INFLUENCE OF PLANTING GEOMETRY ON GROWTH AND YIELD OF BLACKGRAM VARIETIES

MOHSINA JAHAN TURON

REGISTRATION NO.10-03841

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY DHAKA-1207

JUNE, 2016

INFLUENCE OF PLANTING GEOMETRY ON GROWTH AND YIELD OF BLACKGRAM VARIETIES

BY

MOHSINA JAHAN TURON
REGISTRATION NO.10-03841

A Thesis

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

SEMESTER: JANUARY- JUNE, 2016

Approved by:

(Prof. Dr. Md. FazlulKarim)
Supervisor

(Prof. Dr. Md. Shahidul Islam)
Co-supervisor

(Prof. Dr. Md. FazlulKarim)
Chairman
Examination Committee

Dedicated

To

My Beloved Parents and Elder Brother

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

PABX: 9110351 & 9144270-79

CERTIFICATE

This is to certify that the thesis entitled“*INLUENCE OF PLANTING GEOMETRY ON GROWTH AND YIELD OF BLACKGRAM VARIETIES*”***submitted to theFaculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of*** *MASTER OF SCIENCE (MS)****in****AGRONOMY****,embodies the results of a piece of bona fide research work carried out by****MOHSINA JAHAN TURON,* ***Registration. No.*** **10-03841*****under my supervision and guidance. No part of this 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.

Dated:

(Prof.Dr. Md. Fazlul Karim)

Supervisor

Dhaka, Bangladesh

ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to the almighty ***Allah Rabbul Al-Amin*** *for His gracious kindness and infinite mercy in all the endeavors the author to let her successfully completes the research work and the thesis leading to Master of Science.*

The author would like to express her heartfelt gratitude and most sincere appreciations to her Supervisor ***Prof. Dr. Md. Fazlul Karim****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise grateful appreciation is conveyed to Co-Supervisor* ***Prof. Dr. Md. Shahidul Islam,*** *Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.*

The authress would like to express her deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The authress wishes to extend her special thanks to her class mates and friends Semonti, Rumi, Munni, Ruma, Fahmida, Tamim, Rezwan and her roommates Rifa, Swarna, Moon , Akhlima, Hridi apu and junior brother Raju and Vashanifor their keen help as well as heartiestco-operation and encouragement during experimentation. Special thanks to all other friends for their support and encouragement to complete this study.

The authress is deeply indebted and grateful to her parents, brothers, sisters, and sister in law relatives as well as her beloved husband who continuously prayed for her success and withoutwhose love, affection, inspiration and sacrifice this work would not have been completed.

Thank you to Ministry of Science and Technology, People's Republic of Bangladesh for awarding author NST fellowship. May Allah bless and protect them all.

Finally the author appreciates the assistance rendered by the staff members of the Department of Agronomy and central farm, Sher-e-Bangla Agricultural University,Dhaka, who have helped her lot during the period of study.

INFLUENCE OF PLANTING GEOMETRY ON GROWTH AND YIELD OF BLACKGRAM VARIETIES

ABSTRACT

An experiment was carried out at Agronomy farm, Sher-e-Bangla Agricultural University, Dhaka to investigate the influence of system of crop intensification method use in blackgram cultivationduring the period from March to June, 2015. The trial comprised of three varieties of blackgram *viz.* V_1= Munshigonj Local, V_2= BARI Mash-2 and V_3= BARI Mash-3 and five plant spacings *viz.* SP_1 = 30cm × 10cm (control), SP_2=20cm × 20cm SP_3=30cm × 30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm × 50cm. The experiment was laid out in a split-plot design with three replications having variety in the main plots and plant spacing in the sub-plots. The fertilizers were applied as basal dose @ N, P and K as 20, 17.20 and 17.6 kg ha^{-1}, respectively at final land preparation in all plots. Results of the experiment revealed that, BARI Mash-2 influenced significantly most of the growth, yield attributes and yield of blackgram. BARI Mash-2 produced maximum seed yield (1.38 t ha^{-1}) and plant spacing 50cm × 50cm gave the higher seed yield $pant^{-1}$ (17.31 g) but 30cm ×10cm gave highest seed yield (1.49 t ha^{-1}). While the highest seed yield (1.80 t ha^{-1}) was recorded form BARI Mash-2 with plant spacing 30cm ×10cm and the minimum (0.66 t ha^{-1}) was recorded from Munshigonj local along with spacing 50cm × 50cm.

LIST OF CONTENTS

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (contd.)

LIST OF APPENDICES

0LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BADC	=	Bangladesh Agricultural Development Corporation
LAI	=	Leaf area index
Ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MP	=	Muriate of Potash
G	=	Gypsum
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
G	=	Gram (g)
Kg	=	Kilogram
Q	=	Quintal
µg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
HI	=	Harvest Index
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Non significant
cm	=	Centimeter
Mm	=	Millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Percent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
Hr	=	Hour
T	=	Ton
viz.	=	Videlicet (namely)

CHAPTER I

INTRODUCTION

There is growing consensus that to meet global food-security requirementsthroughout this 21st century, agricultural sectors will need to pursue appropriate strategies for sustainable intensification of agricultural production (The Royal Society, 2009; Montpellier Panel, 2013). In recent years, the system of crop intensification (SCI) has emerged in a number of Asian and African countries, raising the productivity of the land, water, seed, labor, and capital resources that farmers invest can for growing a wide range of crops (Araya *et al.*, 2013; Dash and Pal, 2011; Watershed Organization Trust, 2013).

The increase in pulses production has been only marginal and may be microscopic when compared with the phenomenal increase achieved in wheat and rice. Pulses are important constituent of Bangladeshi diet and supply meager part of protein, essential amino acid and enrich the soil through symbiotic N_2 fixation from atmosphere.

However, affordable sources of protein are also required for the people of Bangladesh, the majority of which don't have the financial ability to include animal protein in their diet. In this context, grain legume crops i.e. pulses can play an excellent role as sources of plant protein. Blackgram (*Vigna mungo* L.) is one such pulse crop quite popular in Bangladesh which belongs to Fabaceae and sub family papilionaceae.Blackgram is grown under mono, mixed and multiple cropping systems during rainy (kharif), spring and summer seasons under wide range of agro-climatic conditions. The crop not only fixing free atmospheric N_2, but also enrich the soil with N for the growth of succeeding crops (Sen, 1996). It is perfect combination of all nutrients, which includes 48.0% carbohydrate, 22.23% protein, 154 mg calcium, 9.1 mg iron, l.4 g fat, 0.37g riboflavin and 0.42 mg thiamin in per 100 gm of Blackgram (BARI, 2005). It is also rich in vitamin A, B_1, B_3 and has small amount of niacin and vitamin C in it. It contains 78% to 80% nitrogen in the form of albumin and globulin. The dry seeds are good source of phosphorus. It also has very high calorie content (347 kcal). The green parts of blackgram can also be used as animal feed and the residues as manure.

The crop has special importance in intensive cropping system of the country for its short growing duration (Ahmed *et al*., 1993). The crop is potentially useful in improving cropping system as a catch crop due to its rapid growth and development. In Bangladesh, blackgram ranks fourth in acreage and production but ranks second in market price. Blackgram is cultivated in the area of 0.0687 million hectares contributing 9.5% of total pulse production 0.0631 million ton with an average 1.20 t ha^{-1}(DAE, 2016). The average yield of blackgram is very low (756 kg ha^{-1}) compare to other growing areas around the globe. Again the yield limiting factors high yielding variety and optimum spacing are recognized important against the backdrop of blackgram productivity.

An improved variety is the first and foremost-requirement for initiation and accelerated production of any crop. Variety plays an important role in producing high yield of blackgram because different varieties responded differently for their genotypic characters, input requirements and growth process under prevailing environment during the growing season. BARI has developed some varieties of blackgram. Plant height, number of branches, number of pods, 1000 grains weight, grain yield and other contributing characters essentially differ from local variety. High yielding cultivars usually have extensive root system, taller in height, relatively higher number of pods and grains pod^{-1} (Islam and Islam, 2006). These cultivars consequently give higher growth and biological yield (Minhas *et al*., 2007).

Plant density plays an important role in the dominance and suppression during the process of competition (Hassan and Baswaid, 2004). Ahmed *et al.* (1993) obtained a greater yield of blackgram at higher density early kharif. Maintenance of proper spacing is essential for nutrient uptake, low weed infestation and it also reduces plant to plant competition for nutrient uptake and light penetration.

Based on climatic conditions, researchers obtained differential response of mashbean in relation to row spacing. Assaduzzaman *et al*. (2010) found that optimum plant spacing (30cm × 10 cm) performed better in yield contributing traits, with optimum number of plant in unit area, better partitioning of assimilates towards grain contributed greater seed yield. Achakzai and Panizai(2007) found that maximum harvest index (61.44%) was obtained in row spacing of 40 cm. Murade *etal.* (2014) found that, the growth character and yield attributes *viz*; number of leaves, number of branches, leaf area, dry matter, number of pod $plant^{-1}$, number of grain pod^{-1} and grain yield $plant^{-1}$ were recorded higher under wider spacing ($45 cm \times 10$ cm) than closer spacing ($30 cm \times 10$ cm). Singh *et al.* (1994) got seed yields of 1.13, 1.37 and 1.36 t ha^{-1} with 15, 22.5 and 30 cm row spacing. Results obtained by Davi *et al.* (1995) showed that grain yield was highest at 15 cm intra-row spacing. Whereas, Nagaraju *et al.* (1995) revealed that seed yield decreased with an increase in row spacing. Mehmud *et al.* (1997) indicated that increased row spacing manifested increase in the seed weight $plant^{-1}$, pod weight $plant^{-1}$, and 1000 seed weight, but decreased plant height and seed yield unit $area^{-1}$. Kumar *et al*. (1997) obtained the highest seed yield with row spacing of 15 cm (1.09 t ha^{-1}). However, Borah (1994), Mishra and Mishra (1995) concluded that seed yield was not affected by row spacing. Therefore, the experiment was aimed with following objectives during study of blackgram under system of crop intensification system:

1) To search the blackgram varietal response onplanting geometry

2) To evaluate the effect of plant density on the yield and yield attributes of blackgram, and

3) To determine the jointly effect of variety and spacing on the growth and yield of blackgram.

CHAPTER II

REVIEW OF LITERATURE

Blackgram is an important pulse crop grown and consumed throughout the world. Farmers in our country usually cultivate blackgram using traditional methods. No research work has been conducted regarding planting geometry in blackgram in our country. So research findings in this regard is almost zero. However some relevant works on these have been reviewed in this chapter under the following headings.

2.1 System of Crop Intensification

Abraham *et al.* (2014) reported that, in the past half dozen years, farmers and professionals working with them in several Asian and African countries have begun adapting and extrapolating what they have learned from and about the system of rice intensification (SRI) to a range of other crops - finger millet, wheat, sugarcane, tef, oilseeds such as mustard, legumes such as soya and kidney beans, and various vegetables - in what is being called the system of crop intensification (SCI). As with rice, the principles of early and healthy plant establishment, reducing competition between plants, increased soil organic matter, active soil aeration, and the careful application of water are proving able to raise the productivity and profitability of differently-managed crops. Recent reports from the World Bank in India and the Agricultural Transformation Agency in Ethiopia show such changes in crop management improving food security and being scaled up with hundreds of thousands of farmers. This review reports on the productivity and other impacts being observed for many different crops in half a dozen countries for increasing food crop yields with lower cost and input requirements as well as more resilience to adverse effects of climate change.

The World Bank has documented large productivity and profitability gains for food-insecure households under one of its projects in Bihar state. As of June 2012, it reports, 348,759 farmers were using SCI methods on over 50,000 ha. It summarized their yield increases as 86% for rice, 72% for wheat, 56% for pulses, 50% for oilseeds, and 20% for vegetables. The profitability increases for these different crops were calculated, respectively, as averaging 250%, 86% 67%, 93%, and 47% (Behera *et al.*, 2013).

2.1.1System of Rice Intensification

Field experiments were conducted by Rajput*et al.* (2016) during the *kharif* seasons of 2010-11 and 2011-12 at Krishi Nagar farm, Department of Agronomy, JNKVV Jabalpur (Madhya Pradesh) to study the different crop geometries and depths of planting on growth and yield of rice in system of rice intensification. The results revealed that the 30 cm × 30 cm planting geometry had superiority in various parameters *viz*; growth parameter, yield and yield attributes, which were significantly influenced by plant geometry and depth of planting. Rice variety MR-219 with shallow depth of planting (2.5 cm) had markedly superior growth parameters *viz*., number of tillers m^{-2} at harvest. Almost all the yield and yield attributing characters *viz*; test weight, harvest index, grain and straw yields were superior with the MR-219 variety and shallow depth of planting. The results revealed that growth parameters, *viz*. number of tillers m^{-2} at harvest was superior at 20 cm × 20 cm planting geometry as compared to other planting geometries. All growth parameters were significantly superior in MR-219 which resulted in production of more 1000-test weight and sterility percentage and higher yield as comparison to WGL-32100 and PS-3.MR-219 (6.94 t ha^{-1}) proved significantly superior to WGL-32100 (6.32 t ha^{-1}) and PS-3 (6.02 t ha^{-1}) with regard to grain yield, when planted at shallow depth with 25 cm × 25 cm plant geometry. Interaction between varieties and planting geometry on the grain yields was found significant. The variety MR-219 had significantly more grain yield at 25 cm × 25 cm, straw yield at 20 cm x 20 cm and 1000-test weight at 30 cm x 30 cm compared to other planting geometries.

System of Rice Intensification (SRI) paddy was introduced to offset the heavy cost of Conventional paddy cultivation. To decrease the cost of cultivation in Conventional paddy, to increase profits of the farmers in rice cultivation by decreasing the use of fertilizers, pesticides and minimizing water use by scientific water management in the face of labour scarcity, SRI paddy was introduced in Madagascar. In Conventional paddy the spacing of 20cmx15cm was followed and 20-25 days seedlings were used, and whereas, in SRI paddy cultivation, the wider spacing of 25cmx25cms was followed and by 8-12 days seedlings were used. Although large number of labour were needed for weed management in Conventional paddy, minimal labour was required for weed management in SRI paddy because of using weeders and machinery for weed management. While large amount of water to the tune of 2''-5" inundation was required for Conventional paddy cultivation, a film of water up to 1" only is maintained throughout in SRI paddy cultivation. The use of pesticides was heavy in Conventional paddy cultivation, where as the pest management is done without chemical pesticides in SRI paddy cultivation. The profit attained due to SRI paddy cultivation was higher as compared to Conventional paddy cultivation (Shukla *et al*., 2016).

Studies on the effects of seedling age and spacing schedule on the productivity and quality traits of rice adopted under system of rice intensification (SRI) was taken up by Durga *et al*. (2015) at Seed Research and Technology Centre, Rajendranagar, Hyderabad during Kharif, 2008 and 2009 using popular rice cultivar, Swarna (MTU 7029). 16 days seedling planted at 20cm ×20cm, 12 days seedling planted at 20cm ×20cm and 14 days seedling planted at 20cm ×20cm, 12 days seedling planted at 25 cm ×25 cm and 12 days seedling planted at 30cm ×30cmwere found superior for grain yield and were significantly different from the rest of the treatments. Of all the five treatments, 12 days aged seedlings besides recording highest grain yield were also found superior for spikelet fertility and ear bearing tillers $hill^{-1}$. Further, 12 days old seedlings planted at 25 cm ×25 cm recorded 100% germination with longer seedlings and high seedling vigour index 1.

The system of rice intensification (SRI) developed in Madagascar, is a system approach to increase rice productivity through proper management of fewer inputs such as irrigation water and seeds. This study was therefore designed by Kahimba *et al*. (2014)to evaluate the performance of SRI in Mvomero district in Morogoro region, Tanzania by implementing farmer field school (FFS) pilot trials of SRI operated by farmers alongside on-station scientific experiments in Mkindo Irrigation scheme. The experiments were conducted for two consecutive years during the wet season (March-July 2011) and dry season (September 2011- January 2012). One rice variety TXD

306 (SARO) was planted on plots in a randomized complete block design (RCBD) with five treatments based on two water application regimes of flooding and alternate wetting and drying (AWD), while the effects of transplanting age of seedlings and plant spacing (in cm) of 20x20 for T_2, 25x25 for T_3, 30x30 for T_4, and 40x40 for T_5 were evaluated. The plant height, root depth, tillering, biomass and grain yields, irrigation water use, and wetting and drying intervals were evaluated. Highest grain yield was achieved in 25cmx25cm (T_3) and 30cmx30cm (T_4) SRI spacing. Under the SRI practice, 62.51%, 63.64%, 64.67%, and 64.07% water savings were noticed for T_2, T_3, T_4 and T_5, respectively, compared to the control (T_1). SRI practice for planting space of 25cmx25cm to 30x30 cm, wetting and drying interval of three days, and younger seedling of 8-12 days are recommended as good combinations for SRI practice in Mkindo area, Morogoro region.

Rice (*Oryza sativa* L.) is the staple crop in Bangladesh and different factors influence its productivity. Among these factors, desired number of plant spacing per unit area is important for higher yield attainment. Therefore, this study was undertaken by Chakrabortty *et al*. (2014) to define the optimum plant geometry for getting the maximum yield. The experiment was conducted at Agronomy field, Sher-e-Bangla Agricultural University during December**,** 2011 to May**,** 2012 to study the growth and yield of Boro rice (BRRI dhan 50) as affected by planting geometry under System of Rice Intensification (SRI). Experiment comprised 5 level of plant spacing, viz. S_1: 25 cm × 25 cm, S_2: 30 cm × 30 cm, S_3: 35 cm × 35 cm, S_4: 40 cm × 40 cm and S_5: 25 cm × 15 cm following Completely Randomized Block Design with three replication. Maximum dry matter (156.2 g $hill^{-1}$), number of tiller (44.0 $hill^{-1}$), number of effective tiller (36.3 $hill^{-1}$), number of filled grains $panicle^{-1}$(101.5), grain yield (6.9 t ha^{-1}), straw yield (5.9 t ha^{-1}), biological yield (12.7 t ha^{-1}) and harvest index (54.5%) was found from 40cm x 40 cm plant spacing while minimum was observed from 25cm x 25 cm of plant spacing in this study.

The impacts of the system of rice intensification (SRI) and conventional management (CM) on grain yield, yield components and tillering capacity were examined by Chen*et al.* (2013) under 4 rice establishment methods transplanting (TP:2-3 seedlings per hill; 30 cm × 20 cm for SRI and 4-5 seedlings per hill; 20 cm × 20 cm for conventional method), seedling casting (SC:45 kg dry seed per ha; 750 plates per ha (about 28 hills per m^2) for SRI and 60 kg dry seed per ha; 1000 plates per ha (about

37.5 hills per m^2) for conventional method), mechanical transplanting (MT:4-5 seedlings per hill; 30 cm × 16 cm for SRI and 4-5 seedling per hill; 30 cm × 13 cm for conventional method) and direct seeding (DS:30 kg dry seed per ha; about 60-70 plants per m^2 for SRI and 60 kg dry seed per ha; about 120-140 plants per m^2 for conventional method). SRI produced significantly higher grain yield than CM under TP and MT but not under DS or SC. DS and SC produced much higher seedling quality than TP or MT, suggesting that robust seedlings with vigorous roots weaken the positive effect of SRI on rice yield. SRI produced a higher tillering rate than CM, but did not affect ear-bearing tiller rate significantly. Moreover, the net photosynthetic rate of the recent fully expanded leaf at mid-tillering stage was significantly higher in SRI than in CM under MT and TP. The obtained results also indicated that SRI increased biomass accumulation before heading and improved utilization of photosynthates in the grain-filling stage.

Thakur *et al.* (2010) reported that SRI practices through optimum spacing attempt to minimize competition among rice plants for the various growth factors. Although chlorophyll content of the flag leaves and third leaves decreased with ripening, the rate of decrease is different among planting density and chlorophyll content was higher with wider spacing (30cm ×30 cm) compared to narrow spacing (20cm × 20 cm). This high chlorophyll content with wider spacing was attributed to higher root-oxidizing activity of more widely-spaced rice plants (Mishra and Salokhe, 2010).

The SPAD value of the flag leaf of hybrid rice with lower plant density grown under SRI management was higher than with higher plant density at the flowering stage (Lin *et al*., 2009). These reports indicated that wider spacing was more profitable for producing carbohydrate by rice in the later growth stages of rice plants. SPAD value, chlorophyll content or photosynthetic rate will reflect the intensity factor of production of carbohydrate. Total amount of carbohydrate produced by rice plants per unit area is regulated by the intensity factor, the capacity factor (leaf area per unit area), and light intensity inside of the canopy (canopy structure). Leaf area index (LAI) of rice plants planted at 13.5 plants m^{-2} was the highest among other plant densities evaluated (7.5 or 19.5 plants m^{-2}) at 20 days after heading (Lin *et al.*,2005). Although the largest leaf area per hill was found with wide plant spacing (30cm × 30 cm) at flowering (Thakur *et al*., 2010), medium plant spacing (20cm × 20 cm) recorded the highest LAI among treatments at 20 days after heading (Lin *et al*., 2009; Thakur *et al.*, 2010).

Rice yield under SRI management with different plant spacing was evaluated in the Philippines (Miyazato *et al*., 2010). In some cases, the highest rice yield was obtained with even wider spacing (40cm × 40 cm) among the field trials; however, plants with middle spacing (25 × 25 cm) gave higher yields than those with wider spacing (35cm × 35 cm) at Hernanie Domingo, Philippines (Miyazato *et al*., 2010). These reports indicated that suitable plant spacing does not exist among fields a priori even though grown under SRI management. It may be different according to the soil fertility level.

Krishna *et al.* (2009) found that wider spacing of 40cmx40 cm had significant effects on growth and quality parameters.

The SRI method follows transplanting of single plant in one clump at distances of 25cm×25cm or 30cm×30 cm. The uniqueness of this method is that the transplanting is being done between 7th and 9th day of sprouting of seeds. The current practices of transplanting is after 4 to 8 weeks and often 5 to 10 plants in one clump that cause trauma as roots take 12 to 14 days for establishing after transplanting. In conventional way of thick planting (50 to 60 clumps in a square meter), roots of the plant cannot grow widely and deeply resulting in low nutrient uptake from different zones. Yield from SRI practices (3042 kg/ac) and yield form conventional practices (1874 kg/ac) and yield difference is 62.3% (Vishnudas, 2006).

Uphoff (2005) concluded that the wider spacing between hills gives a higher number of effective tillers hill^{-1} than in a standard square pattern with one plant per hill. When asked about the expected yield from these plots. The duration of the variety being used is 158 days, but he expects the SRI crop to mature in <152 days.

Chopra and Chopra (2004) noticed that wider spacing of 20cm × 15cm and 30cm× 15 cm recorded significantly higher number of panicles than the closer spacing 15cm × 15 cm. However, the seed yield was not affected due to different spacing.

