_1 treatment combination.

Table 6. Combined effect of variety and planting geometry on number of pods plant^{-1}, pod length (cm), seeds pod^{-1} and 1000-seed weight (g) of mungbean

Treatment combinations	No. of pods plant^{-1}	Pod length (cm)	No. of seeds pod^{-1}	1000-seed weight (g)
V_1P_1	15.40 g	5.18 d	7.06 g	38.26 f
V_1P_2	18.73 f	6.87 bc	9.67 f	44.30 e
V_1P_3	20.27 c-e	7.05 bc	10.13 f	45.13 de
V_1P_4	20.53 c-e	7.09 b	11.27 de	46.03 de
V_2P_1	19.60 ef	6.49 c	11.47 cd	45.57 de
V_2P_2	19.73 d-f	6.51 c	10.46 ef	46.20 de
V_2P_3	21.40 a-c	6.49 c	12.13 bc	47.30 cd
V_2P_4	22.07 ab	7.09 b	12.20 bc	48.83 bc
V_3P_1	20.13 c-e	6.51 c	10.20 f	47.57 cd
V_3P_2	20.93 b-d	6.77 bc	11.53 b-d	50.90 ab
V_3P_3	22.00 ab	7.26 ab	12.33 b	51.67 a
V_3P_4	22.40 a	7.82 a	13.87 a	52.90 a
$LSD_{(0.05)}$	**1.31**	**0.57**	**0.85**	**2.49**
CV(%)	**3.29**	**4.93**	**4.00**	**3.33**

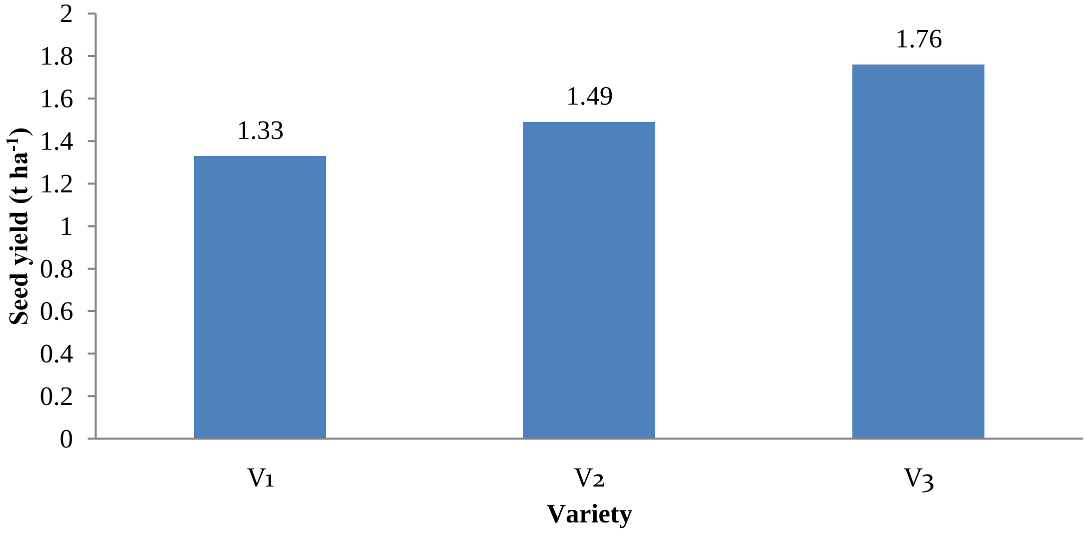
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

4.3 Yield characters 4.3.1

Seed yield

Effect of variety

Seed yield of mungbean was significantly influenced by different characters (Fig. 21). Experimental results revealed that the V_3 (Binamoog-8) variety recorded the highest seed yield (1.76 t ha^{-1}). While V_1 (BARI Mung-5) variety had the lowest seed yield (1.33 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. Dash and Rautaray (2017) observed that maximum seed yield was produced by variety Pusa Vishal as compared to local variety of greengram. This could be due to different genetic variability and adaptability to the environment of greengram varieties.