Uphoff (2004) found that the yield increased significantly, optimum performance with SRI methods has not yet been obtained. Optimum yield depends on spacing and the most appropriate management practices with the best selected variety for the particular conditions.

Nayak *et al.* (2003) revealed that wider spacing of 20cm × 15 cm recorded maximum plant height, total and effective tillers per hill and dry matter accumulation per clump than that closer spacing of 20 cm× 10cm and 15 cm× 15 cm.

Verma *et al.* (2002) found that crop planted with 20cm × 20cm and 20cm × 15 cm produced significantly more number of productive tillers per m^2 than the crop planted with 20 × 10 cm.

Sanico *et al.* (2002) concluded that plant spacing (20cm× 20cm, 20cm × 30cm, 15cm × 30cm and 10 × 30 cm) gave no significant differences on yield components.

Patra and Nayak (2001) found significantly higher panicle per m^2, grain yield and straw yield with closer spacing of 15cm × 10 cm as compared to wider spacing of 20cm × 10 cm. However, panicle length, weight per panicle and 1000-grain weight did not influenced significantly by the spacing.

Geethadevi *et al.* (2000) found that rice crop planted with 20cm × 10 cm spacing produced significantly more effective tillers per hill than the crop planted with 15cm × 10 cmand 10cm × 10 cm.

Shrivastava *et al.* (1999) revealed that more panicle length, filled grains per panicle, 1000-grain weight and grain yield was recorded with closer spacing of 15cm × 10 cm as compared with wider spacing of 20cm × 10cm and 20 ×15 cm.

Siddiqui *et al.* (1999) recorded significantly higher grain and straw yield with closer spacing of 10cm × 10 cm over the wider spacing of 20cm × 10 cm.

Srivastav and Tripathi (1998)observed that number of fertile grain per panicle was more with closer spacing of 15cm × 10 cm than with wider spacing of 20cm × 15 cm.

Padmaja and Reddy (1998) recorded significantly higher grain yield with 15cm × 15 cm spacing than that with 20cm × 15 cm spacing. They were also found significantly more filled spikelets per panicle with wider spacing of 20cm × 15 cm as compared to that closer spacing of 15cm × 15 cm.

Instead of planting seedlings densely, as is common because having more plants seems likely to produce more rice, with SRI seedlings are planted widely spaced, in a square pattern (to facilitate weeding as well as to give more space between plants), 25 by 25 cm or more widely, up to 50 by 50 cm. It seems counter-intuitive that fewer plants should give much more yield (seeding rates with SRI are 5-10 kg ha^{-1} compared to over 100 kg/ha with traditional methods). Yet innovative farmer practices for growing wheat in Mexico, documented by CIMMYT, showed that wide spacing can give much better yields (Sayre and Ramos, 1997). Plants with more room to grow; have a larger root system and better exposure to light and air. Wider spacing improves the canopy's photosynthesis which leads to greater root growth and accompanying productive tillering percentage and the spikelet number per panicle, provided that other favorable conditions for growth such as soil aeration are provided.

Nguu and De Datta (1979) reported for conventional rice cultivation that a relatively short-statured variety with moderate tillering capacity must have close spacing for maximum yield; i.e., plant spacing of 15cm×15 cm gives significantly greater yields than 20cm×20cm and 25cm×25 cm.

2.2.2Review related to Blackgram

2.2.1 Effect of variety

Plant height

A field experiment was conducted by Panotra*et al*. (2016)at Agricultural Research Farm, Baruat, UP during 2008 and 2009 to assess the performance of Black gram under different varieties (T-9, PU-19 and PU-35). These varieties were sown on different dates of sowing *viz* 5^{th} August, 15^{th} August and 25^{th} August. From the result of experiment it can be concluded that, T-9 produce maximum plant height (23.57 cm) followed by PU-19 (20.94 cm) and minimum plant height (20.04 cm) was for PU-35.

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4 x 2.4m for each genotype. They reported that plant height was 2 folds more in Mash1-1 (120cm) than Mash 338 (60cm).

Branches plant^{-1}

A field experiment was conducted by Panotra*et al*. (2016)at Agricultural Research Farm, Baruat, UP during 2008 and 2009 to assess the performance of Black gram under different varieties (T-9, PU-19 and PU-35). These varieties were sown on different dates of sowing *viz* 5th August, 15th August and 25th August. From the result of experiment it can be concluded that, T-9 produce maximum branches plant^{-1} (5.15) followed by PU-35 (4.43) and minimum branches plant^{-1} (4.18) was for PU-19.

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4 x 2.4m for each genotype. They reported that number of branches plant^{-1} was more in Mash338 (9.40) than Mash1-1(7.80).

Response of ten mashbean genotypes namely 9010, 98-CM-525, 98- CM-524, 9006, ES-1, 9081, 98-CM-523, Mash-3, 9092 and 98-CM-522 to three planting densities viz. 10, 15 and 20 cm. was studied by Khan and Asif (2001) under field conditions during Kharif 2001. The experiment was carried out in randomized complete block design laid out in factorial fashion with three replications having net plot size of 1.2 m x 4 m. Result of the experiment revealed that maximum number of branches plant^{-1} (8) were observed in the genotypes ES-1, while minimum number of branches plant^{-1} (5.78) were found in the genotype 9092.

Dry matter weight pant^{-1}

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4 x 2.4m for each genotype. They reported that dry weight was more in Mash1-1 (20.80 g) than Mash338 (16.40 g).

Pods plant^{-1}

A field experiment was conducted by Panotra*et al*. (2016)at Agricultural Research Farm, Baruat, UP during 2008 and 2009 to assess the performance of Black gram under different varieties (T-9, PU-19 and PU-35). These varieties were sown on different dates of sowing *viz* 5th August, 15th August and 25th August. From the result of experiment it can be concluded that, T-9 produce maximum number of pods plant^{-1} (51.28) followed by PU-35 (44.33) and minimum number of pods plant^{-1} (41.83) was for PU-19.

A field experiment was conducted by Jagannath *et al.* (2014) at Agronomy Farm, College of Agriculture, Dapoli, Maharashtra during summer season of 2011. The experiment was laid out in split-plot design assigning four varieties (TAU-1, T-9, BDU-1 and TPU-4) in main-plot and four levels of phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) in sub-plot make 16-treatment combination were replicated thrice.Results showed that, maximum pods plant^{-1} (20.12) was recorded by TAU-1 where as the minimum pods plant^{-1} (19.06) was recorded byT-9.

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4 x 2.4m for each genotype. They reported that number of pods plant^{-1} was higher in Mash338 (26.30) than Mash 1-1(24.0).

Seeds pod^{-1}

A field experiment was conducted by Jagannath *et al.* (2014)at Agronomy Farm, College of Agriculture, Dapoli, Maharashtra during summer season of 2011. The experiment was laid out in split-plot design assigning four varieties (TAU-1, T-9, BDU-1 and TPU-4) in main-plot and four levels of phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) in sub-plot make 16-treatment combination were replicated thrice.Results showed that, maximum seeds pod^{-1} (6.44) was recorded by TAU-1 where as the minimum seeds pod^{-1} (5.87) was recorded by TPU-4.

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4 x 2.4m for each genotype. They reported that number of seeds pod^{-1} were higher in Mash338 (6.80) than Mash 1-1 (6.60).

Response of ten mashbean genotypes namely 9010, 98-CM-525, 98- CM-524, 9006, ES-1, 9081, 98-CM-523, Mash-3, 9092 and 98-CM-522 to three planting densities viz. 10, 15 and 20 cm. was studied by Khan and Asif (2001) under field conditions during Kharif 2001. The experiment was carried out in randomized complete block design laid out in factorial fashion with three replications having net plot size of 1.2 m x 4 m. Result of the experiment revealed that maximum number of seeds pod^{-1} were observed in genotypes 98-CM-525 and 9006 (6.22) and minimum (5.55) were found in the genotype 98-CM-524.

1000 seed weight

A field experiment was conducted by Jagannath *et al.* (2014)at Agronomy Farm, College of Agriculture, Dapoli, Maharashtra during summer season of 2011. The experiment was laid out in split-plot design assigning four varieties (TAU-1, T-9, BDU-1 and TPU-4) in main-plot and four levels of phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) in sub-plot make 16-treatment combination were replicated thrice.Results showed that, maximum 1000-grain weight (43.77 g) was recorded by TAU-1 where as the minimum 1000-grain weight (39.56 g) was recorded by TPU-4.

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4 x 2.4m for each genotype. They reported that 100seed weight was more in Mash1-1 (3.84 g) than Mash338 (3.61 g).

Grain yield

A field experiment was conducted by Panotra*et al*. (2016)at Agricultural Research Farm, Baruat, UP during 2008 and 2009 to assess the performance of Black gram under different varieties (T-9, PU-19 and PU-35). These varieties were sown on different dates of sowing *viz* 5th August, 15th August and 25th August. From the result of experiment it can be concluded that, among the variety of blackgram PU-35 produce maximum grain yield (11.07 q ha^{-1}) followed by PU-19 (10.67 q ha^{-1}) and minimum grain yield (10.33 q ha^{-1}) was for T-9.

Jagannath *et al.* (2014) conducted a field experiment at Agronomy Farm, College of Agriculture, Dapoli, Maharashtra during summer season of 2011. The experiment was laid out in split-plot design assigning four varieties (TAU-1, T-9, BDU-1 and TPU-4) in main-plot and four levels of phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) in sub-plot make 16-treatment combination were replicated thrice.Results showed that, maximum grain yield (1040 kg ha^{-1}) was recorded by TAU-1 where as the minimum grain yield (892 kg ha^{-1}) was recorded byT-9.

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4 x 2.4m for each genotype. They reported that grain yield higher in Mash338 1 (1676 kg ha^{-1}) than Mash 1-11 (1204 kg ha^{-1})

Stover yield

A field experiment was conducted by Panotra*et al*. (2016)at Agricultural Research Farm, Baruat, UP during 2008 and 2009 to assess the performance of Black gram under different varieties (T-9, PU-19 and PU-35). These varieties were sown on different dates of sowing *viz* 5th August, 15th August and 25th August. From the result of experiment it can be concluded that, among the varieties tested PU- 35 produced significantly straw yield (26.58 q ha^{-1}) than other varieties viz PU-19 and T-9.

A field experiment was conducted by Jagannath *et al.* (2014)at Agronomy Farm, College of Agriculture, Dapoli, Maharashtra during summer season of 2011. The experiment was laid out in split-plot design assigning four varieties (TAU-1, T-9, BDU-1 and TPU-4) in main-plot and four levels of phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) in sub-plot make 16-treatment combination were replicated thrice.Results showed that, maximum stover yield (1514 kg ha^{-1}) was recorded by TAU-1 where as the minimum stover yield (1351 kg ha^{-1}) was recorded byBDU-1.

Biological yield

A field experiment was conducted by Panotra*et al*. (2016)at Agricultural Research Farm, Baruat, UP during 2008 and 2009 to assess the performance of Black gram under different varieties (T-9, PU-19 and PU-35). These varieties were sown on different dates of sowing *viz* 5th August, 15th August and 25th August. From the result of experiment it can be concluded that, among the variety of blackgram PU-35 produce maximum biological yield (37.65 q ha^{-1}) followed by PU-19 (36.16 q ha^{-1}) and minimum biological yield (10.33 q ha^{-1}) was for T-9.

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4 x 2.4m for each genotype. They reported that biological yield higher in Mash1-1 (8313 kg ha^{-1}) than Mash338 (6110 kg ha^{-1})

Harvest index

A field experiment was conducted by Panotra*et al*. (2016)at Agricultural Research Farm, Baruat, UP during 2008 and 2009 to assess the performance of Black gram under different varieties (T-9, PU-19 and PU-35). These varieties were sown on different dates of sowing *viz* 5th August, 15th August and 25th August. From the result of experiment it can be concluded that, harvest index did not significantly influenced by varietal variation. Although, among the variety of blackgram PU-19 gave maximum harvest index (41.86%) and minimum harvest index (41.32%) was for T-9

A field experiment was conducted by Jagannath *et al.* (2014)at Agronomy Farm, College of Agriculture, Dapoli, Maharashtra during summer season of 2011. The experiment was laid out in split-plot design assigning four varieties (TAU-1, T-9, BDU-1 and TPU-4) in main-plot and four levels of phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) in sub-plot make 16-treatment combination were replicated thrice.Results showed that, maximum harvest index (40.72%) was recorded by TAU-1 where as the minimum harvest index (39.03%) was recorded byT-9.

Analysis of yielding ability and growth patterns of mashbean (*Vigna mungo* L. Hepper.) genotypes were carried out by Sharma *et al.* (2012)on loamy sand soil where two cultivars of mash bean were sown in the field at Punjab Agricultural University during the *Kharif* season in the second week of July from 2003 to 2005. The experiment was laid out with the random block design with the six replications of plot size 4m x 2.4m for each genotype. They reported that harvest index higher in Mash338 (27.40%) than Mash 1-1(14.40%).

2.2.2 Effect of spacing

Plant height

A field experiment was conducted by Achakzai and Panizai (2007) at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8m x 5 m with three replications. Results revealed that in response to different row spacing, the plant height values were statistically non-significant with each other. However, moderate row spacing viz., 30 and 35 cm numerically produced the highest plant height i.e., 49.89 and 49.22 cm respectively.

Leaves plant^{-1}

A field experiment was conducted by Achakzai and Panizai (2007) at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8 m x 5 m with three replications. Results revealed that in respect of various row spacing, number of leaves plant^{-1} does not significantly different from each other. However, numerically a maximum number leaves plant^{-1} (24.33) was obtained with spacing of 45 cm.

Branches plant^{-1}

Achakzai and Panizai (2007) carried out an investigation at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8 m x 5 m with three replications. Results revealed that in respect of various row spacing, number of branches plant^{-1} did not significantly different from each other. However, numerically a maximum number of branches plant^{-1} (3.12) was obtained with spacing of 45 cm.

Response of ten mashbean genotypes namely 9010, 98-CM-525, 98- CM-524, 9006, ES-1, 9081, 98-CM-523, Mash-3, 9092 and 98-CM-522 to three planting densities viz. 10, 15 and 20 cm. was studied by Khan and Asif (2001) under field conditions during Kharif 2001. The experiment was carried out in randomized complete block design laid out in factorial fashion with three replications having net plot size of 1.2 m x 4 m. Result of the experiment revealed that maximum number of branches plant^{-1} (6.9) was observed at the seeding density of 20 cm and minimum (6.1) were recorded at seeding density of 10 cm.

Pods plant^{-1}

A field experiment was conducted by Achakzai and Panizai (2007) at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8 m x 5 m with three replications. Results revealed that different level of row spacing did not significantly influenced the total number of pods plant^{-1}. However, numerically a maximum number of 45 pods plant^{-1} was noted in row spacing of 45 cm.

Pod length

A field experiment was conducted by Achakzai and Panizai (2007) at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8 m x 5 m with three replications. Results revealed that in relation to different row spacing, pod length have not responded significantly. However, numerically highest value for pod length (4.88 cm) was obtained for 25 cm row spacing.

1000 seed weight

A field experiment was conducted by Achakzai and Panizai (2007) at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8 m x 5 m with three replications. Results revealed that 1000 seed weight was not significantly influenced by different row spacing. However, heaviest 1000 seed weight (63.94 g) was recorded 25 cm row spacing.

Grain yield

A field experiment was conducted by Achakzai and Panizai (2007) at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8 m x 5 m with three replications. Results revealed that data regarding mean values of that yield plant^{-1} responded insignificantly in response to various levels of row spacing. However, numerically a maximum grain yield plant^{-1} (12.73 g) was obtained from 35 cm row spacing.

A field experiment was conducted by Achakzai and Panizai (2007) at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8 m x 5 m with three replications. Results revealed that data regarding mean values of that yield ha^{-}

^{1}responded insignificantly in response to various levels of row spacing. However, numerically a maximum yield ha^{-1} (2516 kg) was obtained from 35 cm row spacing.

Response of ten mashbean genotypes namely 9010, 98-CM-525, 98- CM-524, 9006, ES-1, 9081, 98-CM-523, Mash-3, 9092 and 98-CM-522 to three planting densities viz. 10, 15 and 20 cm. was studied by Khan and Asif (2001) under field conditions during Kharif 2001. The experiment was carried out in randomized complete block design laid out in factorial fashion with three replications having net plot size of 1.2 m x 4 m. Result of the experiment revealed that non-significant differences were observed among different genotypes regarding the seed yield. However, the genotype ES-1 produced maximum seed yield (178.55 kg ha^{-1}) of all other genotypes. Different seeding densities affected significantly the seed yield. Maximum seed yield (172.77 kg ha^{-1}) was obtained at the density level of 10 cm and minimum (99.03 kg ha^{-1}) was recorded at the planting density of 20 cm. Interaction between genotypes and planting densities was found to be non significant.

Biological yield

Field experiments were conducted by Lokanadhan (2015) during 2012-13 rabi and summer seasons at Tamil Nadu Agricultural University, Coimbatore to assess the seasonal and geo-metrical variations in pre-release blackgram genotypes/variety under garden land and rice fallow condition.The experiments were laid out in split plot design with three replications. The experiments comprised of twenty treatments with five treatments in main plot *viz.*, planting geometry S_1 - 30 cm x 10 cm, S_2– 30 cm x 30 cm, S_3– 20 cm x 10 cm, S_4– 25 cm x 10 cm, S_5– 20 cm x 20 cm. The sub plot was genotypes/varieties V_1 - Co BG 6, V_2 - Co BG - 759, V_3 - Co BG - 10-5, V_4 - Co BG - 11-2. They reported that, biomass production of blackgram were significantly higher at 30 x 10 cm planting geometry than at 20cm x 10 cm, 25cm x 10 cm, 20cm x 20 cm and 30cm x 30 cm respectively. Maximum biomass production (2625 kg ha^{-1}) was gained by 30cm x 10 cm and minimum biomass production 2144 kg ha^{-1} was recorded for 30cm x 30 cm plant spacing.

Response of ten mashbean genotypes namely 9010, 98-CM-525, 98- CM-524, 9006, ES-1, 9081, 98-CM-523, Mash-3, 9092 and 98-CM-522 to three planting densities viz. 10, 15 and 20 cm. was studied by Khan and Asif (2001) under field conditions during Kharif 2001. The experiment was carried out in randomized complete block design laid out in factorial fashion with three replications having net plot size of 1.2 m x 4 m. Result of the experiment revealed that various genotypes showed non-significant differences for the total biomass (kg ha^{-1}). However significant differences were found among the seeding densities for the total biomass. Maximum biomass was observed at seeding density of 15 cm (4190.73 kg ha^{-1}) and minimum (2543.5 kg ha^{-1}) was found at seeding density of 20 cm.

Harvest index

A field experiment was conducted by Achakzai and Panizai (2007) at Agricultural Research Institute, Quetta in year 2003 to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mashbean grown under semi-arid climate. Experiment was laid out in a Randomized Complete Block Design (RCBD) with a sub-plot size of 8 x 5 m with three replications. Results revealed that data concerned about harvest index predicted that it was significantly, but inconsistently influenced by varying level of row spacing. Maximum and statistically at par harvest index of 61.44, 60.71, 57.08 and 56.59% were obtained from row spacing viz; 40, 20, 45 and 30 cm, respectively. Minimum harvest index (48.76%) was provided by 25 cm row spacing.

Response of ten mashbean genotypes namely 9010, 98-CM-525, 98- CM-524, 9006, ES-1, 9081, 98-CM-523, Mash-3, 9092 and 98-CM-522 to three planting densities viz. 10, 15 and 20 cm. was studied by Khan and Asif (2001) under field conditions during Kharif 2001. The experiment was carried out in randomized complete block design laid out in factorial fashion with three replications having net plot size of 1.2 m x 4 m. Result of the experiment revealed that non-significant differences were observed among different genotypes regarding harvest index (%). Significant differences were recorded among various seeding densities for harvest index. Maximum harvest index (9.28%) was found at the seeding density of 10 cm while minimum harvest index (6.63%) was recorded at planting density of 20 cm. Interaction between different genotypes and planting densities was found to be non-significant.

2.2.3 Combined effect of variety and spacing

Plant height

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20x15, 30x15 and 40x15 cm. The result of the experiment showed that the maximum plant height i.e. 36.73 cm in treatment T_6 (30 cm x15 cm with T9) and the minimum i.e. 31.78 cm was observed in treatment T_2 (20 cmx15 cm, SHEKHAR 2).

Response of ten mashbean genotypes namely 9010, 98-CM-525, 98- CM-524, 9006, ES-1, 9081, 98-CM-523, Mash-3, 9092 and 98-CM-522 to three planting densities viz. 10, 15 and 20 cm. was studied by Khan and Asif (2001) under field conditions during Kharif 2001. The experiment was carried out in randomized complete block design laid out in factorial fashion with three replications having net plot size of 1.2 m x 4 m. Result of the experiment revealed that non-significant differences were observed among different genotypes for the plant height at maturity Similarly plant height was found to be non-significant among different seeding densities. Interaction between seeding densities and different genotypes was also non-significant.

Leaves plant^{-1}

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20x15, 30x15 and 40x15 cm. The result of the experiment showed that the maximum number of leaves i.e. 21.73 leaves per plant in treatment T_9 (40 cm x15 cm, T9) and minimum i.e. 16.06 leaves per plant in treatment T_1 (120 cm x15cm, PUSA 1).

Branches plant^{-1}

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20cm x15cm, 30cm x15 cm and 40cm x15 cm. The result of the experiment showed that the maximum number of branches i.e. 7.26 branches per plant was recorded in treatment T_9 (40cm x15 cm, T9) and the minimum number of branches i.e. 5.26 branches per plant was recorded in treatment T_2 (20cm x15 cm, SHEKHAR 2).

Dry matter weight pant^{-1}

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20 cm x15 cm, 30 cm x15 cm and 40 cm x15 cm. The result of the experiment showed that the maximum dry weight i.e. 23.96 g was recorded in treatment T_9 (40 cm x15 cm, T9) and minimum i.e. 18.4 g of the dry weight was observed in treatment T_1 (20 cm x15 cm, Pusa1).

Pods plant^{-1}

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20 cm x15 cm , 30 cm x15 and 40 cm x15 cm. The result of the experiment showed that the maximum number of pods per plant i.e. 15.63 pods per plant was observed in treatment T_6 (30 cm x15cm, T9) and minimum i.e. 11.78 pods per plant was observed in T_2 (20cm x15 cm, SHEKHAR 2).

Seeds pod^{-1}

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20 cm x15 cm , 30 cm x15 cm and 40 cm x15 cm. The result of the experiment showed that the maximum number of grains i.e. 8.6 grains per pods was observed in treatment T_6 (30cm x15 cm, T9) and minimum i.e. 5.46 grains per pods was observed in treatment T_7 (40cm x15 cm, PUSA 1).