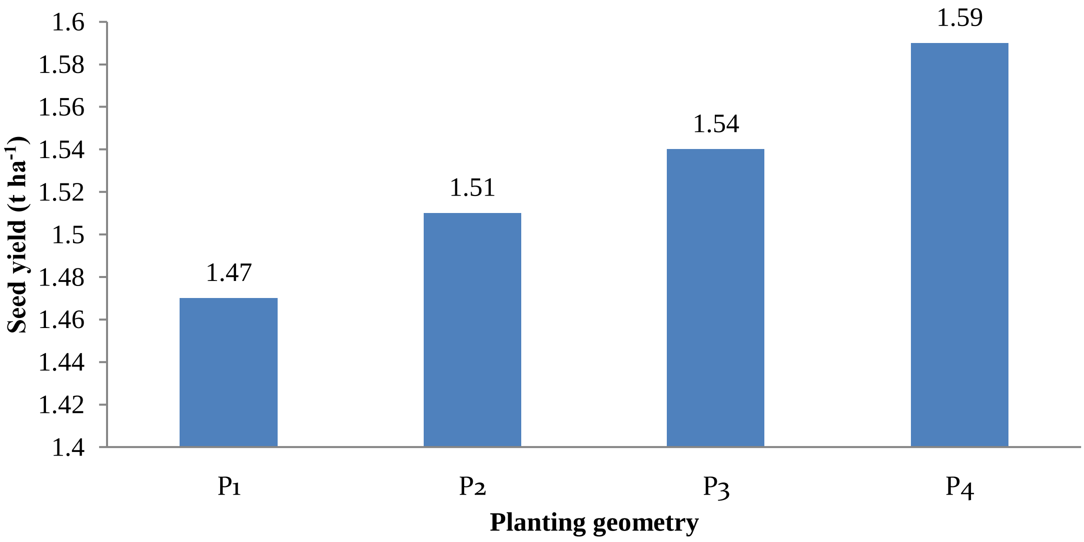


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 21. Effect of variety on seed yield of mungbean ($LSD_{(0.05)}$= 0.02).

Effect of planting geometry

The seed yield of mungbean was significantly influenced by the different planting geometry (Fig. 22). The results of the experiment showed that the P_4 treatment (30 cm × 10 cm) had the highest seed yield (1.59 t ha^{-1}). Whereas the lowest seed yield (1.47 t ha^{-1}) was found in the P_1 treatment. Kumar and Rajput (2020) reported that planting geometry 30 cm × 10 cm showed significantly higher yield attributing characters, yield, gross return and net return.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 22. Effect of planting geometry on seed yield of mungbean ($LSD_{(0.05)}$= 0.03).

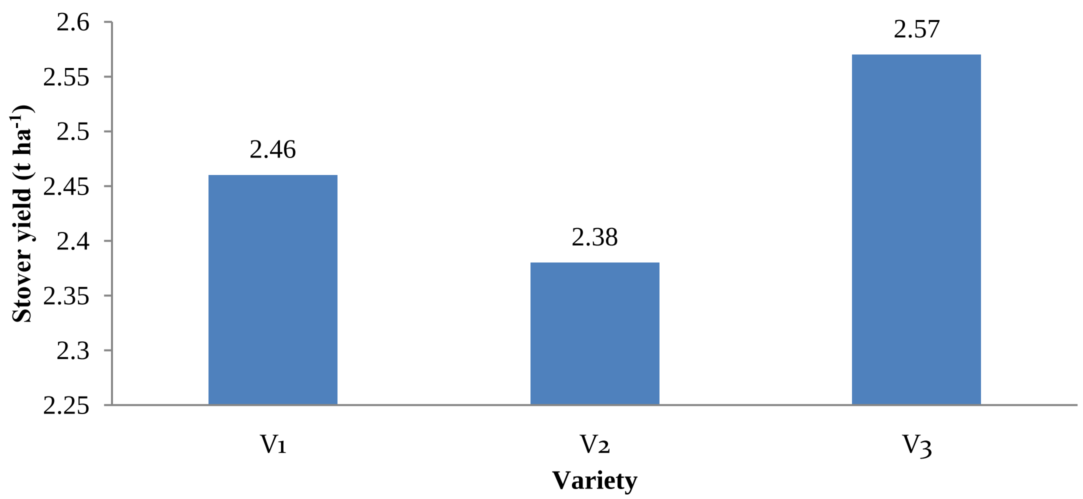
Combined effect of variety and planting geometry

Depending on the variety and planting geometry, mungbean seed yield varied significantly (Table 7). According to the experimental results, the V_3P_4 treatment combination had the highest seed yield (1.83 t ha^{-1}) which was statistically comparable to the V_3P_3 (1.78 t ha^{-1}) treatment combination. While the V_1P_1 treatment combination had the lowest seed yield (1.27 t ha^{-1}) which was statistically similar to that of V_1P_2 (1.31 t ha^{-1}) treatment combination.

4.3.1 Stover yield

Effect of variety

The stover yield was significantly influenced by different mungbean varieties (Fig. 23). The results of the experiment showed that the V_3 (Binamoog-8) variety had the highest stover yield (2.57 t ha^{-1}) while V_2 (BARI Mung-6) variety had the lowest (2.38 t ha^{-1}). Dash and Rautaray (2017) reported that the maximum stover yield was produced by variety Pusa Vishal as compared to local variety of greengram. This could be due to different genetic variability and adaptability to the environment of greengram varieties.

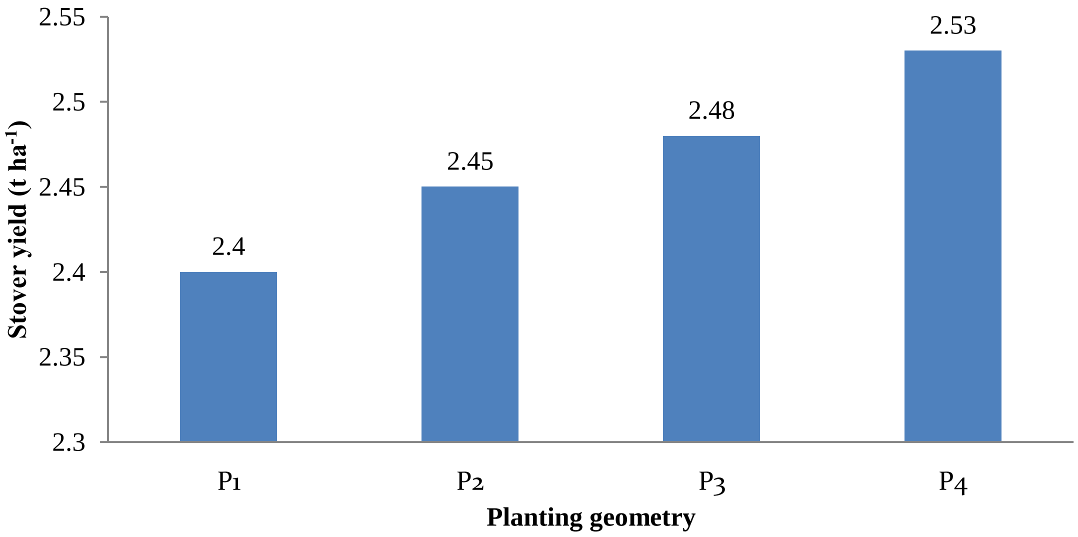


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 23. Effect of variety on stover yield of mungbean ($LSD_{(0.05)}$= 0.03).

Effect of planting geometry

The different planting geometry had shown significant effect on the stover yield of mungbean (Fig. 24). The experimental findings showed that the P_4 (30 cm × 10 cm) treatment recorded the highest stover yield (2.53 t ha^{-1}). While the lowest stover yield was achieved with the P_1 treatment (2.40 t ha^{-1}). Stover yield is one of main product of growth parameters like plant height, number of branches and dry matter accumulation. Therefore, the increase in these characters because of adequate spacing resulted in increase of strover yield of mungbean. Similar result was also observed by Kabir and Sarkar (2018) who reported that spacing of 30 cm × 10 cm gave the highest stover yield of mungbean.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 24. Effect of planting geometry on stover yield of mungbean ($LSD_{(0.05)}$= 0.04).