Pod length

Tanya*et al.* (2015)conducted an experiment at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20cmx15cm, 30cm x15cm and 40cm x15 cm. The result of the experiment showed that the the maximum of the pod length i.e. 8.11 cm was observed in treatment T_9 (40cm x15 cm, T9) and minimum i.e. 5.63 cm was observed in treatment T_1 (20cm x15 cm,). , PUSA 1)

1000 seed weight

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20 cm x15 cm , 30 cm x15 cm and 40 cm x15 cm. The result of the experiment showed that the maximum 1000 seed weight i.e. 45.3 g was observed in treatment T_9 (40cmx15 cm, T9) and minimum i.e. 27.3 g was observed in treatment T_2 (20cm x 15 cm, SHEKHAR 2).

Response of ten mashbean genotypes namely 9010, 98-CM-525, 98- CM-524, 9006, ES-1, 9081, 98-CM-523, Mash-3, 9092 and 98-CM-522 to three planting densities viz. 10, 15 and 20 cm. was studied by Khan and Asif (2001) under field conditions during Kharif 2001. The experiment was carried out in randomized complete block design laid out in factorial fashion with three replications having net plot size of 1.2 m x 4 m. Result of the experiment revealed that all the genotypes were found to be non-significant as regards the 1000-grain weight (gm) non-significant differences were observed among different seeding densities for 1000-grain weight. Interaction between genotypes and seeding densities was also found to be non-significant.

Grain yield

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of

Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20 cm x15 cm , 30 cm x15 cm and 40 cm x15 cm. The result of the experiment showed that maximum grain yield i.e. 8.13 q per ha was recorded from treatment T_3 (20cm x15 cm, T9) and minimum i.e. 6.23 q per ha was recorded in treatment T_7 (40cm x15 cm PUSA 1,)

Field experiments were conducted by Lokanadhan (2015) during 2012-13 rabi and summer seasons at Tamil Nadu Agricultural University, Coimbatore to assess the seasonal and geo-metrical variations in pre-release blackgram genotypes/variety under garden land and rice fallow condition.The experiments were laid out in split plot design with three replications. The experiments comprised of twenty treatments with five treatments in main plot *viz.*, planting geometry S_1– 30cm x 10 cm, S_2– 30cm x 30 cm, S_3– 20cm x 10 cm, S_4– 25cm x 10 cm, S_5– 20cm x 20 cm. The sub plot was genotypes/varieties V_1 - Co BG 6, V_2 - Co BG - 759, V_3 - Co BG - 10-5, V_4 - Co BG - 11-2. They reported that, maximum grain yield was recorded with planting geometry of 30 x 10 cm in variety Co BG 6 (1046 and 746 kg ha^{-1}) followed by the genotype Co BG 759 with 20 x 20 cm (940 and637 kg ha^{-1}), haulm yield of (1938 and 1917 kg ha^{-1}).

Stover yield

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20 cm x15 cm , 30 cm x15 cm and 40 cm x15 cm. The result of the experiment showed that maximum straw yield i.e. 14.23 q per ha was recorded in treatment T_6 (30cm x15cm, T9) and minimum i.e. 11.26 q per ha was recorded in treatment T_8 (40cmx15 cm, SHEKHAR 2).

Harvest index

An investigation was carried out by Tanya*et al.* (2015)at experimentation center and research field of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed-to-be-University, Allahabad to study the effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system during Kharif season of 2014-15 in Randomize Block Design with three replication, treatments were allotted in each plot randomly. Treatments were consists of different varieties of Black gram i.e. PUSA 1, SHEKHAR 2 and T 9, and spacing i.e. 20 cm x15 cm , 30 cm x15 cm and 40 cm x15 cm. The result of the experiment showed that the maximum harvest index i.e. 37.87 % was observed in treatment T_8 (40cmx15 cm, Shekhar2) minimum i.e. 33.51 % was observed in treatment T_7 (40cmx15 cm, PUSA 1).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field laboratory of Sher-e-Bangla Agricultural University, Dhaka to system of crop intensification method use in blackgram cultivation. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Description of the experimental site

3.1.1 Site and soil

Geographically the experimental field was located at 23° 77' N latitude and 90° 33' E longitudes at an altitude of 9 m above the mean sea level. The soil belonged to the Agro-ecological Zone - Modhupur Tract (AEZ -28) (Appendix-I). The land topography was medium high and soil texture was silty clay with pH 6.1. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix-II.

3.1.2 Climate and weather

The climate of the locality is subtropical which is characterized by high temperature and heavy rainfall during Kharif season (April-September) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature. The prevailing weather conditions during the study period have been presented in Appendix-III.

3.2 Plant materials

BARI Mash-2, BARI Mash-3 and Munshigonj local were used as planting material. BARI Mash-2 was released and developed by BARI in 1996. Plant height of the cultivar ranges from 33 to 35 cm. Average yield of this cultivar is about 1.4-1.5 t ha^{-1}. The seeds of BARI Mash-2 for the experiment were collected from BARI, Joydepur

Gazipur. The seeds were drum-shaped and blackish and free from mixture of other seeds, weed seeds and extraneous materials.

BARI Mash-3 developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. It was introduced from India and released in 1996. BARI Mash-3 is erect growth habit and attains a height of 35 -38 cm, flowers 35-40 days after emergence and reaches physiological maturity 70-75 days after emergence. Leaves are trifoliate, alternate and green, leaf pubescence is present, petioles are short and purple-green, the corolla is yellowish green, the raceme position is under the canopy, mature pods are black with dense pubescence; seeds are drum-shaped and blackish, seed larger than local variety, 1000 seed weight 40-45 g. cooking time 30-37 min, crop duration 65-70 days. Planting season is August to September. Average yield is 1.5-1.6 t ha^{-1}. It is tolerant to Yellow Mosaic Virus. It contains 21-24% protein

Seeds of Munshigonj local variety collected from local farmer of Munshigonj.Leaves are trifoliate, light green color.Bushy plants,vegetative growth is more,maximum yield upto 1 t ha^{-1}.

3.3 Treatments

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

A. Factor-1: Variety (3):

a) V_1= Munshigonj local
b) V_2= BARI Mash-2
c) V_3= BARI Mash-3

B. Factor-2: Plant spacing (5):

a) SP_1 = 30cm × 10cm
b) SP_2=20cm × 20cm
c) SP_3=30cm × 30cm
d) SP_4 = 40cm × 40cm
e) SP_5 = 50cm × 50cm

Treatment combinations(15):

V_1SP_1	$V_2\ SP_1$	V_3SP_1
V_1SP_2	$V_2\ SP_2$	$V_3\ SP_2$
V_1SP_3	$V_2\ SP_3$	$V_3\ SP_3$
V_1SP_4	$V_2\ SP_4$	V_3SP_4
V_1SP_5	$V_2\ SP_5$	$V_3\ SP_5$

3.4 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. Variety was placed in the main plot where as plant spacing in the sub plot. There are 15 treatment combinations and 45 unit plots. The unit plot size was 6 m^2 (3m × 2 m). The main plot and unit plots were separated by 1.0 m and 0.50 m spacing respectively.

3.5 Land preparation

The experimental land was opened with a power tiller on 15 March, 2015 and cross ploughing was done with power tiller followed by laddering. Land preparation was completed 20 March, 2015 and then land was ready for sowing seeds.

3.6 Fertilizer application

The fertilizers were applied as basal dose @ N, P and K as 20, 17.20 and 17.6 kg ha^{-1} respectively at final land preparation in all plots. All fertilizers were applied by broadcasting and mixed thoroughly with soil (Afzal *et al*., 2003).

3.7 Sowing of seeds

Seeds were sown at the rate of 40 kg ha^{-1} in the furrow on 21 March, 2015 and the furrows were covered with the soils soon after seeding. Row to row distance and plant to plant distance was maintained as par treatment.

3.8 Intercultural operations

3.8.1 Weed control

The crop was infested with some weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was done at 20 DAS after sowing (10 April, 2015) and second weeding at15 days after first weeding (25 April, 2015).

3.8.2 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre sowing and other two were given10 DAS (31 March, 2015) and 25 DAS (16 April, 2015).

3.8.3 Plant protection measures

The crop was infested by insects. The insecticide Ripcord was sprayed at the rate of 1 L ha^{-1} to protect the crop against insect pests, first 30 DAS (20 April, 2015) and second one at 45 DAS (6 May, 2015).

3.9 Harvesting and sampling

The crop was harvested plot wise when about80 percent pod became mature at 65 DAS**.** The harvested pods were sorted into individual bags for each plot. They were taken to the threshing floor and sun dried for three days. Afterwards the seeds and stover were separately weighed. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed.

3.10 Threshing

The crop was sun dried for three days by placing them on the open threshing floor. Seeds were separated from the plants by beating the bundles with bamboo sticks.

3.11 Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.12 Recording of data

The data were recorded on the following parameters

i. Plant height (cm)
ii. Leaves $plant^{-1}$ (no.)
iii. Branches $plant^{-1}$ (no.)
iv. Above ground dry weight $plant^{-1}$ (g)
v. Crop growth rate (g m^{-2} d^{-1})
vi. Relative growth rate (g g^{-1} d^{-1})

vii. Pods plant^{-1} (no.)
viii. Seeds pod^{-1} (no.)
ix. Pod length (cm)
x. 1000 seeds weight (g)
xi. Seed yield plant $^{-1}$ (g)
xii. Seed yield (t ha^{-1})
xiii. Stover yield (t ha^{-1})
xiv. Biological yield (t ha^{-1})
xv. Harvest index (%)

3.13 Procedure of recording data

Five plants were randomly selected from inner rows of each plot at 20, 35, 50 DAS and harvest to which different growth data of plant. Yield contributing and yield data were taken at harvest from ten randomly selected plants.

i. Plant height (cm)

The height of the selected plants was measured from the ground level to the tip of the plant and average value determined.

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

Leaves plant^{-1} was counted from each plant sample and then averaged.

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

It was done by counting total number of branches of all sampled plants then the average data were recorded.

iv. Above ground dry weight plant^{-1}(g)

The sample plants were oven dried for 72 hours at 70°C and then dry weight plant^{-1} was determined.

v. Crop growth rate (g m^{-2} d^{-1})

The crop growth rate values at different growth stages were calculated using the following formula (Brown, 1994).

$$CGR = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2} \text{ d}^{-1}$$

Where,

W_1= Total dry matter production at previous sampling date

W_2= Total dry matter production at current sampling date

T_1= Date of previous sampling

T_2= Date of current sampling

GA= Ground area (m^2)

vi. Relative growth rate (g g^{-1} d^{-1})

The relative growth rate (RGR) values at different growth stages were calculated using the following formula (Brown, 1994).

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1} \text{ mg g}^{-1} \text{ d}^{-1}$$

Where,

W_1= Total dry matter production at previous sampling date

W_2= Total dry matter production at current sampling date

T_1= Date of previous sampling

T_2= Date of current sampling

Log_e= Natural logarithm

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

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

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

Seeds pod^{-1} was counted from 20 selected pods ofplants and then the average seed number was calculated.

ix. Pod length (cm)

Length of pod was measured by meter scale from 20 pods of sampled plants and then the average seed number was calculated.

x. 1000 seeds weight (g)

1000 seeds were counted, which were taken from the seeds sample of each plot separately, then weighed in an electrical balance and data were recorded.

xi. Seed yield plant^{-1}(g)

20 plants were randomly sampled from the plot avoiding border plant and average seed weight of single plant was recorded in gram.

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

Seed yield was recorded from 1.5 m^2 area and was expressed in terms of yield (t ha^{-1}).

xiii. 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}.

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

The summation of seed yield and above ground stover yield was the biological yield. Biological yield = seed yield + Stover yield.

xv. Harvest index (%)

Harvest index was calculated on dry basis with the help of following formula:

Harvest index (HI %) = $\frac{Seedyield}{Biologicalyield} \times 100$

Here, Biological yield = Seed yield + stover yield

3.14 Data analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Present study was undertaken to determine performance planting geometry in blackgram cultivation. Data on different yield contributing characters and yield were recorded to find out the optimum plant spacing on three blackgram varieties. The results of the experiment have been presented and discussed in this chapter.

4.1 Plant height (cm)

4.1.1 Effect of variety

Plant height increased gradually from 20 DAS to harvest. Plant height varied significantly at 35, 50 and harvest due to varietal variation of blackgram (Fig.1). At 35 DAS the longest plant (35.40 cm) was recorded from BARI Mash-2 (V_2) which was statistically similar with blackgram variety BARI Mash-3 (V_3) and the shortest plant (30.21 cm) was recorded from Munshigonj Local (V_1). The longest plant height (56.20 and 69.13 cm, at 50 DAS and harvest, respectively) were recorded from V_1. On the other hand the shortest plant (41.67 and 56.57 cm at 50 and harvest, respectively) were recorded from V_3 which were statistically similar with V_2 at both 50 DAS and harvest. This result might be due to the genetic variation of different blackgram varieties.

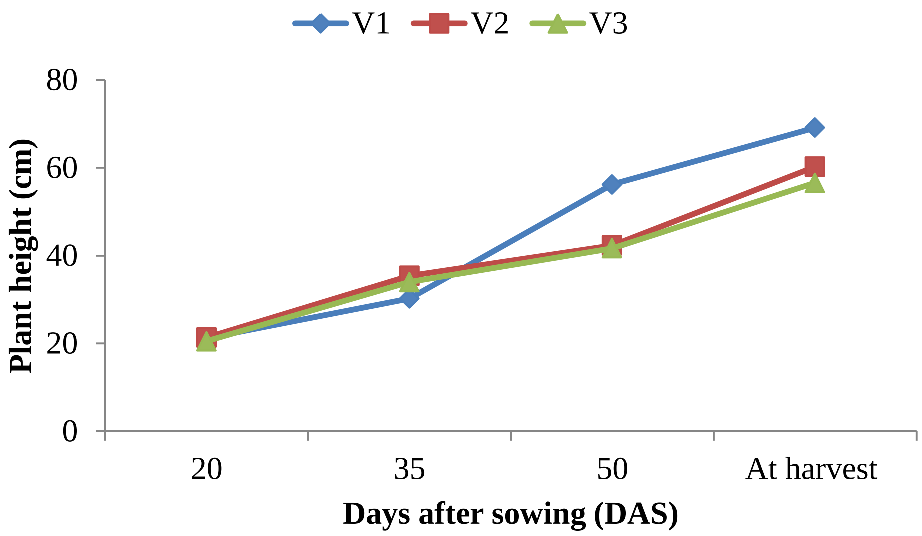


Figure 1. Effect of variety on plant height of blackgram at different days after sowing (LSD $_{(0.05)}$ =NS, 2.57, 6.37 and 6.12 at 20, 35, 50 DAS and harvest, respectively)

V_1= Munshigonj local, V_2=BARI Mash-2and V_3= BARI Mash-3

4.1.2 Effect of plant spacing

Significant variation was observed on the plant height of blackgram when seeds were sown maintaining different spacing except 20 DAS (Fig. 2). At 35 and 50 DAS, among the different plant spacing, SP_2 (20 cm × 20cm) showed the highest plant height (36.22 and 50.22 cm, respectively) which was statistically similar with SP_3 only at 50 DAS. On the other hand, SP_5 (50 cm × 50 cm) showed thelowest plant height (31.78 cm) at 35 DAS which was statistically at par with all the plant spacing except SP_2 and at 50 DAS, SP_4 (40 cm × 40 cm) showed the lowest plant height (43.89 cm) which showed similarity with SP_5 and SP_1. At harvest, the longest plant (63.23 cm) was gained from SP_5 which showed similarity with all the plant spacing except SP_1 whereas the shortest plant (60.11 cm) was gained from SP_1which showed similarity with all the plant spacing except SP_5. Similar results were also obtained by Tanya *et al.* (2015),Achakzai and Kayani (2007) andIhsanullah *et al.* (2002) who reported that plant height increases with the increasing of plant spacing.

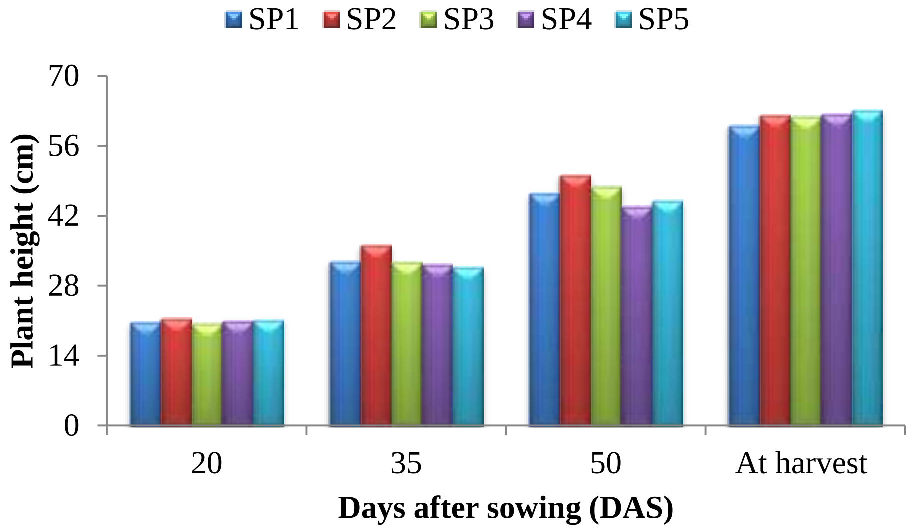


Figure 2. Effect of spacing on plant height of blackgram at different days after sowing (LSD $_{(0.05)}$ = NS, 1.87, 2.83 and 2.36 at 20, 35, 50 DAS and harvest, respectively)

Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.1.3 Combined effect of variety and plant spacing

Combined effect of variety and plant spacing had significant effect on the plant height of blackgram throughout the growing season (Table 1). At 20 DAS, the highest plant height (23.00 cm) was obtained from treatment combination V_2SP_5 which was statistically similar with V_2SP_4, V_1SP_1, V_1SP_2, V_2SP_3, V_3SP_2, V_1SP_4 and V_3SP_1 and the lowest plant height (19.03 cm) was recorded from V_3SP_3 which was statistically similar with V_3SP_4, V_2SP_1, V_1SP_5, V_2SP_2, V_1SP_3, V_3SP_5 and V_3SP_1. The highest plant height (42.33 cm) was recorded from treatment combination V_2SP_2 at 35 DAS and the lowest plant height (28.07 cm) recorded from V_1SP_1 which was statistically similar with V_1SP_2, V_1SP_3, V_2SP_5, V_1SP_4 and V_3SP_5. At 50 DAS the highest plant height (58.67 cm) was recorded from V_1SP_2 which was statistically at par with V_1SP_3, V_1SP_5, V_1SP_4 and V_1SP_1 and the lowest plant height (38.00 cm) was recorded from V_3SP_4 which shown statistical similarity with V_2SP_4, V_2SP_5, V_3SP_5, V_3SP_3, V_3SP_1 and V_2SP_1. At harvest, the longest plant height (70.37 cm) was recorded from V_1SP_5 which was statistically similar with V_1SP_4, V_1SP_2 and V_1SP_3. On the other hand the lowest plant height (53.67 cm) was gained from V_3SP_4 which shown similarity with V_2SP_1, V_3SP_5, V_3SP_2 and V_3SP_3.

Table 1. Combined effect of variety and spacing on plant height of blackgram at different days after sowing

Treatment combination	Plant height at different days after sowing (DAS)			
	20	35	50	At harvest
V_1SP_1	22.00 ab	28.07 g	54.33 a	66.00 bc
V_1SP_2	21.83 ab	29.00 g	58.67 a	69.77 ab
V_1SP_3	20.53 b-d	29.00 g	56.67 a	69.50 ab
V_1SP_4	21.33 a-c	30.67 e-g	55.33 a	70.00 ab
V_1SP_5	20.00 b-d	34.33 b-d	56.00 a	70.37 a
V_2SP_1	19.27 cd	36.33 bc	42.67 b-d	55.67 fg
V_2SP_2	20.33 b-d	42.33 a	45.67 bc	60.00 de
V_2SP_3	21.77 ab	34.67 b-d	46.00 b	58.67 ef
V_2SP_4	22.23 ab	33.50 c-e	38.33 d	63.50 cd
V_2SP_5	23.00 a	30.17 fg	39.00 d	63.33 cd
V_3SP_1	21.20 a-d	34.33 b-d	42.67 b-d	58.67 ef
V_3SP_2	22.17 ab	37.33 b	46.33 b	57.00 e-g
V_3SP_3	19.03 d	34.67 b-d	41.00 cd	57.50 e-g
V_3SP_4	19.50 cd	32.67 d-f	38.00 d	53.67 g
V_3SP_5	20.60 b-d	30.83 e-g	40.33 d	56.00 e-g
LSD $_{(0.05)}$	**2.25**	**3.23**	**4.90**	**4.09**
CV (%)	**6.35**	**5.77**	**6.23**	**3.91**

V_1= Munshigonj local, V_2= BARI Mash-2 and V_3= BARI Mash-3; Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

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

4.2.1 Effect of variety

Blackgram varieties exerted significant variation on leaves plant^{-1} at different days after sowing (Fig. 3). V_1 gave the maximum leaves plant^{-1} (4.39, 15.83, 55.35 and 66.20 at 20, 35, 50 DAS and harvest, respectively) which was statistically similar with V_2 at 35 DAS and V_3 gave the minimum leaves plant^{-1} (4.00, 13.04, 23.53 and 38.00 at 20, 35, 50 DAS and harvest, respectively) which were statistically similar with V_2 at 20 and 50 DAS.

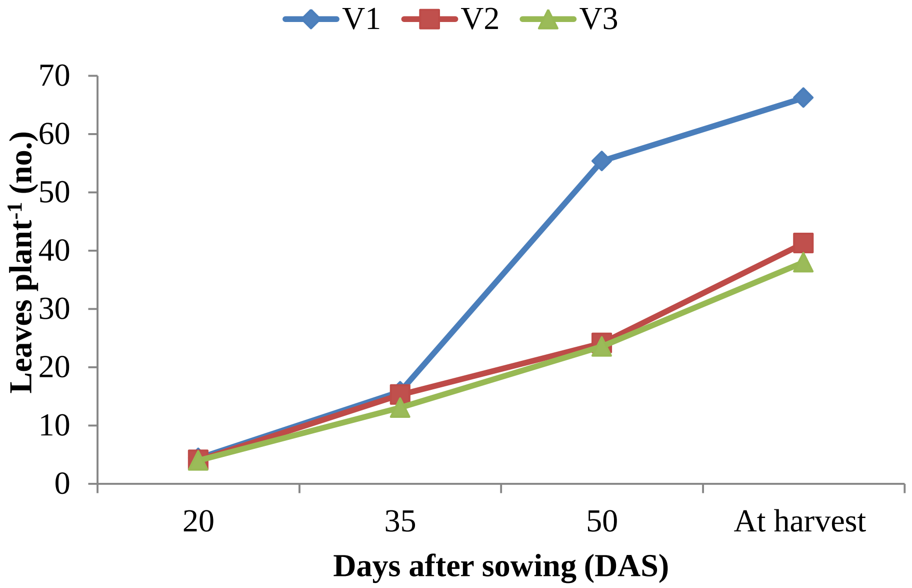


Figure 3. Effect of variety on leaves plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ = 0.24, 0.80, 3.94 and 3.05 at 20, 35, 50 DAS and harvest, respectively)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.2.2 Effect of plant spacing

There was a marked difference observed in leaves plant^{-1} of blackgramdue to different plant spacing throughout the growing season (Fig. 4). SP_5 gave the maximum leaves plant^{-1} (4.37, 16.63, 38.67 and 59.22 at 20, 35, 50 DAS and harvest, respectively) which was statistically at par with SP_4 at 35 and 50 DAS. On the other hand SP_2 gave the minimum leaves plant^{-1} (4.01 and 30.67) at 20 and 50 DAS, respectively which was statistically similar with all plant spacing except SP_5 at 20 DAS and SP_1 at 50 DAS, SP_1 gave the minimum leaves plant^{-1} (12.78 and 40.33) at 35 DAS and harvest, respectively which was statistically similar with SP_2 at 35 DAS and harvest. Similar finding was also reported by Tanya *et al.* (2015) andAchakzai and Kayani (2007) who reported that maximum number of leaves plant^{-1} (24.33) on wider plant geometry(45cmin mashbean.

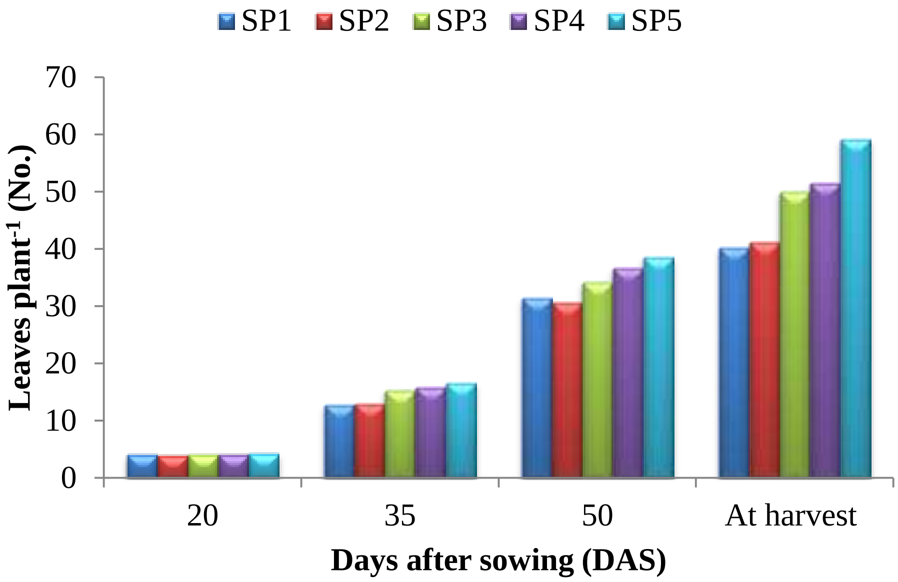


Figure 4. Effect of spacing on leaves plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ = 0.23, 1.12, 2.57 and 2.13 at 20, 35, 50 DAS and harvest, respectively)

Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.2.3 Combined effect of variety and plant spacing

There was a gradual increase of leaves plant^{-1} from sowing to 30 DAS but it increased rapidly at 35 to 50 DAS then again a gradual increase up to harvest. Combined effect of variety and plant spacing exerted marked significant difference on leaves plant^{-1} of blackgramat different days after sowing (Table 2). Maximum leaves plant^{-1} (4.57) was obtained from treatment combination V_2SP_5 which was statistically similar with V_1SP_1, V_1SP_5, V_1SP_3, V_1SP_2 and V_1SP_4 at 20 DAS and minimum leaves plant^{-1} (3.83) was obtained from V_2SP_2, V_2SP_3 and V_3SP_1 which showed similarity with V_3SP_2, V_2SP_1, V_2SP_4, V_3SP_4, V_3SP_5 and V_3SP_3. V_1SP_5 scored the maximum leaves plant^{-1} (18.17, 57.67 and 73.67 at 35, 50 DAS and harvest, respectively) which was statistically similar with V_1SP_4, V_2SP_5 and V_1SP_3 at 35 DAS, V_1SP_4, V_1SP_3, V_1SP_2 and V_1SP_1 at 50 DAS and V_1SP_4 at harvest. V_3SP_2 scored the minimum leaves plant^{-1} (11.33) at 35 DAS which showed similarity with V_3SP_1 and V_1SP_1; both V_2P_2 and

V_3SP_1 gave the minimum leaves plant^{-1} (19.00) at 50 DAS which showed similarity with V_3SP_2, V_2SP_1 and V_2SP_3; V_3SP_1 gave the minimum leaves plant^{-1} (27.67) at harvest which showed similarity with V_2SP_1 and V_3SP_2.

Table 2. Combined effect of variety and spacing on leaves plant^{-1} of blackgram at different days after sowing

Treatment combination	Leaves plant^{-1} at different days after sowing (DAS)			
	20	35	50	At harvest
V_1SP_1	4.47 ab	12.33 g-i	53.33 a	64.00 b
V_1SP_2	4.30 a-d	14.33 d-f	53.67 a	61.00 b
V_1SP_3	4.40 a-c	16.67 a-c	55.00 a	61.00 b
V_1SP_4	4.30 a-d	17.67 ab	57.10 a	71.33 a
V_1SP_5	4.47 ab	18.17 a	57.67 a	73.67 a
V_2SP_1	4.00 c-e	14.00 e-g	22.00 de	29.33 fg
V_2SP_2	3.83 e	13.33 f-h	19.00 e	32.00 f
V_2SP_3	3.83 e	15.67 c-e	23.33 c-e	50.00 d
V_2SP_4	4.03 c-e	16.00 b-d	25.67 cd	40.67 e
V_2SP_5	4.57 a	17.40 a-c	30.67 b	54.33 c
V_3SP_1	3.83 e	12.00 hi	19.00 e	27.67 g
V_3SP_2	3.90 de	11.33 i	19.33 e	30.67 fg
V_3SP_3	4.10 b-e	13.67 f-h	24.33 cd	39.33 e
V_3SP_4	4.03 c-e	13.87 e-h	27.33 bc	42.67 e
V_3SP_5	4.07 b-e	14.33 d-f	27.67 bc	49.67 d
LSD $_{(0.05)}$	**0.40**	**1.95**	**4.45**	**3.69**
CV (%)	**5.75**	**7.84**	**7.70**	**4.51**

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3;; Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm andS p_5 = 50cm ×50cm

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

4.3.1 Effect of variety

Significant variation of branches plant^{-1} was found due to varietal variation of blackgram (Fig. 5). Maximum branches plant^{-1} (3.25, 5.81 and 8.93 at 35, 50 DAS and harvest, respectively) was recorded for V_2 which was statistically similar with V_3 at 35 DAS and harvest and the minimum branches plant^{-1} at V_1 (2.37, 3.99 and 6.27 at 35, 50 DAS and harvest, respectively).

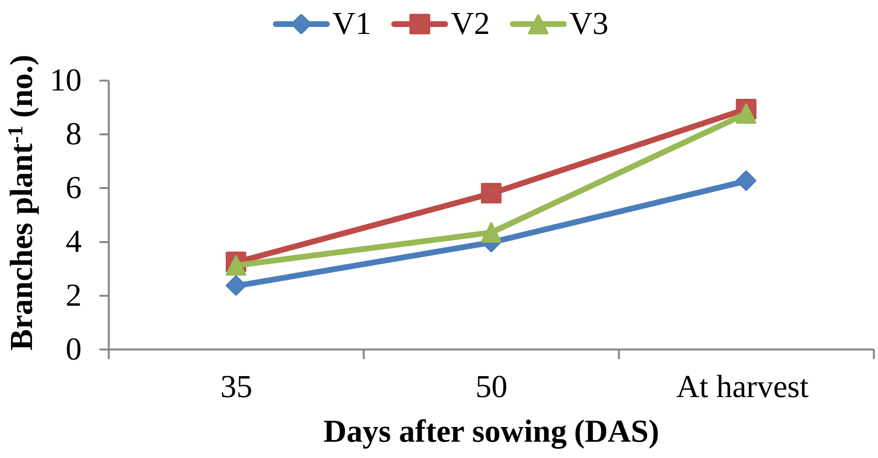


Figure 5. Effect of variety on branches plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ = 0.24, 0.24 and 0.54 at 35, 50 DAS and harvest, respectively)

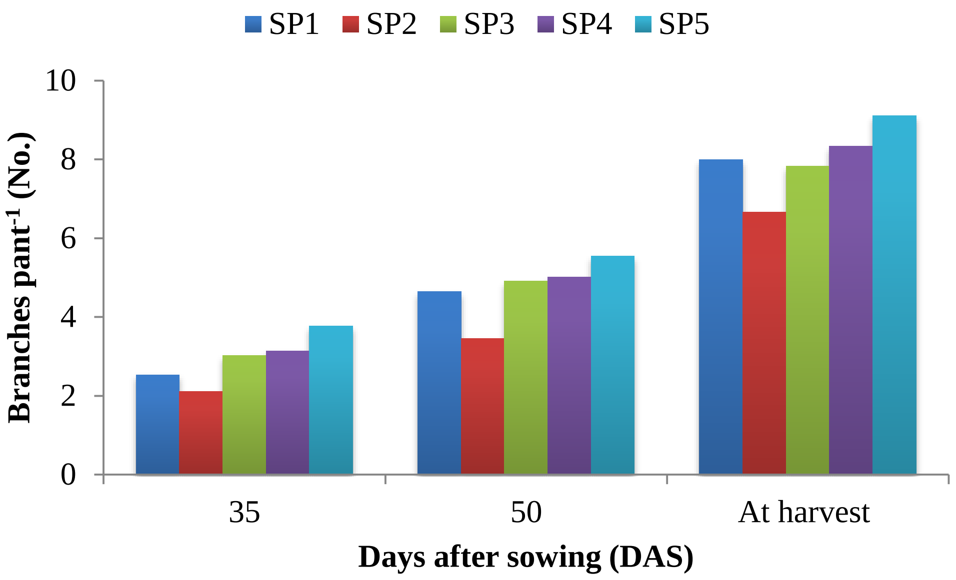
V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.3.2 Effect of plant spacing

Significant variation was observed in the branches plant^{-1} of blackgram in case of different plant spacing (Fig. 6). The highest branches plant^{-1} (3.77, 5.54 and 9.11 at 35, 50 and 65, respectively) was recorded from SP_5. The lowest branches plant^{-1} (2.11, 3.46 and 6.67 at 35, 50 and 65, respectively) was recorded in SP_2 treatment. Kahimba *et al.* (2014) reported thatplanting in squaremethod with wider spacing resulted in profuse tillering under SRI cultivation, which facilitated plants for better utilization of light, soil nutrients and water. The advantage of SRI method in enhancing numbers of tillers has also been reported earlier by Sato and Uphoff (2007) and Katambara *et al.* (2013). Tanya *et al.* (2015) and Achakzai and Kayani (2007) also observe maximum number of braches plant^{-1} (3.12) on wider plant geometry (45cm).

Figure 6. Effect of spacing on branches plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ = 0.21, 0.34 and 0.64 at 35, 50 DAS and harvest, respectively)

Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm



×50cm

4.3.3 Combined effect of variety and plant spacing

The combined effect of variety and plant spacingon the branches plant^{-1} of blackgram was significant (Table 3). The highest branches plant^{-1} (4.07, 6.40 and 10.67 at 35, 50 DAS and harvest, respectively) was recorded with the treatment combination of V_2SP_5 which was statistically similar with V_3SP_5 at 35 DAS, V_2SP_4 and V_2SP_1 at 50 DAS and V_2SP_3 at harvest. On the other hand, the lowest branches plant^{-1} (1.70 and 2.93 at 35 and 50 DAS, respectively) was found in V_1SP_2 which was statistically similar with V_3SP_2 at 50 DAS; at harvest the lowest branches plant^{-1} (5.16) recorded from V_1SP_3 which was statistically similar with V_1SP_2.

Table 3. Combined effect of variety and spacing on branches plant^{-1} of blackgram at different days after sowing

Treatment combination	Branches plant^{-1} at different days after sowing (DAS)		
	35	50	At harvest
V_1SP_1	2.20 fg	3.87 f	6.50 g
V_1SP_2	1.70 h	2.93 h	5.33 h
V_1SP_3	2.13 g	4.07 ef	5.16 h
V_1SP_4	2.47 e-g	4.17 ef	7.00 fg
V_1SP_5	3.33 cd	4.90 cd	7.33 e-g
V_2SP_1	2.70 e	6.33 a	8.33 c-e
V_2SP_2	2.13 g	4.27 ef	7.00 fg
V_2SP_3	3.67 bc	5.67 b	9.67 ab
V_2SP_4	3.67 bc	6.37 a	9.00 bc
V_2SP_5	4.07 a	6.40 a	10.7 a
V_3SP_1	2.70 e	3.73 fg	9.17 bc
V_3SP_2	2.50 ef	3.17 gh	7.67 d-f
V_3SP_3	3.27 d	5.00 cd	8.67 b-d
V_3SP_4	3.27 d	4.50 de	9.00 bc
V_3SP_5	3.90 ab	5.33 bc	9.33 bc
LSD $_{(0.05)}$	**0.37**	**0.58**	**1.11**
CV (%)	**7.45**	**7.33**	**8.27**

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3; Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.4 Above ground dry weight plant^{-1} (g)

The trend of above ground dry matter was very slow at early stage then it was increased rapidly from 50 to 60 DAS

4.4.1 Effect of variety

The above ground dry weight plant^{-1} was significantly influenced by different blackgram variety (Fig. 7). The maximum above ground dry weight plant^{-1} (0.71, 5.90, 13.93 and 46.93 g at 20, 35, 50 DAS and harvest, respectively) was obtained from V_1. The minimum above ground dry weight plant^{-1}(0.35, 4.41, 10.08 and 36.73 g at 20, 35, 50 DAS and harvest, respectively) was obtained from V_3 treatment. This result might be due to genetic variation of blackgram varieties. These results are in line with the findings of Sharma *et al.* (2012),Dasgupta and Das (1991) and Reddy *et al.* (1990).

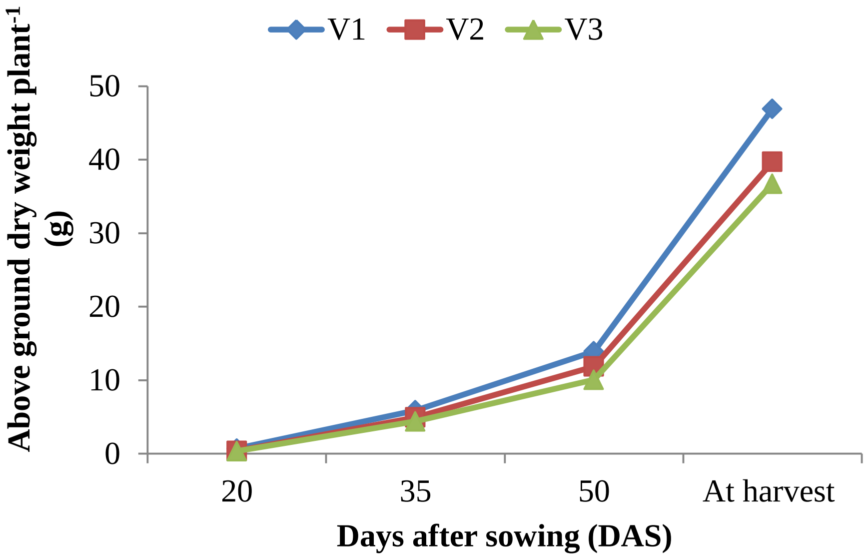


Figure 7. Effect of variety on above ground dry weight plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ =0.03, 0.48, 1.33 and 2.11 at 20, 35, 50 DAS and harvest, respectively)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.4.2 Effect of plant spacing

Figure 8 indicated that the maximum above ground dry weight plant^{-1} (0.51 g) was obtained from treatment Sp_2 at 20 DAS which was statistically similar with Sp_5; again the maximum above ground dry weight plant^{-1} (5.61, 14.25 and 50.33 g at 35, 50 DAS and harvest, respectively) was recorded from Sp_5. The minimum above ground dry weight plant^{-1}(0.46 g at 20 DAS was obtained from Sp_1; 4.72 g at 35 DAS was obtained from SP_3; 10.11 and 34.08 g at 50 DAS and harvest, respectively) was obtained from SP_2 treatment which were statistically similar with SP_3 and SP_4 at 20 DAS, SP_2 at 35 DAS and SP_1 at harvest. Dry matter is the constant dry weight of a plant. Wider plant spacing might help better use of intercepting sunlight, better utilization of photosynthetic active radiation, optimum nutrients up taking and utilization, less inter and intra plant competition, ultimately opportunity for growing vigorous plant than the narrower spacing plant which results higher dry matter accumulation for wider plant spacing.

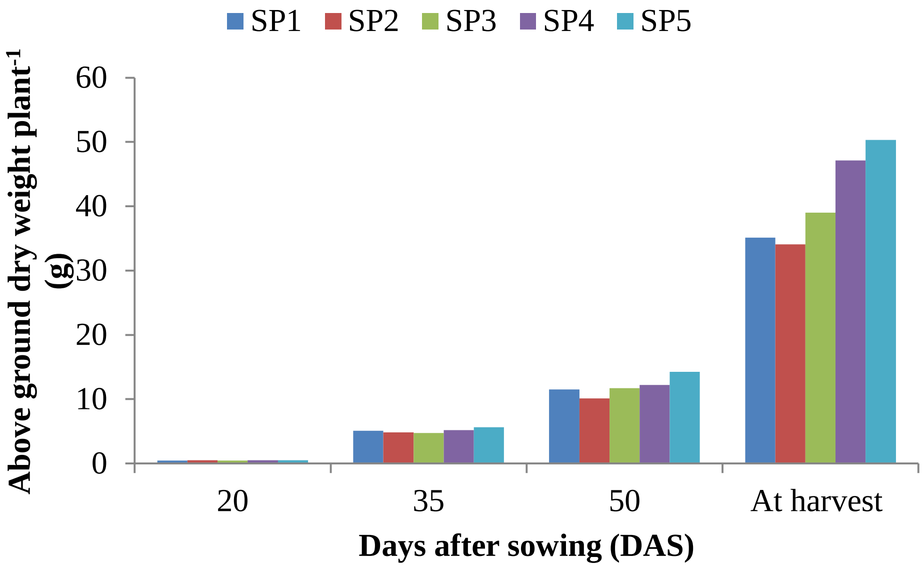


Figure 8. Effect of spacing on above ground dry weight plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ = 0.03, 0.33, 0.80 and 2.81 at 20, 35, 50 DAS and harvest, respectively)

Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.4.3 Combined effect of variety and plant spacing

Above ground dry weight plant^{-1} was found significant in respect of combined effect of variety and plant spacing throughout the growing season of blackgram (Table 4). The maximum above ground dry weight plant^{-1}(0.70 g at 20 DAS) was obtained from V_1SP_2 and 6.50, 15.67 and 56.67 g at 35, 50 DAS and harvest, respectively from V_1SP_5 which was statistically at par with V_1SP_1 at 35 DAS; V_1SP_4 and V_2SP_5 at 50 DAS and V_1SP_4 at harvest. The minimum above ground dry weight plant^{-1} (0.29 and 3.67 g at 20 and 35 DAS, respectively was obtained from V_3SP_3; 8.67 g was obtained from V_3SP_2 at 50 DAS; 29.33 g was obtained from V_3SP_1 at harvest) which showed similarity with V_3SP_5 at 20 DAS; V_3SP_1, V_2SP_2, V_3SP_3 and V_3SP_4 at 50 DAS and V_2SP_2, V_3SP_2 and V_3SP_3 at harvest.

Table 4. Combined effect of variety and spacing on above ground dry weight plant^{-1} of blackgram at different days after sowing

Treatment combination	above ground dry weight plant^{-1}at different days after sowing (DAS)			
	20	35	50	At harvest
V_1SP_1	0.67 b	6.00 ab	14.00 b	39.67 ef
V_1SP_2	0.78 a	5.83 bc	11.67 d	41.00 d-f
V_1SP_3	0.71 b	5.33 c-e	13.67 bc	44.67 cd
V_1SP_4	0.70 b	5.83 bc	14.67 ab	52.67 ab
V_1SP_5	0.69 b	6.50 a	15.67 a	56.67 a
V_2SP_1	0.38 d-f	4.77 f-h	11.17 de	36.33 f
V_2SP_2	0.35 ef	4.33 h	10.00 ef	30.57 g
V_2SP_3	0.42 d	5.17 d-f	11.50 d	41.33 de
V_2SP_4	0.39 de	5.00 d-g	12.00 d	44.00 c-e
V_2SP_5	0.48 c	5.50 b-d	14.67 ab	46.33 c
V_3SP_1	0.36 ef	4.53 gh	9.33 f	29.33 g
V_3SP_2	0.42 d	4.33 h	8.67 f	30.67 g
V_3SP_3	0.29 g	3.67 i	10.00 ef	31.00 g
V_3SP_4	0.35 ef	4.67 f-h	10.00 ef	44.67 cd
V_3SP_5	0.33 fg	4.83 e-h	12.42 cd	48.00 bc
LSD $_{(0.05)}$	**0.05**	**0.57**	**1.38**	**4.87**
CV (%)	**7.76**	**6.60**	**6.86**	**7.02**

V_1= Munshigonj local, V_2= BARI Mash-2 and V_3= BARI Mash-3**;** Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.5 Crop growth rate (g m^{-2} d^{-1})

4.5.1 Effect of variety

Variety had significant effect on crop growth rate (CGR) of blackgram throughout the growing season (Fig. 9). Maximum crop growth rate (3.46, 5.36 and 22.00 g m^{-2} d^{-1} at 35-20, 50-35 and harvest-50 DAS, respectively) was observed from V_1 and the minimum crop growth rate (2.71, 3.78 and 17.77 g m^{-2} d^{-1} at 35-20, 50-35 and harvest-50 DAS, respectively) was observed from V_3 which was statistically similar with V_2 only at harvest-50 DAS. Similar result also reported by Sharma *et al.* (2012)

and Prasad andSrivastava(1999)who found thatsignificant genotypic differences were observed with respect to CGR.