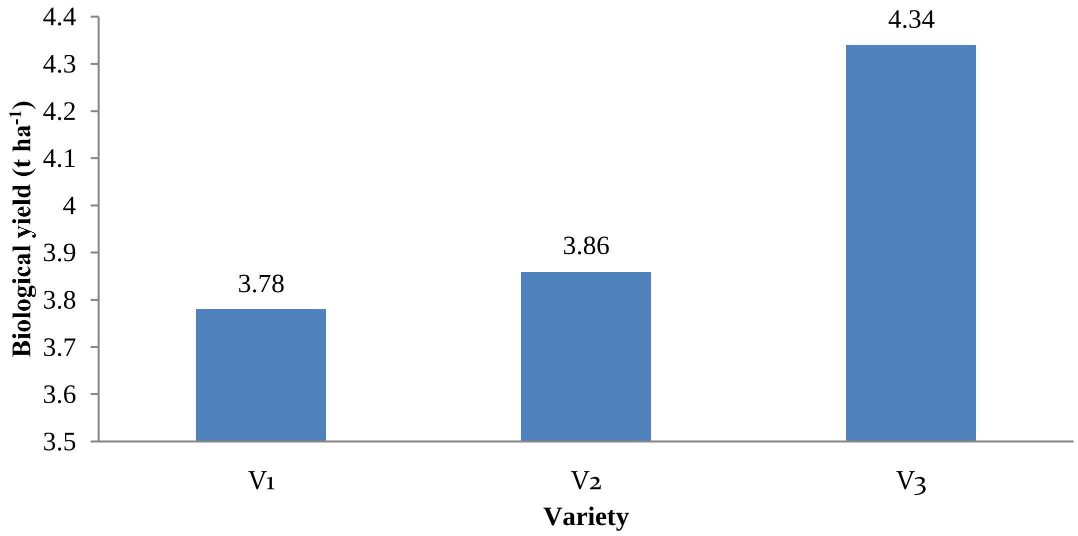
Combined effect of variety and planting geometry

The stover yield of mungbean varied significantly according on the combined effect of variety and planting geometry (Table 7). Experimental results showed that the highest stover yield (2.63 t ha^{-1}) was observed in V_3P_4 treatment combination which was statistically similar with V_3P_3 (2.59 t ha^{-1}) and V_3P_2 (2.56 t ha^{-1}) treatment combinations. Whereas the lowest stover yield (2.32 t ha^{-1}) was revealed by the V_2P_1 treatment combination which was statistically similar with V_2P_3 (2.39 t ha^{-1}), V_2P_2 (2.36 t ha^{-1}) and V_1P_1 (2.39 t ha^{-1}) treatment combinations.

4.3.3 Biological yield (t ha^{-1})

Effect of variety

Mungbean varieties had shown significant effect on the biological yield (Fig. 25). The experimental findings showed that the V_3 (Binamoog-8) variety recorded the highest biological yield (4.34 t ha^{-1}) while the lowest was found in V_1 (BARI Mung-5) variety (3.78 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. Singh *et al.* (2006) discovered that the genotype of mungbean had a significant influence on biological yield.