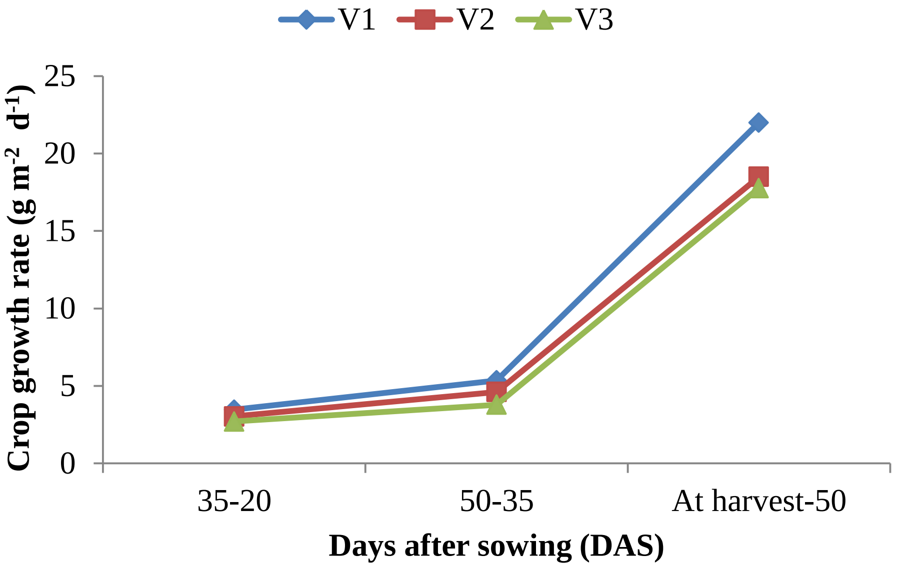


Figure 9. Effect of variety on crop growth rate of blackgram at different days after sowing (LSD $_{(0.05)}$ = 0.29, 0.40 and 0.85 at 35-20, 50-35 and harvest-50 DAS, respectively)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.5.2 Effect of plant spacing

Significant variation of CGR was found due to plant spacing variation at different days after sowing of blackgram (Fig. 10). Maximum crop growth rate (3.41, 5.76 and 24.06 g m^{-2} d^{-1} at 35-20, 50-35 and harvest-50 DAS, respectively) was observed from SP_5 which shown similarity with SP_4 at harvest-50 DAS and the minimum crop growth rate (2.84 g m^{-2} d^{-1} at 35-20 DAS 3.52 g m^{-2} d^{-1} at 50-35 DAS and 15.63 g m^{-2} d^{-1} at harvest-50 DAS) was found from SP_3, SP_2 and SP_1, respectively which was statistically similar with SP_2 at 35-20 DAS and harvest-50 DAS, respectively. Wider plant spacing gave better and vigorous plant growth which trigger more dry matter accumulation of black gram ultimately more CGR than narrower plant spacing.

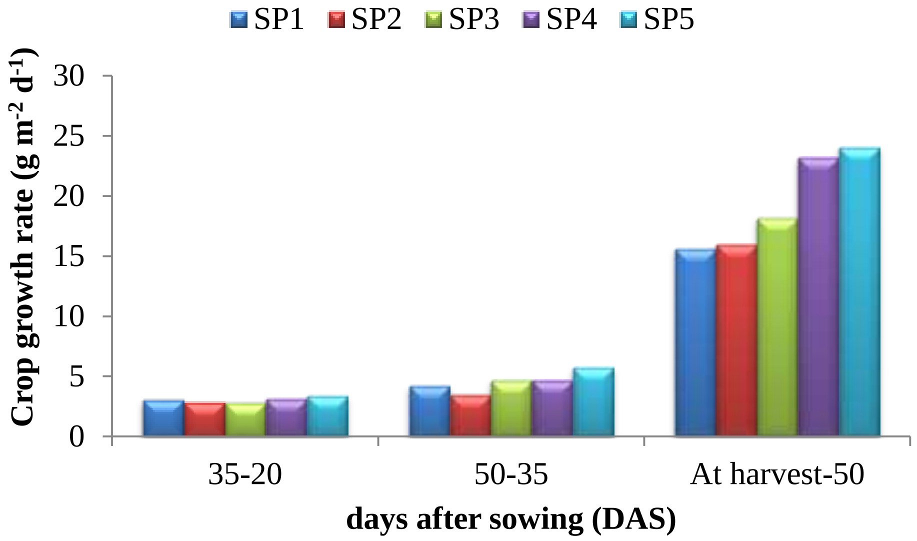


Figure 10. Effect of spacing on crop growth rate of blackgram at different days after sowing (LSD $_{(0.05)}$ = 0.22, 0.31 and 1.49 at 35-20, 50-35 and harvest-50 DAS, respectively)

SP_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.5.3 Combined effect of variety and plant spacing

Significant variation of crop growth rate was observed due to combine effect of variety and plant spacing throughout the growing season blackgram (Table 5). Maximum crop growth rate (3.87, 6.11 and 27.34 g m^{-2} d^{-1} at 35-20, 50-35 and harvest-50 DAS, respectively) was observed from V_1Sp_5 which shown similarity with V_1S_1 at 35-20 DAS; V_2SP_5 and V_1SP_4 at 50-35 DAS and V_1SP_4 at harvest-50 DAS and the minimum crop growth rate (2.25 g m^{-2} d^{-1} at 35-20 DAS, 2.89 g m^{-2} d^{-1} at 50-35 DAS and 13.33 g m^{-2} d^{-1} at harvest-50 DAS) was found from V_3SP_3, V_3SP_2 and V_3SP_1, respectively which was statistically similar with V_3SP_2 at 35-20 DAS, V_3SP_1 at 50-35 DAS and V_2SP_2, V_3SP_3 and V_3SP_2 at harvest-50 DAS, respectively.

Table 5. Combined effect of variety and spacing on crop growth rate of blackgram at different days after sowing

Treatment combination	Crop growth rate at different days after sowing (DAS)		
	35-20	**50-35**	**At harvest-50**
V_1SP_1	3.55 ab	5.33 c	17.11 fg
V_1SP_2	3.37 b-d	3.89 fg	19.56 ef
V_1SP_3	3.08 c-f	5.56 bc	20.67 de
V_1SP_4	3.42 bc	5.89 ab	25.33 ab
V_1SP_5	3.87 a	6.11 a	27.34 a
V_2SP_1	2.93 e-h	4.27 ef	16.44 gh
V_2SP_2	2.66 gh	3.78 fg	13.71 i
V_2SP_3	3.17 c-e	4.22 ef	19.89 e
V_2SP_4	3.08 c-f	4.67 de	21.33 c-e
V_2SP_5	3.35 b-d	6.11 a	21.11 de
V_3SP_1	2.78 f-h	3.20 hi	13.33 i
V_3SP_2	2.61 hi	2.89 i	14.67 g-i
V_3SP_3	2.25 i	4.22 ef	14.00 hi
V_3SP_4	2.88 e-h	3.56 gh	23.11 b-d
V_3SP_5	3.00 d-g	5.06 cd	23.72 bc
LSD $_{(0.05)}$	**0.37**	**0.54**	**2.58**
CV (%)	**7.19**	**7.03**	**7.87**

V_1= Munshigonj local, V_2= BARI Mash-2 and V_3= BARI Mash-3;Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.6 Relative growth rate (g g^{-1} d^{-1})

4.6.1 Effect of variety

There was no significant difference was found among the variety in respect of relative growth rate throughout the growing period blackgram (Fig. 11). Maximum relative growth rate (0.170, 0.085 and 0.085 g g^{-1} d^{-1} at 35-20, 50-35 and harvest-50 DAS, respectively) was found from V_3 where as the minimum crop growth rate (0.141, 0.080 and 0.080 g g^{-1} d^{-1} at 35-20, 50-35 and harvest-50 DAS, respectively) was observed from $V_{1,}$ V_2 and V_2, respectively.

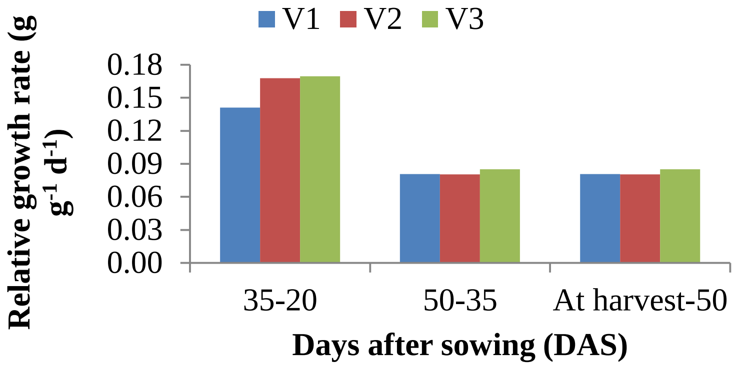


Figure 11. Effect of variety on relative growth rate of blackgram at different days after sowing (LSD $_{(0.05)}$ = NS, NS and NS at 35-20, 50-35 and harvest-50 DAS, respectively)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.6.2 Effect of plant spacing

Figure 12 shown plant spacing had no significant effect on relative growth rate at different days after sowing of blackgram. Maximum relative growth rate (0.164, 0.062 and 0.091 g g^{-1} d^{-1} at 35-20, 50-35 and harvest-50 DAS, respectively) was observed from SP_5, SP_5 and SP_4, respectively. On the other hand the minimum relative growth rate (0.153, 0.049 and 0.075 g g^{-1} d^{-1} at 35-20 DAS, 50-35 DAS and harvest-50 DAS, respectively) was recorded from SP_2, SP_2 and Sp_1, respectively.

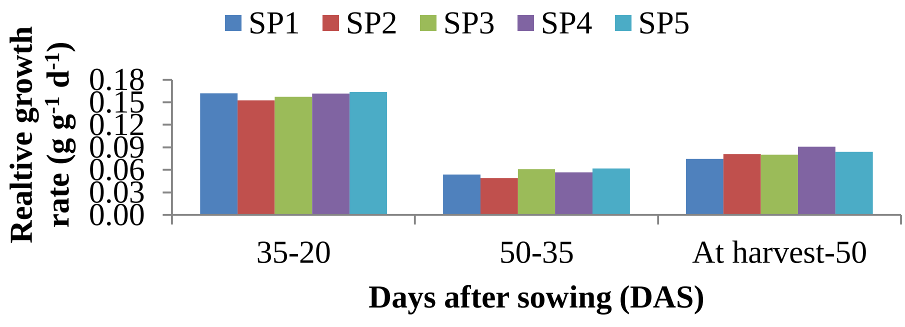


Figure 12. Effect of spacing on relative growth rate of blackgram at different days after sowing (LSD $_{(0.05)}$ = NS, NS and NS at 35-20, 50-35 and harvest-50 DAS, respectively)

Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.6.3 Combined effect of variety and plant spacing

Interaction between variety and plant spacing exerted no significant effect on relative growth rate during growing period of blackgram (Table 6). Maximum relative growth rate (0.179, 0.067 and 0.100 g g^{-1} d^{-1} at 35-20, 50-35 and harvest-50 DAS, respectively) was observed from V_3SP_5, V_3SP_3 and V_3SP_4, respectively and the minimum relative growth rate (0.134, 0.046 and 0.070 g g^{-1} d^{-1} at 35-20 50-35 and harvest-50 DAS, respectively) was found from V_3SP_3 at 35-20 DAS, V_1SP_2 and V_3SP_2 at 50-35 DAS and V_1SP_1 at harvest-50 DAS.

Table 6. Combined effect of variety and spacing on relative growth rate of blackgram at different days after sowing

Treatment combination	Relative growth rate at different days after sowing (DAS)		
	35-20	**50-35**	**At harvest-50**
V_1SP_1	0.146	0.056	0.070
V_1SP_2	0.134	0.046	0.084
V_1SP_3	0.135	0.062	0.079
V_1SP_4	0.141	0.061	0.086
V_1SP_5	0.149	0.058	0.086
V_2SP_1	0.169	0.057	0.078
V_2SP_2	0.1680	0.056	0.075
V_2SP_3	0.168	0.053	0.085
V_2SP_4	0.171	0.059	0.087
V_2SP_5	0.163	0.065	0.077
V_3SP_1	0.170	0.048	0.076
V_3SP_2	0.156	0.046	0.084
V_3SP_3	0.170	0.067	0.076
V_3SP_4	0.173	0.051	0.100
V_3SP_5	0.179	0.063	0.090
$LSD_{(0.05)}$	**NS**	**NS**	**NS**
CV (%)	**4.81**	**8.27**	**6.36**

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3**;** SP_1 = 30cm ×10cm, SP_2=20cm × 20cm, SP_3=30cm ×30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm ×50cm

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

4.7.1 Effect of variety

Significant variation was observed in pods plant^{-1} of blackgram due to varietal variation (Fig. 13). The highest pods plant^{-1} (66.87) was recorded in V_2. The lowest pods plant^{-1} (50.29) was recorded from the V_1. This result was in coinciding with Khan and Asif (2012) and Reddy *et al.* (1990) who observed significant differences between genotypes for number of pods plant^{-1}.

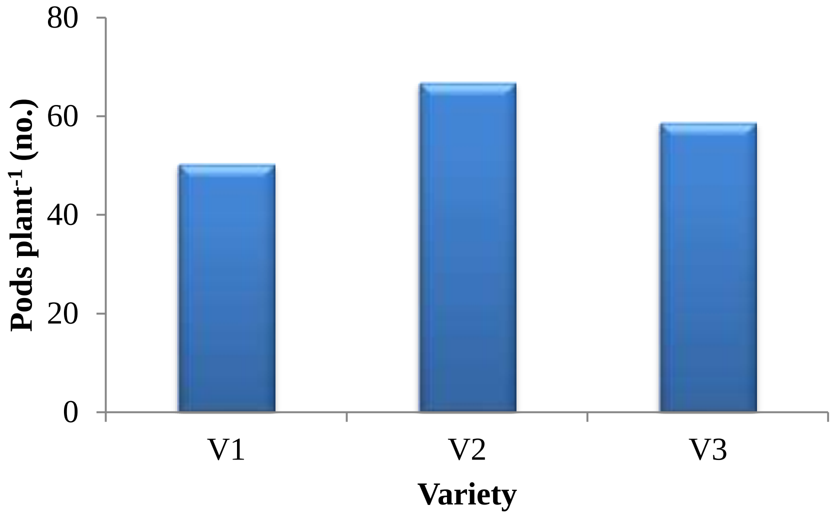


Figure 13. Effect of variety on pods plant^{-1} of blackgram (LSD $_{(0.05)}$ =4.56)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.7.2 Effect of plant spacing

Pods plant^{-1} was significantly affected by different plant spacing of blackgram shown on Figure 14. The maximum pods plant^{-1} (82.53) was recorded in SP_5. The lowest pods plant^{-1} (35.27) was recorded from the SP_1. Wider plant spacing gave higher number of pods plant^{-1} which might have been due to efficient interception of light and utilization of available resources. A significant effect of planting geometry on number of pods plant^{1} has been reported by Nadeem *et al.* (2004) and Ali *et al.* (2001).This was also in conformity with Achakzai and Panizai (2007) and Mehmud *et al.* (1997) but on cotraray by Ihsanullah *et al.* (2002) who reported that wider spacing had significance influence on pod number.

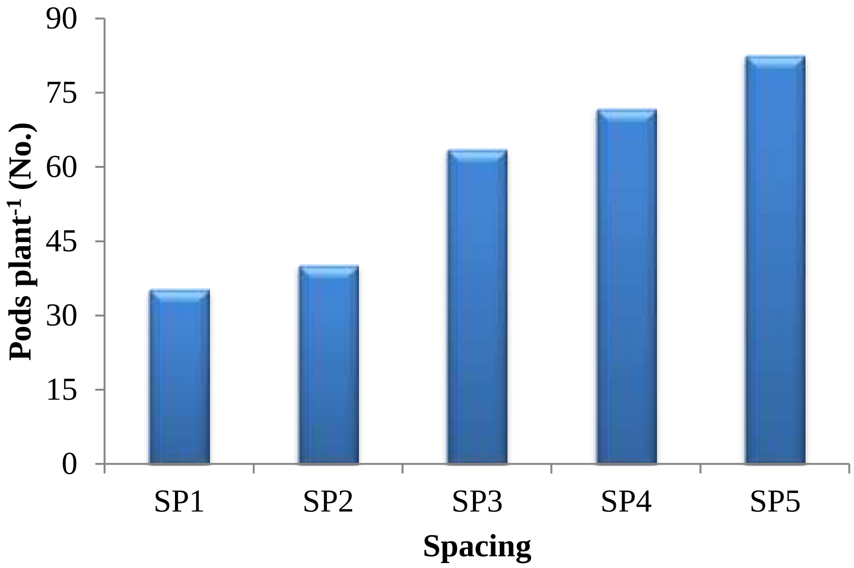


Figure 14. Effect of spacing on pods plant^{-1} of blackgram (LSD $_{(0.05)}$ =4.19)

SP_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.7.3 Combined effect of variety and plant spacing

Pods plant^{-1} of blackgram significantly varied among the combined effect of variety and plant spacing shown on table 7. The maximum pods plant^{-1} (92.90) was found from V_2SP_5 which was statistically significant with V_3SP_5 on the other hand the lowest pods plant^{-1} (30.77) was recorded from the V_1SP_1which was statistically significant with V_1SP_2 and V_3SP_1.

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

4.8.1 Effect of variety

Seeds pod^{-1} was not significantly affected by varietal variation of blackgram (Fig. 15). The highest seeds pod^{-1} (6.51) was recorded in $V_{2.}$ The lowest seeds pod^{-1} (6.24) was recorded from V_1. These results are in line with the results of Sharma *et al.* (2012); Reddy *et al*. (1990) and Dasgupta and Das (1991) who reported that seeds pod $^{-1}$ varies might have been due to genetic variation of blackgram varieties.

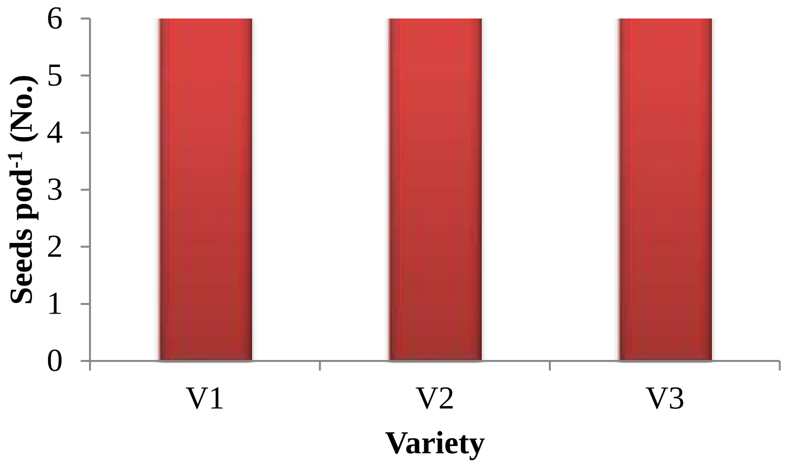


Figure 15. Effect of variety on seeds pod^{-1} of blackgram (LSD $_{(0.05)}$ =NS)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.8.2 Effect of plant spacing

Different plant spacing showed significant variations in respect of seeds pod^{-1} of blackgram (Fig. 16). Among the different plant spacing, Sp_5 showed the highest seeds pod^{-1} (6.57) which was statistically similar with Sp_4 and Sp_3. On the contrary, the lowest seeds pod^{-1} (6.17) was observed with Sp_2 which was statistically similar with Sp_1, Sp_3 and Sp_4.

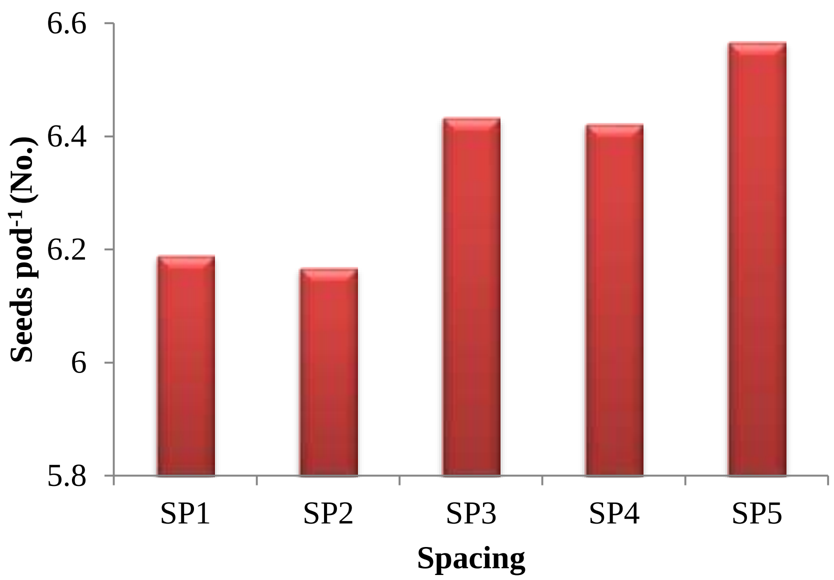


Figure 16. Effect of spacing on seeds pod^{-1} of blackgram (LSD $_{(0.05)}$ =0.27)

Sp_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.8.3 Combined effect of variety and plant spacing

The Combined effect of different variety and plant spacing on seeds pod^{-1} of blackgram had significant effect (Table 7). The highest seeds pod^{-1} (6.80) was recorded with the treatment combination of V_2Sp_5 which was statistically different with V_1SP_1, V_1SP_2, V_2SP_1, V_2SP_2, V_3SP_2 and V_3SP_1. On the other hand, the lowest seeds pod^{-1} (5.97) was found in V_1Sp_1 treatment which was statistically different with V_2SP_3, V_2SP_4, V_2SP_5 and V_3SP_5.

4.9 Pod length (cm)

4.9.1 Effect of variety

Pod length was not significantly affected by varietal variation of blackgram (Fig. 17). The highest pod length (4.32 cm) was recorded in $V_{2.}$ The lowest pod length (4.20 cm) was recorded from V_1.

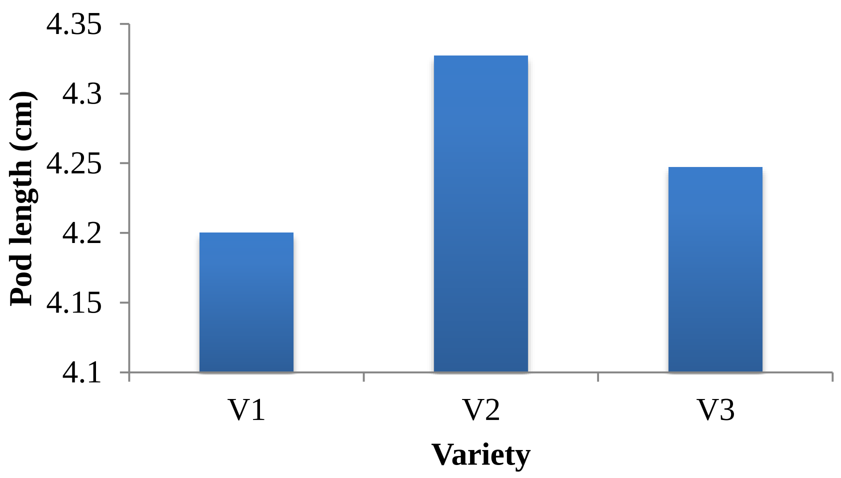


Figure 17. Effect of variety on pod length of blackgram (LSD $_{(0.05)}$ =NS)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.9.2 Effect of plant spacing

There was significant difference among the plant spacing in respect of pod length of blackgram (Fig. 18). Among the different plant spacing, SP_5 showed the highest pod length (4.36 cm) which was statistically similar with SP_4 and SP_3. On the contrary, the pod length (4.17 cm) was observed with S_2 which was statistically similar with SP_1,

SP_3 and SP_4. These findings are in conformity with the results of different researchers;Achakzai and Panizai (2007) and Kumar *etal.* (1997). But there is contradictory opinion with Ihsanullah *et al.* (2002) and Mehmud *et al.* (1997)who suggest that pod length decrease by increasing the spacing in legume crops.

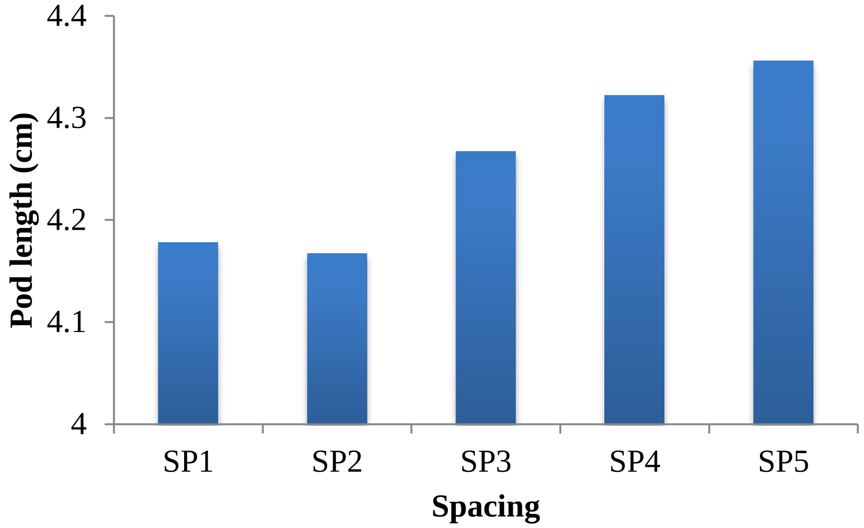


Figure 18. Effect of spacing on pod length of blackgram (LSD $_{(0.05)}$ =0.17)

SP_1 = 30cm ×10cm, SP_2=20cm × 20cm, SP_3=30cm ×30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm ×50cm

4.9.3 Combined effect of variety and plant spacing

The Combined effect of different variety and plant spacing had significantly affected pod length of blackgram (Table 7). The longest pod (4.50 cm) was recorded with the treatment combination of V_2SP_5 which was statistically different with V_1SP_1, V_1SP_2, V_2SP_1, V_2SP_2 and V_3SP_2. On the other hand, the shortest pod (4.13 cm) was found in V_1SP_1 treatment which was statistically different with V_2SP_5 only.

4.10 1000 seeds weight (g)

4.10.1 Effect of variety

The 1000 seeds weight of blackgram was varied significantly with the three varieties of blackgram (Fig. 19). The highest 1000 seeds weight (40.31 g) was recorded in V_2 and the lowest was recorded (30.31 g) in the V_1. Similar result also reported by Sharma *et al.* (2012) and Reddy *et al.* (1990) who reported significant differences among genotypes for 1000-grain weight.

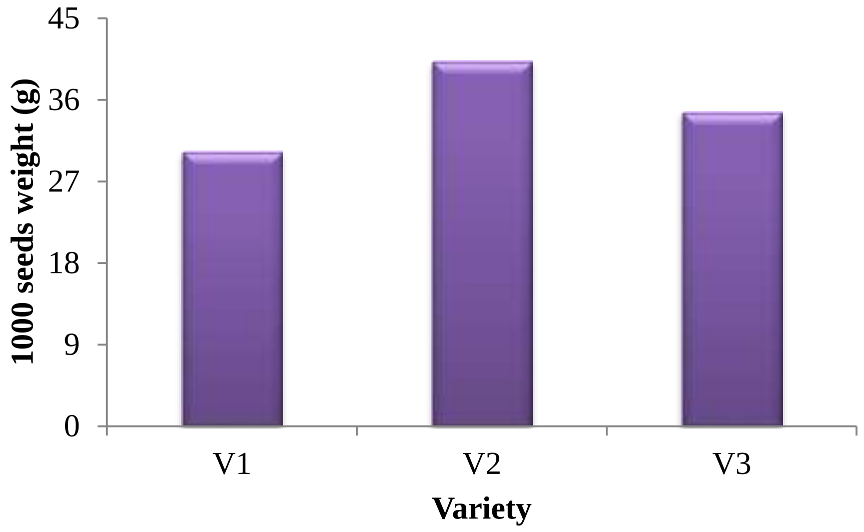


Figure 19. Effect of variety on 1000 seeds weight of blackgram (LSD $_{(0.05)}$ =1.49)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.10.2 Effect of plant spacing

Different plant spacing showed significant variations in respect of the 1000 seeds weight of blackgram (Fig. 20). Among the different plant spacing, SP_5 showed the highest 1000 seeds weight (36.38 g). On the contrary, the lowest 1000 seeds weight (34.33 g) was observed with SP_1 which was statistically identical with rest of the plant spacing except SP_5. Wider plant spacing might help the plant efficient use of photosynthetic active radiation (PAR) uptake more nutrient and water which help more dry matter accumulation in the source and active partitioning of dry mater into the sink, which might help increase the seed size ultimately increased the 1000 seed weight.

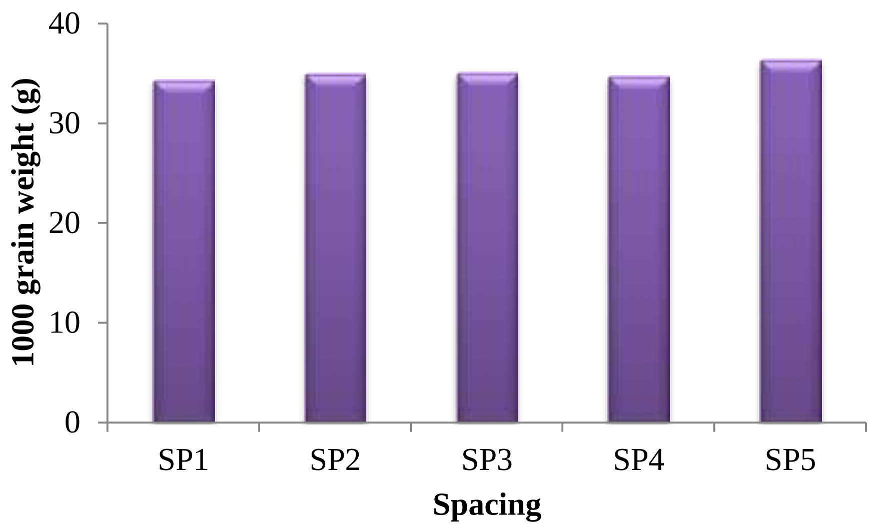


Figure 20. Effect of spacing on 1000 seedsweight of blackgram (LSD $_{(0.05)}$ =1.12)

SP_1 = 30cm ×10cm, SP_2=20cm × 20cm, SP_3=30cm ×30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm ×50cm

4.10.3 Combined effect of variety and plant spacing

The combined effect of different variety and plant spacing exerted significant effect on the 1000 seeds weight of blackgram (Table 7). The highest 1000 seeds weight (41.13 g) was recorded with the treatment combination of V_2SP_5 which was statistically similar with V_2SP_3, V_2SP_4 and V_2SP_1 and the lowest 1000 seeds weight (28.00 g) was found in V_1SP_1 treatment which was statistically identical with V_1SP_2.

4.11 Seed yield plant^{-1} (g)

4.11.1 Effect of variety

The seed yield plant^{-1} of blackgram was varied significantly due to varietal variation of blackgram (Fig. 21). The highest seed yield plant^{-1} (14.89 g) was recorded in V_2 and the lowest was recorded (10.13 g) in the V_1.

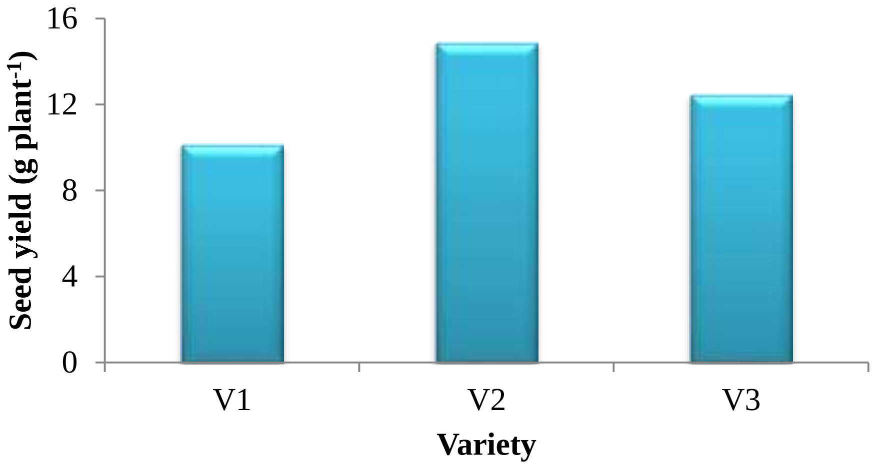


Figure 21. Effect of variety on seed yield plant^{-1} of blackgram (LSD $_{(0.05)}$ =0.97)

V_1= Munshigonj local,V_2= BARI Mash-2 V_3= BARI Mash-3

4.11.2 Effect of plant spacing

Different plant spacing showed significant variations in respect of seed yield plant^{-1} of blackgram (Fig. 22). Among the different plant spacing, SP_5 gave the highest seed yield plant^{-1} (17.31 g). On the contrary, the lowest seed yield plant^{-1} (8.68 g) was recorded from SP_1 which was statistically similar with SP_2.Kahimba *et al.,* (2014) reported that planting in squaremethod with wider spacing resulted in profuse tillering under SRI cultivation, which facilitated plants for better utilization of light, soil nutrients and water. The advantage of SRI method in enhancing numbers of tillers has also been reported earlier by Katambara *et al.* (2013)and Sato and Uphoff (2007).Optimum spacing would have effectively utilized the growth resources, particularly solar radiation as compared to narrow spacing, where plants might have suffered due to mutual shading in case of adjoining rows and more plants. It is corroborating with findings of Singh and Ananthi (2009) and Singh and Verma (1999) in lentil. Like lentil there were more branch plant^{-1}, pods plant^{-1}, seeds pod^{-1}, 1000 seeds weight were in blackgram following the square plant spacing which attributed to more seed yield plant^{-1} of blackgram. On the other hand narrower plant spacing indicates that not much of the photosynthate was partitioned to main economic parts (pod) to make significant contribution to seed yield. This is in agreement with the findings of Kuttimani and Velayudham (2016) and Agugo and Kanu (2010) in greengram, Rajput *et al.* (1984), Nagaraju (1995) and Ihsanullah *et al.* (2002) in blackgram.

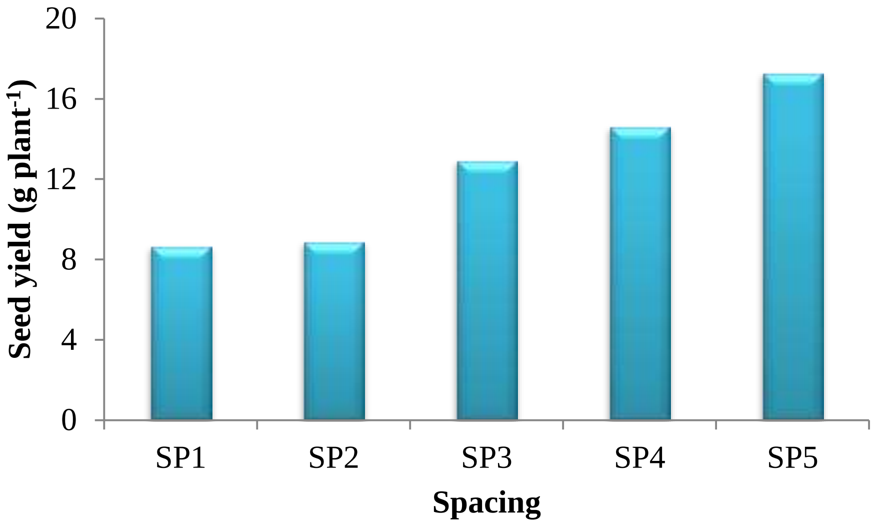


Figure 22. Effect of spacing on seed yield plant^{-1} of blackgram (LSD $_{(0.05)}$ =0.83)

SP_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.11.3 Combined effect of variety and plant spacing

Seed yield plant^{-1} of blackgram significantly affected by combined effect of different variety and plant spacing (Table 7). The highest seed yield plant^{-1} (20.10 g) was recorded with the treatment combination of V_2SP_5 and the lowest seed yield plant^{-1} (6.03 g) was found in V_1SP_1 treatment.

Table 7. Combined effect of variety and spacing on pods plant^{-1}, seeds pod^{-1}, pod length, 1000 seed weight and seed yield plant^{-1} of blackgram

Treatment combination	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	Pod length (cm)	1000 seed wt. (g)	Seed yield plant^{-1} (g)
V_1SP_1	30.77 k	5.967 d	4.133 b	28.00 f	6.03 j
V_1SP_2	34.70 jk	6.033 cd	4.167 b	29.80 ef	7.73 i
V_1SP_3	55.13 h	6.433 a-d	4.200 ab	30.63 de	10.37 g
V_1SP_4	63.47 fg	6.400 a-d	4.233 ab	30.67 de	12.20 ef
V_1SP_5	67.37 ef	6.367 a-d	4.267 ab	32.43 cd	14.33 d
V_2SP_1	38.83 ij	6.333 a-d	4.167 b	39.47 a	11.07 fg
V_2SP_2	44.10 i	6.400 a-d	4.167 b	40.80 a	10.18 gh
V_2SP_3	77.70 cd	6.533 ab	4.400 ab	40.40 a	15.83 c
V_2SP_4	80.83 bc	6.467 a-c	4.400 ab	39.73 a	17.27 b
V_2SP_5	92.90 a	6.800 a	4.500 a	41.13 a	20.10 a
V_3SP_1	36.20 jk	6.267 b-d	4.233 ab	35.53 b	8.93 hi
V_3SP_2	41.40 ij	6.067 b-d	4.167 b	34.40 b	8.80 hi
V_3SP_3	57.90 gh	6.333 a-d	4.200 ab	34.23 bc	12.67 e
V_3SP_4	70.93 de	6.400 a-d	4.333 ab	33.73 bc	14.43 cd
V_3SP_5	87.33 ab	6.533 ab	4.300 ab	35.57 b	17.50 b
LSD $_{(0.05)}$	**7.25**	**0.47**	**0.30**	**1.93**	**1.43**
CV (%)	**7.34**	**4.37**	**4.18**	**3.26**	**6.79**

V_1= Munshigonj local,V_2= BARI Mash-2 V_3= BARI Mash-3**;** SP_1 = 30cm ×10cm, SP_2=20cm × 20cm, SP_3=30cm ×30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm ×50cm

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

4.12.1 Effect of variety

The seed yield of blackgram was significantly differed due to varietal variation of blackgram (Fig. 23). The highest seed yield (1.38 t ha^{-1}) was obtained from V_2 and the lowest one (0.92 t ha^{-1}) was recorded from V_1. The increased seed yield was found 51.09 % higher in V_2 than V_1. Similar result was found by Jagannath *et al.* (2014),Yadahalli and Palled (2004) and Rao and Konda (1988) who reported that TAU-1 recorded significantly highest grain yield over rest of the varieties which could be attributed due to higher values of yield components namely pods plant^{-1}, grains pod^{-1}, 1000 seeds weight. Yield attributes particularly pods plant^{-1} and seeds pod^{-1} showed highly positive correlation (r=0.999) with yield. Sharma *et al.* (2012) also reported that higher yield in Mash 338 was due to more leaf area per plant, number of primary and secondary branches, nodules, leaves, number of pods plant^{-1}, seeds pod^{-1} and efficient partitioning of assimilates. These findings are in accordance with the results obtained by other researchers for most of the legumes (Arsad *et al*., 2004; Siddique *et al*., 2006; Malik *et al.*, 2006; Malik *et al*., 2007). Differences in production potential for different varieties of blackgram are also supported by Panotra *et al.* (2016),Sharma *et al.* (2000) and Sing and Sing (2000).

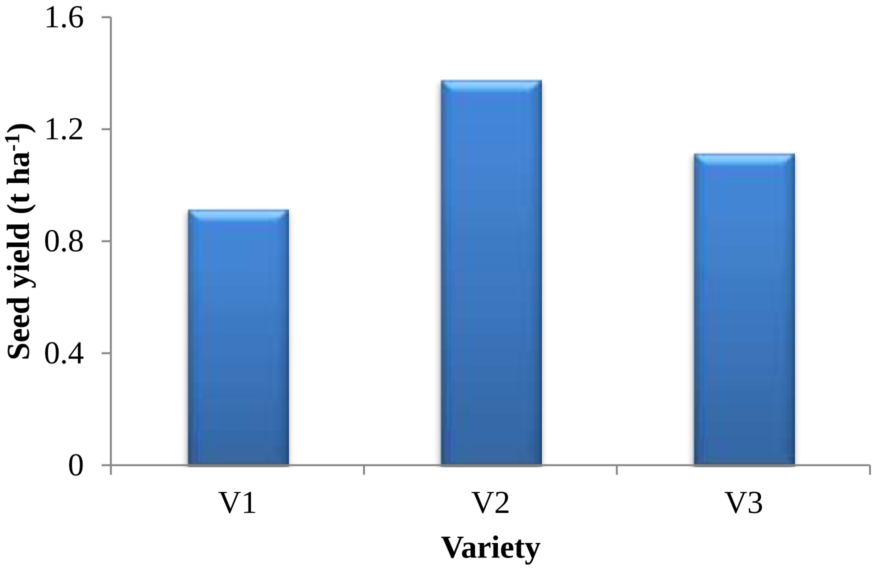


Figure 23. Effect of variety on seed yield of blackgram (LSD $_{(0.05)}$ =0.03)

V_1= Munshigonj local,V_2= BARI Mash-2 V_3= BARI Mash-3

4.12.2 Effect of plant spacing

Different plant spacing had significant variations in respect of seed yield of blackgram (Fig. 24). Sp_1 gave the highest seed yield (1.49 t ha^{-1}) whereas the lowest seed yield (0.80 t ha^{-1}) was recorded from SP_5. Wider spacing SP_5 (50×50cm) gave higher grain yield plant^{-1} but SP_1 (30cm × 10cm) gave higher grain yield ha^{-1} because plant population was higher. Plant spacing Sp_1 produced 86.25% higher seed than SP_5. Kahimba *et al*. (2014) reported that for rice plant a wider spacing of more than 35x35 cm optimal yields were reduced due to low plant population despite enhanced tillering per plant.These results are in agreement with those found by other researchers likeKuttimani and Velayudham (2016), Krishna *et al.* (2008) and Vijayakumar *et al.* (2001). But dissimilar result also reported by Singh *et al.* (1994) got seed yields of 1.13, 1.37 and 1.36 t ha^{-1} with 15, 22.5 and 30 cm row spacing. Results obtained by Davi *et al.* (1995) deciphered that grain yield was highest at 15 cm intra-row spacing. Whereas, Nagaraju *et al.* (1995) revealed that seed yield decreased with an increase in row spacing. Mehmud *et al.* (1997) indicated that increased row spacing manifested increase in the seed weight $plant^{-1}$, pod weight $plant^{-1}$, and1000 seed weight, but decreased plant height and seed yield unit $area^{-1}$.Borah (1994) and Mishra and Mishra(1995) concluded that there is a trend, as row spacing increases, grain yield also increases.

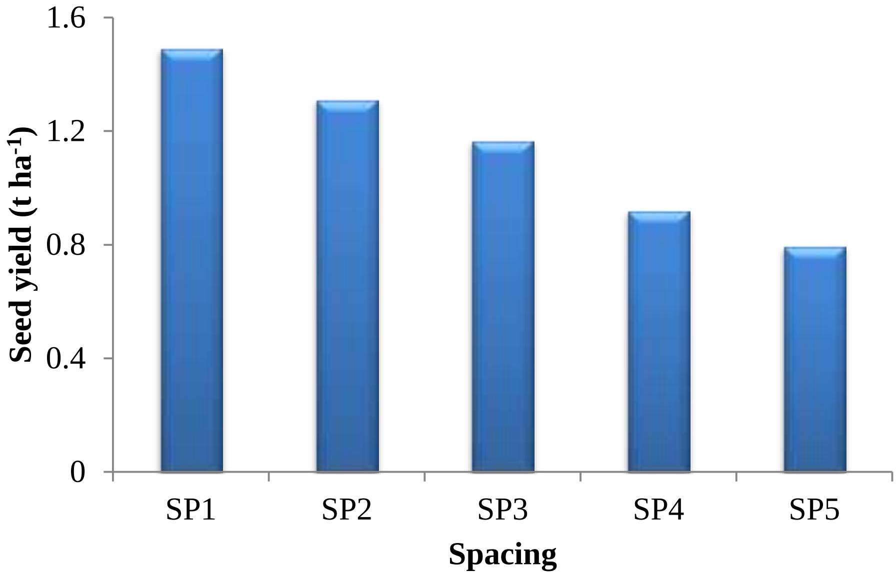


Figure 24. Effect of spacing on seed yield of blackgram (LSD $_{(0.05)}$ =0.08)

SP_1 = 30cm ×10cm, Sp_2=20cm × 20cm, Sp_3=30cm ×30cm, Sp_4 = 40cm × 40cm and Sp_5 = 50cm ×50cm

4.12.3 Combined effect of variety and plant spacing

Seed yield of blackgram varied significantly by combined effect of variety and plant spacing (Table 8). The highest seed yield (1.80 t ha^{-1}) was gained from the treatment combination of V_2SP_1 and the lowest seed yield (0.66 t ha^{-1}) was found in V_1SP_5 treatment which was statistically at par with V_1SP_4. Similar findings were also reported by Tomar and Tiwari (1991) in greengram, Lokanadhan (2015) and Bhairappanavar *et al.* (2005) in blackgram and Siddaraju *et al.* (2010) in cluster bean.

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

4.13.1 Effect of variety

Significant variation was observed on the stover yield of blackgram due to varietal variation (Fig. 25). The highest stover yield of blackgram (1.88 t ha^{-1}) was recorded in V_1. The lowest stover yield (1.41 t ha^{-1}) was recorded in the V_3.