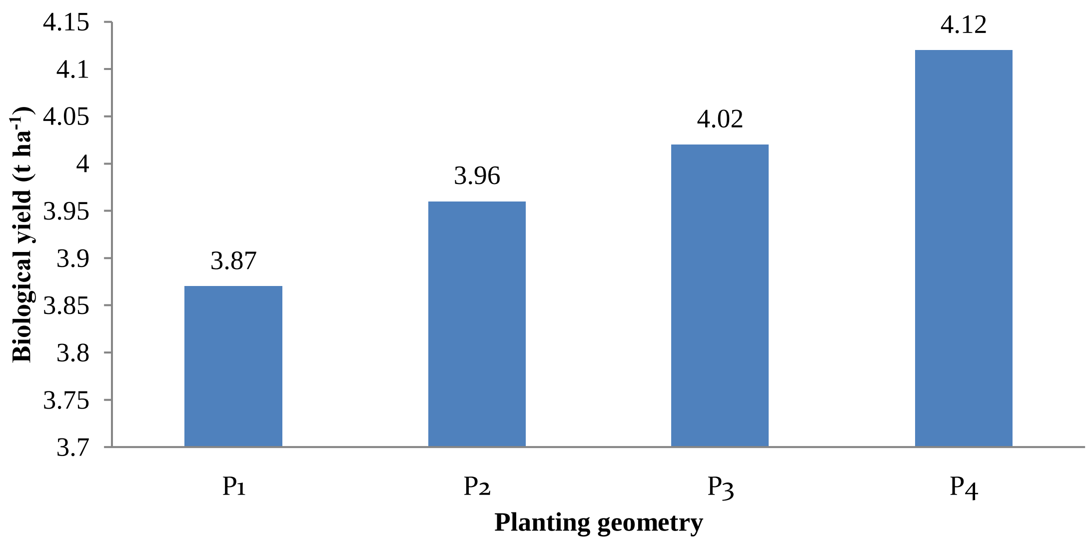


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 25. Effect of variety on biological yield of mungbean ($LSD_{(0.05)}$= 0.06).

Effect of planting geometry

Mungbean cultivated at different planting geometry significantly influenced biological yield of mungbean (Fig. 26). The results of the experiment demonstrated that the highest biological yield (4.12 t ha^{-1}) was obtained by the P_4 (30 cm × 10 cm) treatment. While the P_1 treatment resulted in the lowest biological yield (3.87 t ha^{-1}). The result was similar with the findings of Bonepally *et al.* (2021) who reported that the biological yield (2926 kg ha^{-1}) was found to be maximum in treatment combination with 30 cm × 10 cm + 40 kg ha^{-1}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 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 26. Effect of planting geometry on biological yield of mungbean ($LSD_{(0.05)}$= 0.06)

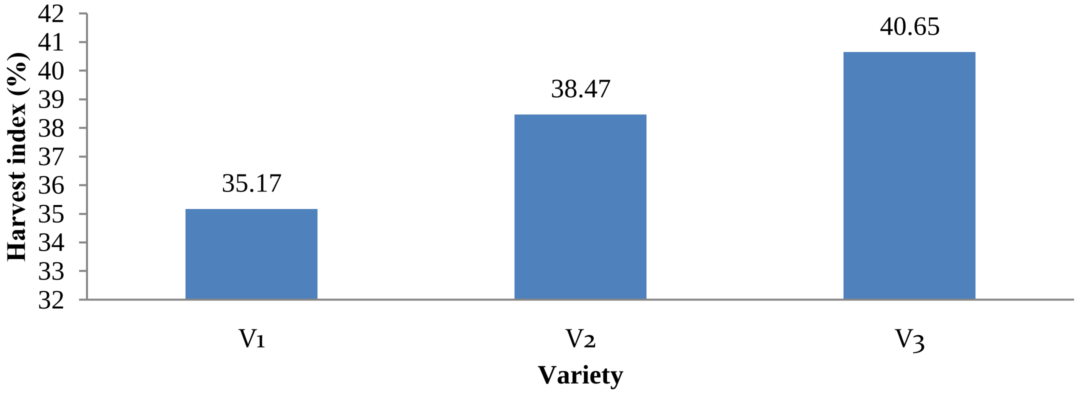
Combined effect of variety and planting geometry

Different varieties along with planting geometry had shown significant effect on the biological yield of mungbean (Table 7). The V_3P_4 treatment combination had the highest biological yield (4.46 t ha^{-1}) which was statistically similar with V_3P_3 (4.37 t ha^{-1}) treatment combination. Whereas the V_1P_1 treatment combination recorded the lowest biological yield (3.66 t ha^{-1}) which was statistically similar with V_1P_2 (3.75 t ha^{-1}) treatment combination.

4.3.4 Harvest index (%)

Effect of variety

Mungbean varieties significantly influenced harvest index (Fig. 27). The results of the investigation showed that the V_3 (Binamoog-8) variety recorded the highest harvest index (40.65 %) 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 Mung-5) variety had the lowest harvest index (35.17 %). The difference of harvest index (HI) varied greatly between varieties due to genetic diversity. Mondal *et al.* (2011) reported that harvest index of mungbean significantly influenced due to varieties.