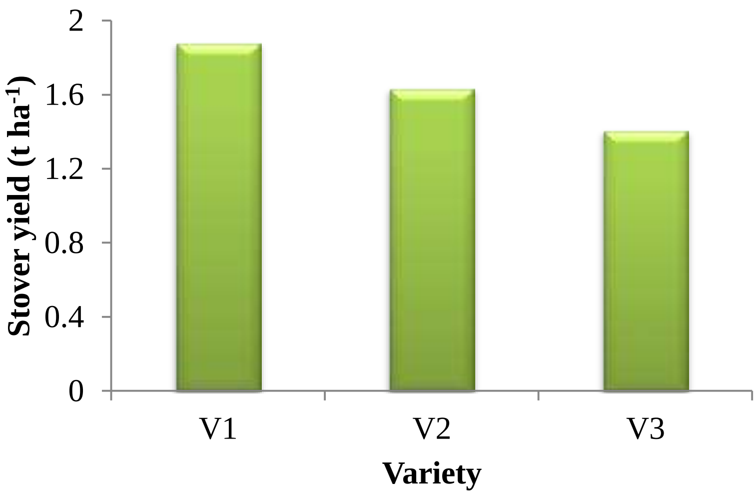


Figure 25. Effect of variety on stover yield of blackgram (LSD $_{(0.05)}$ =0.03)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.13.2 Effect of plant spacing

Different plant spacing showed significant variations in respect of stover yield of blackgram (Fig. 26). Among the different plant spacing, Sp_1 showed the highest stover yield (1.95 t ha^{-1}). On the contrary, the lowest stover yield (1.32 t ha^{-1}) was observed with Sp_5 treatment.

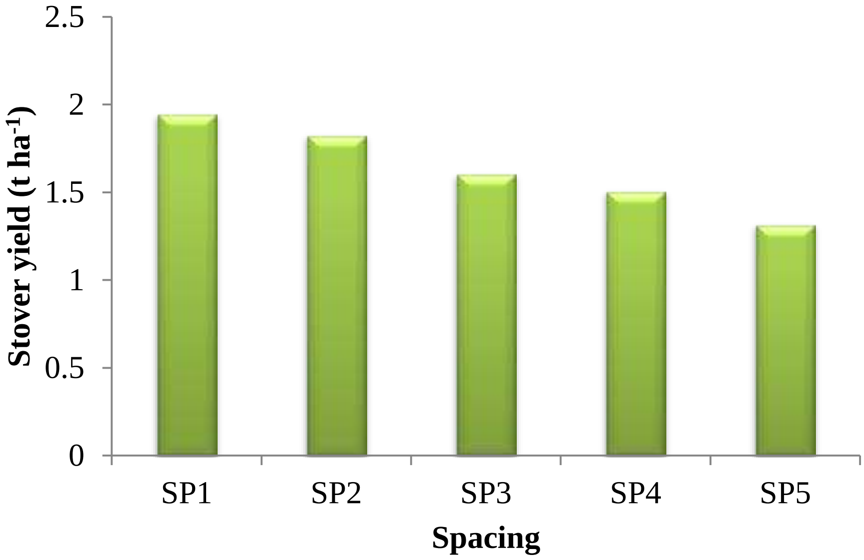


Figure 26. Effect of spacing on stover yield of blackgram (LSD $_{(0.05)}$ =0.09)

SP_1 = 30cm ×10cm, SP_2=20cm × 20cm, SP_3=30cm ×30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm ×50cm

4.13.3 Combined effect of variety and plant spacing

The combined effect of different variety and plant spacing on the stover yield was significant shown on Table 8. The highest stover yield (2.23 t ha^{-1}) was recorded with the treatment combination of V_1SP_1. On the other hand, the lowest stover yield (1.15 t ha^{-1}) was found in V_3SP_5 which was statistically identical with V_3SP_4 treatment combination.

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

4.14.1 Effect of variety

Significant variation was observed on the biological yield of blackgram due to varietal difference (Fig. 27). The highest biological yield of blackgram (3.02 t ha^{-1}) was recorded in V_2. The lowest biological yield (2.53 t ha^{-1}) was recorded in the V_3.

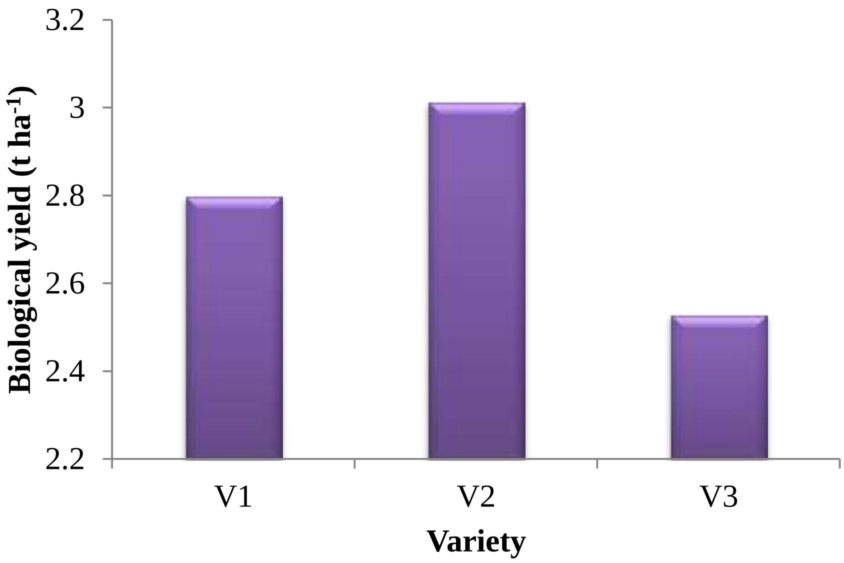


Figure 27. Effect of variety on biological yield of blackgram (LSD $_{(0.05)}$ =0.06)

4.14.2 Effect of plant spacing

Different plant spacing showed significant variations in respect of biological yield of blackgram (Fig. 28). Among the different plant spacing, SP_1 gave the highest biological yield (3.44 t ha^{-1}). On the other hand, the lowest biological yield (2.12 t ha^{-1}) was observed with SP_5 treatment. This would have contributed to more biomass and hence higher haulm yield. This was also documented earlier by Kuttimani and Velayudham (2016).

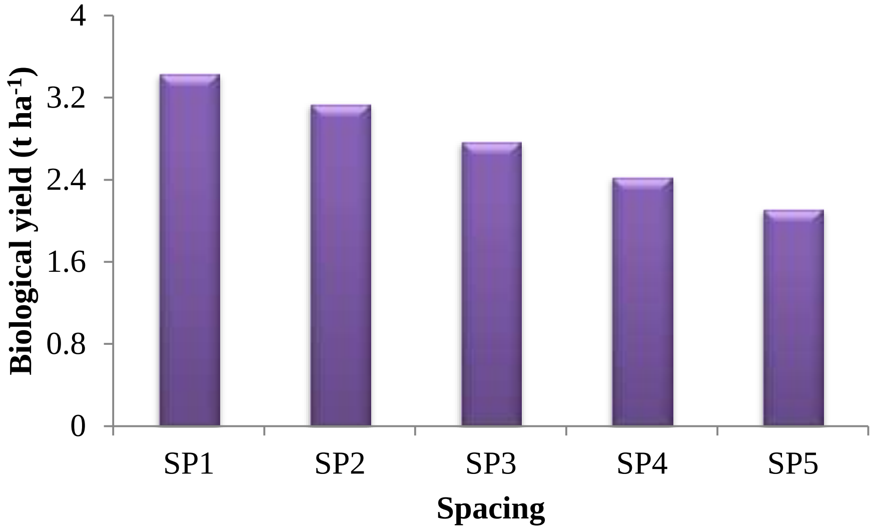


Figure 28. Effect of spacing on biological yield of blackgram (LSD $_{(0.05)}$ =0.13)

SP_1 = 30cm ×10cm, SP_2=20cm × 20cm, SP_3=30cm ×30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm ×50cm

4.14.3 Combined effect of variety and plant spacing

The combined effect of different variety and plant spacing on the biological yield of blackgram was significantly varied (Table 8). The highest biological yield (3.67t ha^{-1}) was recorded with the treatment combination of V_2Sp_1 which were statistically similar with V_1Sp_1. On the other hand, the lowest biological yield (1.96 t ha^{-1}) was found in V_3Sp_5 treatment combination which was statistically similar with V_3Sp_4 and V_1Sp_5.

4.15 Harvest index (%)

4.15.1 Effect of variety

Results presented in Figure 29, harvest index was significantly influenced by blackgram variety. The highest and lowest harvest index of blackgram (45.17% and 32.47%) was recorded in V_2 and V_1, respectively. The harvest index was 39.11% higher in V_2 compared to V_1.

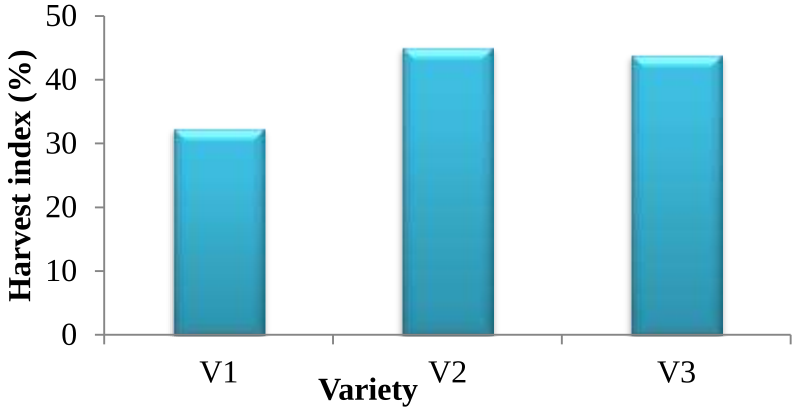


Figure 29. Effect of variety on harvest index of blackgram (LSD $_{(0.05)}$ =0.84)

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3

4.14.2 Effect of plant spacing

There was a marked difference among the plant spacing on the harvest index of blackgram shown on figure 30. Among the different plant spacing, Sp_1 showed the highest harvest index (43.28%) which was statistically similar with Sp_2 and Sp_3 and the lowest one was observed (37.68%) with Sp_5 treatment which was statistically at par with Sp_4 only. 14.86% higher harvest index was recorded from Sp_1 than Sp_5. The results are in contradictory with the findings obtained by Shrivastav *et al.* (1996) who concluded that increased level of row spacing generally increases the harvest index.

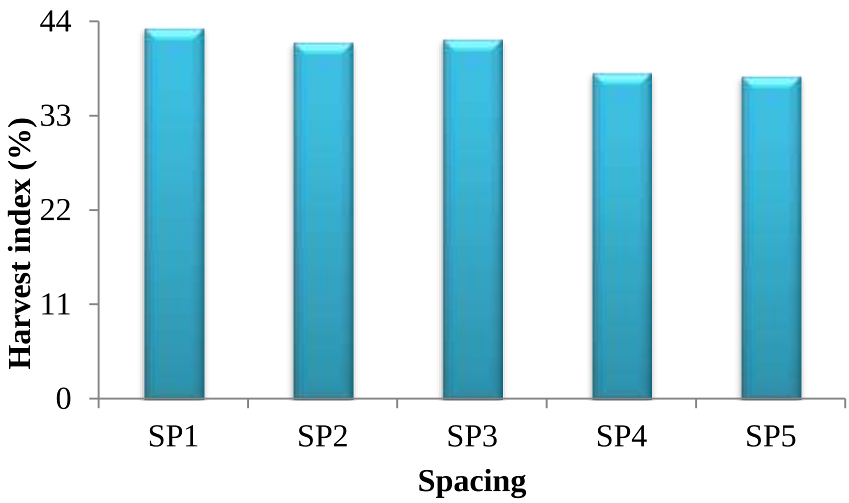


Figure 30. Effect of spacing on harvest index of blackgram (LSD $_{(0.05)}$ = 2.04)

SP_1 = 30cm ×10cm, SP_2=20cm × 20cm, SP_3=30cm ×30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm

×50cm

4.14.3 Combined effect of variety and plant spacing

The combined effect of different variety and plant spacing exerted significant variation on harvest index presented in table 8. Result revealed that, the highest harvest index (49.10%) was recorded from V_2SP_1 which showed similarity with V_2SP_3, V_2SP_2 and V_3SP_3 and lowest harvest index (30.60%) was gained from V_1SP_5 which was statistically identical with V_1SP_4, V_1SP_3 and V_1SP_2.

Table 8. Combined effect of variety and spacing on seed yield, stover yield, biological yield and harvest index of blackgram

Treatment combination	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1SP_1	1.22 de	2.23 a	3.45 ab	35.32 f
V_1SP_2	1.05 fg	2.06 b	3.11 cd	33.71 fg
V_1SP_3	0.87 hi	1.88 c	2.75 ef	31.77 g
V_1 SP_4	0.78 ij	1.74 cd	2.52 g	30.94 g
V_1 SP_5	0.66 j	1.50 e	2.17 hi	30.60 g
V_2 SP_1	1.80 a	1.87 c	3.67 a	49.10 a
V_2 SP_2	1.61 b	1.82 c	3.43 b	46.88 a-c
V_2 SP_3	1.49 bc	1.62 de	3.11 c	47.94 ab
V_2 SP_4	1.08 f	1.56 e	2.64 fg	40.83 e
V_2 SP_5	0.92 gh	1.31 f	2.23 h	41.08 e
V_3SP_1	1.46 c	1.75 cd	3.21 c	45.42 b-d
V_3 SP_2	1.28 d	1.61 de	2.89 de	44.36 c-e
V_3 SP_3	1.13 ef	1.32 f	2.46 g	46.14 a-c
V_3 SP_4	0.90 hi	1.23 fg	2.13 hi	42.46 de
V_3 SP_5	0.81 hi	1.15 g	1.96 i	41.37 e
LSD $_{(0.05)}$	**0.13**	**0.16**	**0.22**	**3.53**
CV (%)	**6.67**	**5.89**	**4.65**	**5.17**

V_1= Munshigonj local,V_2= BARI Mash-2 and V_3= BARI Mash-3**;** SP_1 = 30cm ×10cm, SP_2=20cm × 20cm, SP_3=30cm ×30cm, SP_4 = 40cm × 40cm and SP_5 = 50cm ×50cm

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from March to June, 2015 to study the system of crop intensification method use in blackgram cultivationin Kharif 1 season under the Modhupur Tract (AEZ-28). The experiment was comprised with three varieties *viz.* Munshigonj Local (V_1)BARI Mash-2 (V_2), BARI Mash-3 (V_3) and and five plant spacing *viz.* SP_1 = 30cm × 10 cm (control), SP_2=20cm × 20 cm, SP_3=30cm × 30 cm, SP_4 = 40cm × 40 cm and SP_5 = 50cm × 50 cm . The experiment was laid out in a split-plot design with three replications having variety in the main plots and different plant spacing in the sub-plots.

The data on crop growth parameters like plant height, leaves plant^{-1}, branches plant^{-1}, above ground dry matter plant^{-1}, CGR and RGR were recorded at different growth stages. Yield and other crop characters like pods plant^{-1},seeds pod^{-1}, pod length, 1000-seeds weight, seed yield plant^{-1}, seed yield ha^{-1}, stover yield biological yield and harvest index were recorded after harvest. Data were analyzed using MSTAT-C package. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Results showed that three varieties of blackgram had significant effect on growth and yield parameters except relative growth rate, seeds pod^{-1} and pod length. The increase of plant height was more or less gradual up to harvest, highest plant height (69.13 cm) was accounted for V_1 (Munshigonj local) and the lowest one (56.57 cm) was from V_3. The highest leaves plant^{-1} (66.20) was found from V_1 at harvest and minimum one (38.00) from V_3. The V_2 produced maximum branches plant^{-1} (8.93) where minimum branches plant^{-1} (6.27) was recorded from V_1 at harvest. Above ground dry weight plant^{-1} was rapidly increased from 50 days to at harvest of growth stages which was highest (46.93 g) in the V_1(Munshigonj Local) compared to the V_3(BARI Mash-3)(36.73 g).The maximum number crop growth rate (22.00 g m^{-2} d^{-1}) was achieved by V_1 and the lowest one (17.77 g m^{-2} d^{-1}) was from V_3. The maximum pods plant^{-1}(66.87), 1000 seed weight (40.31 g), seed yield plant^{-1} (14.89 g), seed yield (1.38 t

ha^{-1}), biological yield (3.02 t ha^{-1}) and harvest index (45.17%) was recorded from V_2 whereas the minimum pods $plant^{-1}$ (50.29) , 1000 seed weight (30.31 g), seed yield $plant^{-1}$ (10.13 g), seed yield (0.92 t ha^{-1}) and harvest index (32.47%) was from V_1. The highest stover yield (1.88 t ha^{-1}) was given by V_1 and lowest stover yield (1.41 t ha^{-1}) and biological yield (2.53 t ha^{-1}) was recorded for V_3. The seed yield increase was found 51.09 % higher in V_2 than V_1. The harvest index was 39.11% higher in V_2 compared to V_1.

Plant spacing also significantly influenced all growth and yield attributes except relative growth rate. The results revealed that the tallest plant (63.23 cm) was found in the S_5 where as the shortest one (60.11 cm) was from S_1at harvest. At harvest, the Sp_5 produced maximum leaves $plant^{-1}$ (59.22), branches $plant^{-1}$ (9.11), above ground dry weight $plant^{-1}$ (50.33 g), crop growth rate (24.06 g m^{-2} d^{-1}), pods $plant^{-1}$ (82.53), seeds pod^{-1} (6.57), pod length (4.36 cm), 1000 seed weight (36.38 g), seed yield $plant^{-1}$ (17.31 g). The minimum leaves $plant^{-1}$ (40.33), crop growth rate (15.63 g m^{-2} d^{-1}), pods $plant^{-1}$ (35.27), 1000 seed weight (34.33 g) and seed yield $plant^{-1}$ (8.68 g) was recorded from Sp_1 and the minimum branches $plant^{-1}$ (6.67), above ground dry weight $plant^{-1}$ (34.08 g), seeds pod^{-1} (6.17), pod length (4.17 cm) was counted for Sp_2. The highest seed yield (1.49 t ha^{-1}), stover yield (1.95 t ha^{-1}), biological yield (3.44 t ha^{-1}) and harvest index (43.28%) were obtained from Sp_1 and the lowest seed yield (0.80 t ha^{-1}), stover yield (1.32 t ha^{-1}), biological yield (2.12 t ha^{-1}) and harvest index (37.68%) were obtained from SP_5. Plant spacing SP_1 produced 86.25% higher seed than S_5. 14.86% higher harvest index was recorded from SP_1 than SP_5.

Interaction effect of varieties and different plant spacing also significantly affected growth as well as yield and yield contributing characters except relative growth rate. The tallest plant height (70.37 cm) was found in the combination of V_1SP_5 at harvest and the shortest plant height (53.67 cm) was found in the V_3SP_4. The maximum leaves $plant^{-1}$ (73.67) was counted for treatment combination V_1SP_5 whereas the minimum leaves $plant^{-1}$ (27.67) was counted for treatment combination V_3SP_1 at harvest. At harvest the maximum branches $plant^{-1}$ (10.67) was recorded from V_2SP_5 and the minimum branches $plant^{-1}$ (5.16) was recorded from V_1SP_3. At harvest the maximum (56.67 g) above ground dry weight $plant^{-1}$at harvest was recorded form combination of V_1SP_5 and the lowest (29.33 g) above ground dry weight $plant^{-1}$was recorded form V_3SP_1. The maximum crop growth rate (27.34 g m^{-2} d^{-1}) was counted for treatment combination V_1 SP_5 whereas the minimum crop growth rate (13.33 g m^{-2} d^{-1}) was counted for treatment combination V_3 SP_1 at harvest-50 DAS. The maximum pods $plant^{-1}$(92.90), seeds pod^{-1}(6.80), pod length (4.50 cm), 1000-seeds wt. (41.13 g), seed yield $pant^{-1}$ (20.10 g) was produced by V_2 SP_5 and the minimum pods $plant^{-1}$(30.77), seeds pod^{-1}(5.97), pod length (4.13 cm), 1000-seeds wt. (28.00 g), seed yield $pant^{-1}$ (6.03 g) was produced by V_1 SP_1. The highest seed yield (1.80 t ha^{-1}), biological yield (3.67 t ha^{-1}), harvest index (49.10%) was found from V_2SP_1, where as the lowest seed yield (0.66 t ha^{-1}), biological yield (1.96 t ha^{-1}), harvest index (30.60%) was found from V_1SP_5, V_3SP_5 and V_1SP_5, respectively. The maximum stover yield (2.23 t ha^{-1}) was recorded from V_1SP_1 whereas the minimum one (1.15 t ha^{-1}) was from V_3SP_5.

It may be concluded that system of crop intensification technique had significant influence in individual plant but failed to produce potential yield figure per unit area due to lower plant population where recommended spacing 30cm × 10cm showed greater yield along with BARI Mash 2.

However, to reach a specific conclusion and recommendation the same experiment need to be repeated and more research work should be done over different Agro-ecological zones study the location effect towards planting geometry method.

REFERENCES

Abraham, B., Araya, H., Berhe, T., Edwards, S., Gujja, B., Khadka, R. B., Koma, Y. S., Sen, D., Sharif, A., Styger, E., Uphoff, N. and Verma, A. (2014). The system of crop intensification: reports from the field on improving agricultural production, food security, and resilience to climate change for multiple crops. *Agril. Food Security*. **3**: 4.

Achakzai, A. K. K. and Kayani, S. A. (2007). Effect of fertilizer and inoculation on the growth and yield of soybean cv. Williams-82 in pot culture. *Pakisan. J. Agric. Res.* **18**(1): 83-93.

Achakzai, A. K. K. and Panizai,M. K. (2007). Effect of row spacing on growth, yield andyield components of mashbean.*Sarhad J. Agric.* **23**(1): 5-10.

Afzal, M. A., Bakar, M. A., Luna, N. K., Rahman, M. M., Hamid, A., Haque, M. M. and Shanmungasudaram, S. (2003). Registration of 'Barimungs' Mungbean. *Crop Sci*. **43**: 930-931.

Agugo, O. and Kanu (2010). A preliminary field assessment of mungbean (*Vigna radiata* (L.) Wilczek) yield in rain forest zone southeastern Nigeria. *American-Eurasian J. Agrl. Environ. Sci.* **8**(6): 752-757.

Ahmed, A., Shamdane, G. and Maniruzzaman, A. F. M. (l993). Effect of time weeding and plants density on the growth and yield of Blackgram. *Bangladesh J. Agric. Res.* **l6**(2): l9-22.

Ali, A., Nadeem, M. A., Tayyab, M., Tahir, M. and Sohail, R. (2001). Determining suitable planting geometry for two mungbean (*Vigna radiata* L.) cultivars under Faisalabad conditions. *Pakistan J. Biol. Sci*. **4**: 344-45.

Araya, H., Edwards, S., Asmelash, A., Legasse, H., Zibelo, G. H., Mohammed, E. and Misgina, S. (2013). SCI: Planting with Space. *Farming Matters*. **29**: 35-37.

Arsad, M. A., Bakhsh, A. and Ghafoor, A. (2004). Path co-efficient analysis in chickpea (*Cicer arietinum* L.) under rainfed conditions. *Pakistan J. Bot.***36**(1): 75-81.