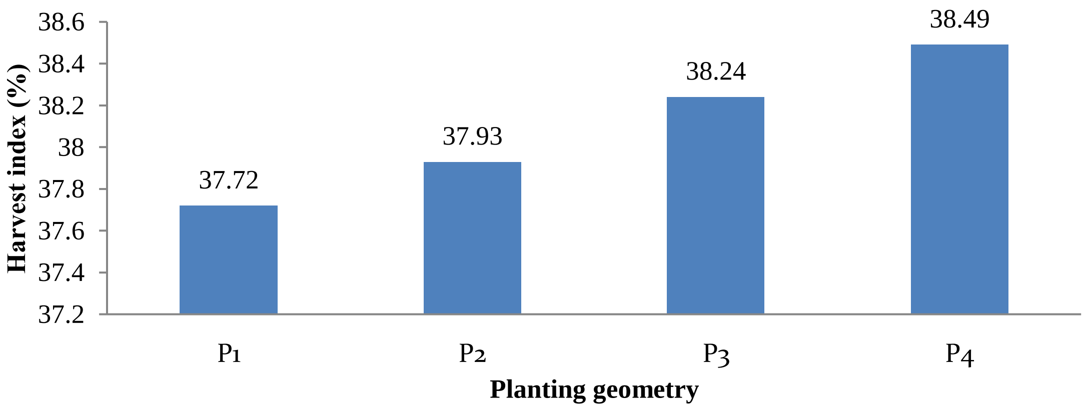


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5 % level of probability.
Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8

Figure 27. Effect of variety on harvest index of mungbean ($LSD_{(0.05)}$= 0.6).

Effect of planting geometry

Planting geometry had shown significant effect on the harvest index of mungbean (Fig. 28). The experimental findings showed that the P_4 (30 cm × 10 cm) treatment, had the highest harvest index (38.49 %) which was statistically similar to the P_3 (38.24 %) and P_2 (37.93 %) treatments, whereas the P_1 treatment recorded the lowest harvest index (37.72 %). The result was quite similar with the findings of Raman (2020) who reported that harvest index of blackgram was found to be superior at the 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 % level of probability.
Here, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

Figure 28. Effect of planting geometry on harvest index of mungbean ($LSD_{(0.05)}$= 0.57).

Combined effect of variety and planting geometry

The harvest index of mungbean was significantly influenced by different varieties and planting geometry (Table 7). The highest harvest index (41.03 %) was recorded by the V_3P_4 treatment combination, which was statistically similar to the V_3P_3 (40.73 %), V_3P_2 (40.47 %) and V_3P_1 (40.38 %) treatment combinations. The lowest harvest index (34.67 %) was recorded by the V_1P_1 treatment combination, which was statistically identical to the V_1P_2 (34.93 %), V_1P_3 (35.43 %) and V_1P_4 (35.64 %) treatment combination.

Table 7. Combined effect of variety and planting geometry on seed yield, stover yield, biological yield and harvest index of mungbean

Treatment combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1P_1	1.27 j	2.39 f-h	3.66 h	34.67 c
V_1P_2	1.31 ij	2.44 ef	3.75 gh	34.93 c
V_1P_3	1.35 hi	2.46 d-f	3.81 fg	35.43 c
V_1P_4	1.40 gh	2.53 b-d	3.93 de	35.64 c
V_2P_1	1.43 fg	2.32 h	3.75 gh	38.13 b
V_2P_2	1.47 ef	2.36 gh	3.83 e-g	38.38 b
V_2P_3	1.50 de	2.39 f-h	3.89 d-f	38.56 b
V_2P_4	1.54 d	2.43 fg	3.97 d	38.79 b
V_3P_1	1.70 c	2.51 c-e	4.21 c	40.38 a
V_3P_2	1.74 bc	2.56 a-c	4.30 bc	40.47 a
V_3P_3	1.78 ab	2.59 ab	4.37 ab	40.73 a
V_3P_4	1.83 a	2.63 a	4.46 a	41.03 a
$LSD_{(0.05)}$	**0.06**	**0.07**	**0.11**	**1.00**
CV(%)	**3.13**	**2.18**	**3.45**	**2.27**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

Here, V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8, P_1= Broadcast, P_2=Paired row (15 cm × 10 cm), P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm)

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from March to June 2021, to study the growth and yield response of mungbean varieties to planting geometry. The experiment consisted of two factors, and followed split plot design with three replications. Here Factor A: Mungbean varieties (3) *viz*., V_1 = BARI Mung-5, V_2 = BARI Mung-6, V_3 = Binamoog-8 and Factor B: Different planting geometry (4) *viz*., P_1= Broadcast, P_2=Paired row (15 cm × 10 cm) cm, P_3= Square planting (20 cm × 20 cm) and P_4= Row sowing (30 cm × 10 cm). The purpose of evaluating the experiment's outcomes, data on various parameters were evaluated. These data revealed significant variations in terms of mungbean growth, yield, and yield-contributing traits as a result of variety, planting geometry, and combination of these factors.

In case of variety, the highest growth parameters *i.e*. plant height, leaves plant^{-1}, branches plant^{-1}, nodules plant^{-1}, nodules dry weight plant^{-1} and above ground dry matter weight plant^{-1} were observed by V_3 (Binamoog-8) variety. However, this variety also recorded the highest pods plant^{-1} (21.37), pod length plant^{-1} (7.09 cm), seeds pod^{-1} (11.98), 1000-seed weight (50.76 g), seed yield (1.76 t ha^{-1}), biological yield (4.34 t ha^{-1}) and harvest index (40.65 %) comparable to other treatments. Whereas the lowest yield contributing characterizes and yield *viz.,* pods plant^{-1} (18.73), pod length plant^{-1} (6.55 cm), seeds pod^{-1} (9.53), 1000-seed weight (43.43 g), seed yield (1.33 t ha^{-1}) and harvest index (35.17 %) were observed in V_1 (BARI Mung-5) variety.

In terms of different planting geometry, P_4 (30 cm × 10 cm) treatment showed the highest growth characteristics, including plant height, leaves plant^{-1}, branches plant^{-1}, nodules plant^{-1}, nodules dry weight plant^{-1}, and above ground dry matter weight plant^{-1}. However, in comparison to other treatments, this treatment also had the highest pods plant^{-1} (21.67), pod length plant^{-1} (7.33 cm), seeds pod^{-1} (12.45), 1000seed weight (49.25 g), seed yield (1.59 t ha^{-1}), stover yield (2.53 t ha^{-1}) biological yield (4.12 t ha^{-1}) and harvest index (38.49 %). While the P_1 treatment showed the lowest seed yield (1.47 t ha^{-1}), pods plant^{-1} (18.38), pod length plant^{-1} (6.06 cm), seeds pod^{-1} (9.58) and 1000-seed weight (43.80 g).

In case of treatment combination, the V_3P_4 demonstrated the best growth traits in terms of plant height, leaves plant^{-1}, branches plant^{-1}, nodules plant^{-1}, nodules dry weight plant^{-1}, and above ground dry matter weight. The treatment combination, however, also produced the highest pods plant^{-1} (22.40), pod length plant^{-1} (7.82 cm), seeds pod^{-1} (13.87), 1000-seed weight (52.90 g), seed yield (1.83 t ha^{-1}), biological yield (2.63 t ha^{-1}), stover yield (4.46 t ha^{-1}) and harvest index (41.03 %) when compared to all treatment combinations. With pods plant^{-1} (15.40), pod length plant^{-1} (5.18 cm), seeds pod^{-1} (7.06), 1000-seed weight (38.26 g) the V_1P_1 treatment combination had the lowest seed yield (1.27 t ha^{-1}) and harvest index (34.67 %) comparable to other treatment combinations.

Conclusion

Based on the above findings it may be concluded that variety Binamoog-8 was found superior in all traits of growth and yield than other two varieties. Spacing at 30 cm × 10 cm seems optimum for having higher yield. Binamoog-8 along with 30 cm × 10 cm spacing proved to be a good management for mungbean higher yield.

RECOMENDATION

This experiment was carried out for single season while further studies needed in the following area:

- Such study needs to be tested again in different mungbean growing area of Bangladesh to re-evaluate treatment variable.
- This experiment could be replicated in different agro-ecological zone of Bangladesh.

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APPENDICES

Appendix I. Map showing the experimental location

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^{-1})	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

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

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

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

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

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

Sources of variation	**DF**	Mean square values			
		15 DAS	30 DAS	45 DAS	At harvest
Replication (R)	2	0.04083	0.0833	4.111	1.750
Variety (V)	2	8.62563*	7.2903*	169.768*	98.256*
Error (a)	4	0.11583	0.5833	6.111	4.000
Planting geometry (P)	3	2.22189*	23.2334*	202.183*	206.622*
V×P	6	0.37249*	3.5475*	16.429*	10.786*
Error (b)	18	0.09083	0.4167	5.444	3.250

*: Significant at 5% level of probability

Appendix V. Analysis of variance of the data of branches plant^{-1} of mungbean at harvest

Sources of variation	**DF**	Mean square values
Replication (R)	2	0.00041
Variety (V)	2	0.17868*
Error (a)	4	0.00041
Planting geometry (P)	3	0.10777*
V×P	6	0.01524*
Error (b)	18	0.00107

*: Significant at 5% level of probability

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

Sources of variation	**DF**	Mean square values			
		15 DAS	30 DAS	45 DAS	At harvest
Replication (R)	2	0.03000	0.04083	0.07208	0.34194
Variety (V)	2	0.37390*	0.66023*	5.39470*	8.03450*
Error (a)	4	0.01000	0.03581	0.08957	0.10444
Planting geometry (P)	3	0.41203*	0.66529*	1.62687*	2.73662*
V×P	6	0.08213*	0.06529*	0.72817*	0.81021*
Error (b)	18	0.01667	0.03748	0.08374	0.18361

*: Significant at 5% level of probability

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

Sources of variation	**DF**	Mean square values			
		Nodules plant^{-1}		Nodules dry weight plant^{-1}	
		45 DAS	At harvest	45 DAS	At harvest
Replication (R)	2	0.3571	1.0278	3.000E-06	4.083E-06
Variety (V)	2	26.4919*	43.9604*	9.975E-05*	1.683E-04*
Error (a)	4	0.3221	0.6528	1.750E-06	1.083E-06
Planting geometry (P)	3	26.1670*	53.2930*	8.867E-05*	1.047E-04*
V×P	6	6.5196*	2.4409	1.842E-05*	5.917E-06*
Error (b)	18	0.3337	0.7778	2.167E-06	2.083E-06

*: Significant at 5% level of probability

Appendix VIII. Analysis of variance of the data of above ground dry matter weight plant^{-1} of mungbean at harvest respectively

Sources of variation	**DF**	Mean square values
Replication (R)	2	1.333
Variety (V)	2	17.064*
Error (a)	4	0.917
Planting geometry (P)	3	108.568*
V×P	6	1.551*
Error (b)	18	1.056

*: Significant at 5% 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 mungbean

Sources of variation	**DF**	Mean square values			
		Pods plant^{-1}	Pod length	Seed pod^{-1}	1000-seed weight
Replication (R)	2	0.1111	0.19444	0.0751	1.028
Variety (V)	2	22.5020*	1.00154*	20.6116*	161.208*
Error (a)	4	0.6111	0.06944	0.2509	2.028
Planting geometry (P)	3	20.0172*	2.54722*	13.7794*	49.151*
V×P	6	2.2061*	0.61472*	2.3633*	4.837*
Error (b)	18	0.4444	0.11111	0.1939	1.694

*: Significant at 5% level of probability

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

Sources of variation	**DF**	Mean square values			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication (R)	2	0.00241	0.00403	0.01267	0.3333
Variety (V)	2	0.57033*	0.11843*	1.06128*	91.4694*
Error (a)	4	0.00066	0.00103	0.00317	0.3333
Planting geometry (P)	3	0.02487*	0.02389*	0.09736*	1.0169*
V×P	6	0.00009*	0.00019*	0.00041*	0.0362*
Error (b)	18	0.00124	0.00203	0.00412	0.3333

*: Significant at 5% level of probability