Asaduzzaman, M., Sultana, S., Roy, T. S. and Masum, S. M. (2010). Weeding and Plant spacing effects on the growth and yield of blackgram. *Bangladesh Res. Pub. J*. **4**(1): 62-68.

BARI (Bangladesh Agricultural Research Institute) (2005). Production of Blackgram in Bangladesh, Bangladesh Agricultural Research Institute, Joydepur, Gazipur. Bangladesh.

Behera, D., Chaudhury, A. K., Vutukutu, V. K., Gupta, A., Machiraju, S. and Shah, P. (2013). Enhancing Agricultural Livelihoods through Community Institutions in Bihar, India, South Asia Livelihoods Learning Series. New Delhi: World Bank, and Patna: Jeevika.

Bhairappanavar, S. T., Jayadeva, H. M., Gowda, T. H. and Shivanna, S. (2005). Effect of nutrients and spacing on the yield of urdbean under late sown condition. *Leg. Res*.**28**(1): 46-48.

Borah, U. K. (1994). Response of black gram varieties to row spacing under rainfed conditions. *Annals Agric. Res*. **15**(4): 516-517.

Brown, R. H. (1994) In: growth of the green plant. Physiological basis of crop growth and development. Teasar, M. B. (Ed.). Madison, Wisconsin. pp. 1533-173.

Chakrabortty, S., Biswas, P. K., Roy, T. S., Mahmud, M. A. A., Mehraj, H. and Uddin, A. F. M. J. (2014). Growth and Yield of Boro Rice (BRRI Dhan 50) as Affected by Planting Geometry under System of Rice Intensification.*J. Biosci. Agril. Res*. **2**(1): 36-43.

Chen, S., Zheng, X., Wang, D., Xu, C. and Zhang, X. (2013). Influence of the Improved System of Rice Intensification (SRI) on Rice Yield, Yield Components and Tillering Characteristics under Different Rice Establishment Methods. *Plant Prod. Sci.***16**(2): 191-198.

Chopra, N. K. and Chopra, N. (2004). Seed yield and quality of ‘Pusa44’ rice as influenced by nitrogen fertilizer and row spacing. *Indian J. Agril. Sci*. pp. 144-146.

DAE (2016). Field Service Wing. Department of Agricultural Extension, Khamarbari, Framgate, Dhaka.

Dasgupta, T. and Das, P. K. (1991). Genetic divergence in black gram. *Indian. J. Agri. Res*. **25**: 7-13.

Dash, T. K. and Pal (2011). Growing Crops with SRI Principles. Bhubaneswar: SRI Secretariat and Sir Dorabji Tata Trust.

Davi, D., Kumar, R. and Khippal, A. (1995). Effect of different intra-row spacing on the growth of pigeon pea and urdbean intercropping. *Discovery and Innovation.***9**(1-2): 47-51.

Durga, K. K., Rao, P. S. and Raju, K. (2015). Effect of seedling age and spacing schedule on the productivity a nd quality traits of rice under system of rice intensification (SRI). *J. Cereals Oilseeds.***6**(3): 15-19.

Geethadevi, T., Andani, G., Krishnappa, M. and Babu, B. T. R. (2000). Effect of nitrogen and spacing on growth and yield of hybrid rice. *Curr. Res. Univ. Agril. Sci. Bangalore*. pp. 73-75.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. 2nded. John Wiley and Sons. New York. p. 64.

Hassan, A. A. and Baswaid, A. S. (2004). The effect of seed rate application on the growth and yield of Balckgram. University of Aden, Yemen. *J. Nat. Appl. Sci.***5**(1): 1-10.

Ihsanullah., Taj, F. H., Akbar, H., Basir, A. and Noorullah, (2002). Effect of row spacing on the agronomic traits and yield of mung bean (*Vigna radiata* L. Wilczek). *Asian J. Plant Sci*. **1**(4): 328-329.

Islam, M. F. and Islam, M. S. (2006). Response of chickpea to nitrogen, phosphate, potash,sulfur an zinc fertilization in calcareous dark gray flood plain soils of Bengladesh,11th Ann. Bengladesh Conference, Dhaka, BAAS. **1**: 26.

Jagannath, M. A., Chavan, M. G., Rajemahadik, V. A. and Singh, J. K. (2014). Response of Summer Blackgram (*Vigna mungo*) Varieties to Phosphorus Levels under Lateritic Soils of Konkan. *Int. J. Sci. Engr.. Techno*. **3**(3): 259-262.

Kahimba, F. C., Kombe, E. E. and Mahoo, H. F. (2014). The Potential of System of Rice Intensification (SRI) to Increase Rice Water Productivity: a Case of Mkindo Irrigation Scheme in Morogoro Region, Tanzania. *Tanzania J. Agril. Sci.***12**(2): 10-19.

Katambara, Z., Kahimba, F. C., Mahoo, H. F., Mbungu, W. B., Mhenga, F., Reuben, P., Maugo, M. and Nyarubamba, A. (2013). Adopting the system of rice intensification (SRI) in Tanzania: A review. *Agril. Sci*.**4**(8): 369-375.

Khan, M. B. and Asif, M. (2001). Growth and yield response of mashbean genotypes to various planting densities. Bahauddin Zakariya University, Multan, Pakistan. *J. res. Sci*. **12**(2): 167-170.

Krishna, A. and Biradarpatil, N. K. (2009). Influence of seedling age and spacing on seed yield and quality of short duration rice under system of rice intensification cultivation. *Karnataka J. Agric. Sci.* pp. 53-55.

Krishna, A., Biradarpatil, N. K. and Channappagoudar, B. B. (2008). Influence of system of rice intensification (SRI) cultivation on seed yield and quality. *Agril. Sci.***21**(3): 369-372.

Kumar, S. G., Gomathinayajam, P. and Rathnaswmy, R. (1997). Effect of row spacing on a dry matter accumulation of black gram. *Madras Agric. J*.**84**(3): 160-162.

Kuttimani, R. and Velayudham, K. (2016). System of Crop Intensification (SCI) Techniques on Yield andEconomics of Greengram. *J. Agril. Veterinary Sci*. **9**(7): 01-04.

Lin, X. Q., Zhu, D. F., Chen, H. Z., Cheng, S. H. and Uphoff, N. (2009). Effect of plant density and nitrogen fertilizer rates on grain yield and nitrogen uptake of hybrid rice (*Oryza sativa* L.). *J. Agric. Biochem. Sust. Develop*. **1**: 44-53.

Lin, X., Zhou, W., Zhu, D. and Zhang, Y. (2005). Effect of SWD irrigation on photosynthesis and grain yield of rice (*Oryza sativa* L.). *Field Crops Res*. **94**: 67-75.

Lokanadhan, S. (2015). Studies on seasonal and geometrical variations in growth attributes and yield of blackgram (*Vigna mungo* (L.) Hepper). *Int. J. App. Pure Sci. Agric.***1**(9): 76-81.

Malik, M. F. A., Asharf, M., Qureshi, A. S. and Ghafoor, A. (2007). Assessment of genetic variability correlation and path analysis for yield and its components in Soybean. *Pakistan J. Bot*. **39**(2): 405-413.

Malik, M. F. A., Qureshi, A. S., Ashraf, M. and Ghafoor, A. (2006). Genetic variability of the main yield related characters in Soybean. *Int. J. Agric Biol*. **8**(6): 815-819.

Mehmud, M., Chiezey, U. F., Ahmed, M. K. and Rofia, I. (1997). Effect of different levels of phosphorus fertilizers and intra row spacing on the gram yield, growth and yield components of black gram (*Vigna mungo* L. Hepper). *Discovery and Innovation*. **9**(1-2): 47-51.

Minhas, R. S., Jaggi, R. S. and Sharma, P. (2007). Response of gram to NPK application in wet temperature zone of Himachal Pradesh. *Indian J. Agril. Chem.***20**: 95-99.

Mishra, A. and Salokhe, V. M. (2010). Seedling characteristics and early growth of transplanted rice under different water regimes. *Exp. Agric*. **44**: 365-383.

Mishra, M. and Mishra, A. (1995). Effect of fertilizers, weed control and row spacing on summer blackgram (*Phaseolus mungo*). *Indian J. Agron*. **40**(3): 434-438.

Miyazato, T., Robert, A. and Lazaro, R. C. (2010). Irrigation management transfer (IMT) and system of rice intensification (SRI) practice in the Philippines. *Paddy Water Environ.***8**: 91–97.

Montpellier Panel (2013). Sustainable Intensification: A New Paradigm for African Intensification. Imperial College, London.

Murade, N. B., Patil, D. B., Jagta, H. D. and More, S. M. (2014). Effect of spacing and fertilizer levels on growth and yield of urdbean. *The Bioscan*. **9**(4):1545-1547.

Nadeem, M. A., Ali, A., Sohail, R. and Maqbool, M. (2004). Effect of Different Planting Pattern on Growth, Yield and Quality of Grain Legumes. *Pakistan j. life soc. sci.***2**(2): 132-135.

Nagaraju, A. P., Shivanandah, N. P. and Shambulingappa, K. G. (1995). Response of urdbean genotype to row spacing. *Indian J. Pulses Res*. **8**(2): 190-191.

Nayak, B. C., Dalei, B. B. and Chodhury, B. K. (2003). Response of hybrid rice to date of planting, spacing and seedling rate during wet season. *Indian J. Agron*. pp. 172-174.

Nguu, N. V. and Datta, D. S. K. (1979). Increasing of plant density and plant geometry. *Field Crops Res.***2**: 19-34.

Padmaja, K. and Reddy, B. B. (1998). Effect of seedling density in nursery, age of seedling and crop geometry on growth and yield of hybrid rice during wet season. *Oryza*. pp. 380-381.

Panotra, N., Kumar, A. and Singh, O. P. (2016). Effect of varieties and dates of sowing on growth parameters, yield attributes and yield of black gram (*Vigna mungo* L.)*Int. J. Sci. Environ. Techno.***5**(6): 3821-3826.

Patra, A. K. and Nayak, B. C. (2001). Effect of spacing on rice varieties of various duration under irrigated condition. *Indian J. Agron.* pp. 449-452.

Prasad, S. and Srivastava, J. P. (1999). Physiological analysis of yielding ability in mungbean. *Indian. J. of Pulses Res.***12**: 49-56.

Rajput, A., Sharma, S., Rajput, S. S. and Jha, G. (2016). Impact of different crop geometries and depths of planting on growth and yield of rice in system of rice intensification.*Biosci. Biotech. Res. Comm*. **9**(3): 512-516.

Rajput, M. J., Tunio, S., Rajput, M. A. and Rajput, F. K. (1984). Effect of row and plant spacing on yield and yield component in soynbean. *Pakistan J. Agric. Res*. **5**(2): 83-86.

Rao, T. and Konda, C. R. (1988). New and improved high yielding varieties in some pulses crops. Training Programme on Pulse Production Technology from September 28-30, 1988. Eds. M. M. Hosmani and B. M. Chittapur, Department of Agronomy, UAS, Dharwad.

Reddy, S. N., Singh, B. G. and Rao, I. V. S. (1990). Analysis of dry matter production, growth and yield in black gram varieties. *J. Maharashtra Agri. Uni*. **15**: 184-191.

Sanico, A. L., Peng, S., Laza, R. C. and Visperas, R. M. (2002). Effect of seedling age and seedling number per hill on snail damage in irrigated rice. *Crop Protec*. pp. 137-143.

Sato, S. and Uphoff, N. (2007). A review of on-farm evaluation of system of rice intensification (SRI) methods in Eastern Indonesia. In: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. Commonwealth Agricultural Bureau International, Wallingford, UK.

Sayre, K. D and Ramos, O. H. M. (1997). Applications of raised-bed planting systems to wheat. Wheat Program Special Report No. 31. Mexico, C.F.: CIMMYT.

Sen, S. (1996). Economic Botany. New Central Book Agency (Pvt.) Ltd. Calcutta, India. pp. 42-43.

Sharma, B. L., Singh, D. P. and Singh, K. H. (2000). Evaluation of diverse germplasm lines/cultivars under different sowing dates for yield and yield components in blackgram. *Indian J. Agric. Sci.***70**: 154-157.

Sharma, P., Sekhon, H. S. and Bains, T. S. (2012). Performance and Growth Analysis in Mash Bean Genotypes.*World J. Agril. Sci*. **8**(3): 303-308.

Shrivastav, D. K., Rao, S. K. and Tawar, M. L. (1996). Analysis of factors influencing seed yield in urid. *Legume Res*. **19**(1): 62-63.

Shrivastava, G. K., Khanna, P. and Tripathi, R. S. (1999). Response of hybrid and popular rice cultivars to different planting geometry. *Madras Agric. J*. pp. 489-490.

Shukla, S., Bloese, J. and Ray, T. (2016). Effect of yield, quality attributes and cost of rice (*Oryza sativa L.*) variety under System of rice intensification (SRI) Organic and Conventional methods of rice cultivation.*Int. J. Scientific and Res. Pub.***6**(6): 2250-3153.

Siddaraju, R., Narayanaswamy, S., Ramegowda and Prasad, S. R. (2010). Studies on growth, seed yield and yield attributes as influenced by varieties and row spacing in cluster bean (*Cyamopsistetragonoloba* L.). *Mysore J. Agric. Sci*. **44**(1): 16-21.

Siddique, M., Malik, M. F. A. and Awan, S. I. (2006). Genetic divergence association and performance evaluation of different genotypes of mungbean (*Vigna radiata* L). *Int. J. Agric. Biol.* **8**(6): 793- 795.

Siddiqui, M. R. H., Lakpale, R. and Tripathi, R. S. (1999). Effect of spacing and fertilizer on medium duration rice varieties. *Indian J. Agron*. pp. 310-312.

Singh, D. K. and Singh, V. K. (2000). Growth and nitrogen uptake pattern of promising urdbean genotypes under different sowing dates and plant densities during rainy season. *Ann. Agric. Res.***21**: 456-458.

Singh, E. and Ananthi, P. (2009). Effect of row spacing and dates of sowing on growth and yield of lentil (Lens culinaris) under north eastern region of Uttar Pradesh. *Leg. Res*. **32**(4): 307-308.

Singh, R. M and Verma (1999). Effect of seeding rate and row spacing on the yield and quality of lentil (*Lens culinaris*) varieties. *Indian J. Agron*. **44**: 584-7.

Singh, S., Yadav, D. S. and Singh, S. (1994). Response of summer black gram (*Phaseolus mungo*) to row spacing and seed rate. *Indian J. Agron.***39**(2): 314-315..

Srivastav, G. K. and Tripathi, R. S. (1998). Response of hybrid and composit rice to number of seedling and planting geometry. *Ann. Agril. Res.* pp. 235-236.

Tanya, Daniel, S. and Kumar, M. (2015). Comparative study on effect of spacing on the growth and yield of different varieties of black gram (*Vigna radiata* L.) under Subabul (*Leucaena leucocephala*) based agrosilviculture system. *Int. J. Adv. Res.***3**(6): 1190-1196.

Thakur, A. K., Rath, S., Roychowdhury, S. and Uphoff, N. (2010). Comparative performance of rice with system of rice intensification (SRI) and conventional management using different plant spacing. *J. Agron. Crop Sci*. **196**: 146-159.

The Royal Society (2009). Royal Society: Reaping the Benefits: Science and the Sustainable Intensification of Global Agriculture. London.

Tomar, S. S. and Tiwari, A. S. (1991). Effect of plant density on genotypes of greengram and blackgram. *Indian J. Agric. Sci.***61**: 126-127.

Uphoff, N. (2004). Changes and evaluation in SRI methods. In: Proceedings of the International Conference on the Dissemination of the SRI, 1-4 Apr. 2002, Sanya, China. Ithaca, New York: Cornell University.

Uphoff, N. (2005). Report of field visits in Zhejiang and Sichuan provinces, China.

Uphoff, N., Ball, A., Fernandes, E. C. M., Herren, H., Husson, O. Laing, M., Palm, C. A., Pretty, J., Sanchez, P. A., Sanginga, N. and Thies, J. E. eds. (2006). *Biol. Appro. Sus. Soil Systems*. CRC Press, Boca Raton, FL.

Varma, A. K., Pandey, N. and Tripathi, S. (2002). Effect of transplanting spacing and number of seedlings on productive tillers, spikelet sterility, grain yield and harvest index of hybrid rice. *IRRN.* pp. 27-51.

Vijayakumar, M., Ramesh, S., Chandrasekaran, B., and Thiyagarajan, M. (2001). Effects of system of rice intensification (SRI) practices on yield attribute and water productivity of rice (*Oryza sativa* L.). *Res. J. Agric Biol. Sci.***2**(6): 236-242.

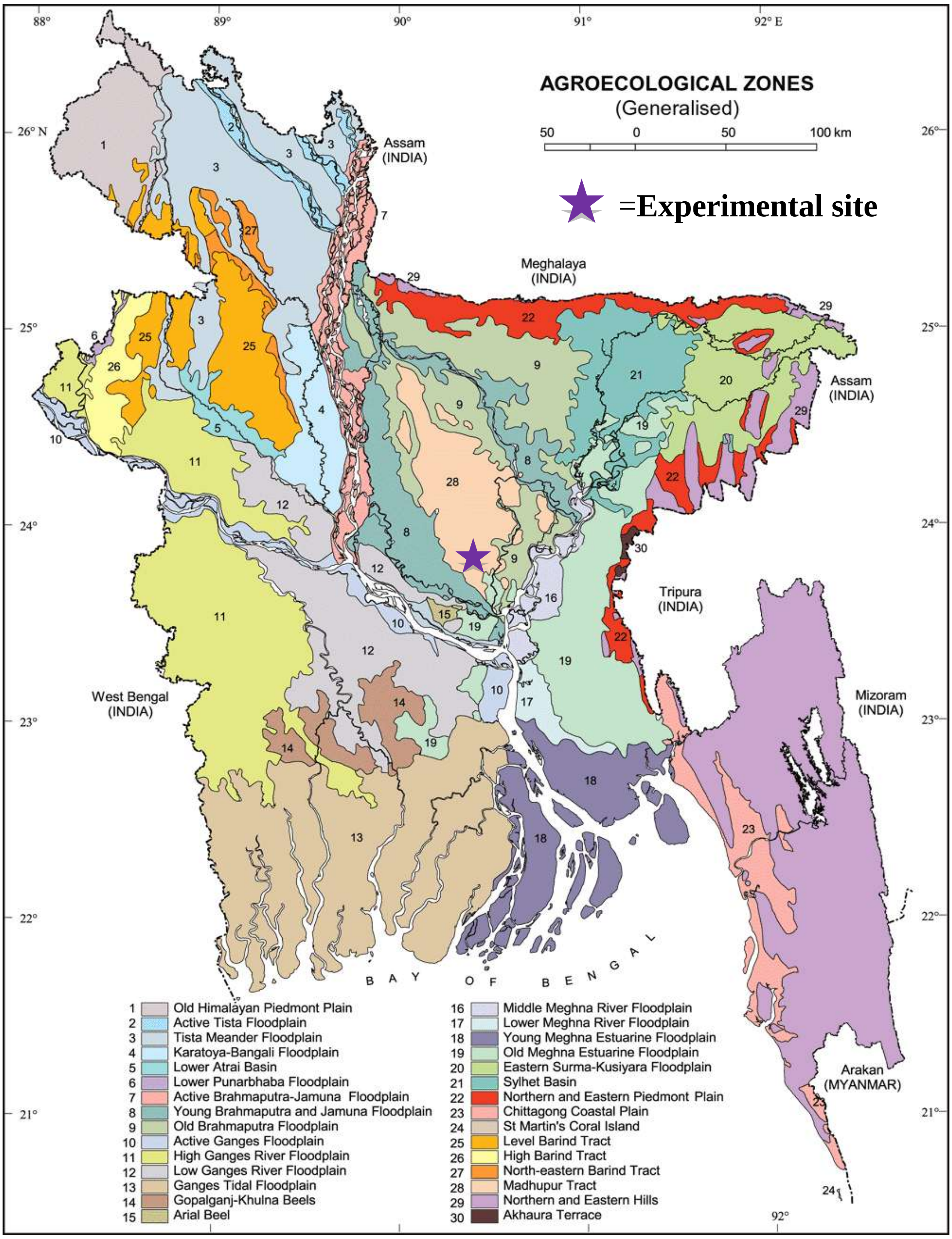
Vishnudas, C. K. (2006). SRI trials in Wayanad. Experiences of RASTA. *In: LEISA India*. **8**(4): 16-17.

Watershed Organisation Trust (2013). SCI: System of Crop Intensification - A Step towards Climate-Resistant Agriculture. Pune, WOTR.

Yadhalli G. S. and Palled, Y. B. (2004). Response of black gram genotypes to Dates of Sowing and phosphorus levels in Northern Transitional Tract of Karnataka. *Karnataka J. Agric. Sci.***17**(2): 215-219.

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
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**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total weeding (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from March to June 2015

Month (2015)	Air temperature (degrees Celsius)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
March	32.10	20.56	45.11	4
April	32.79	23.38	63.48	166
May	34.07	25.42	67.83	185
June	32.75	26.70	74.57	375

Source: Bangladesh Meteorological Department (Climate & weather division), Agargaon, Dhaka- 1212

Appendix IV. Analysis of variance of the data on plantheightof blackgram as influenced by combined effect of variety and plant spacing

Source of variation	df	Mean square of plant height at different days after sowing (DAS)			
		20	35	50	At harvest
Replication	2	4.12	20.47	3.80	20.57
Variety (A)	2	2.79^{NS}	107.61*	1009.87*	625.72*
Error	4	9.28	6.42	39.47	36.38
Plant spacing (B)	4	1.30^{NS}	27.60*	54.59*	11.96*
Variety(A) X Plant spacing (B)	8	6.25*	34.45*	10.51*	20.45*
Error	24	1.78	3.67	8.47	5.88

*Significant at 5% level of significance

^{NS} Non significant

Appendix V. Analysis of variance of the data on leaves plant^{-1} of blackgram as influenced by combined effect of variety and plant spacing

Source of variation	df	Mean square of leaves plant^{-1} at different days after sowing (DAS)			
		20	35	50	At harvest
Replication	2	0.01	1.48	6.85	8.82
Variety (A)	2	0.69*	32.82*	4968.90*	3568.96*
Error	4	0.06	0.63	15.13	9.02
Plant spacing (B)	4	0.16*	27.07*	103.91*	554.76*
Variety(A) X Plant spacing (B)	8	0.09*	1.96*	8.94*	73.96*
Error	24	0.06	1.33	6.98	4.79

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on branches plant^{-1} of blackgram as influenced by combined effect of variety and plant spacing

Source of variation	df	Mean square of branches plant^{-1} at different days after sowing (DAS)		
		35	50	At harvest
Replication	2	0.04	0.82	0.02
Variety (A)	2	3.42*	13.93*	33.51*
Error	4	0.06	0.06	0.29
Plant spacing (B)	4	3.55*	5.41*	7.09*
Variety(A) X Plant spacing (B)	8	0.19*	0.49*	1.41*
Error	24	0.05	0.12	0.44

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on above ground dry weight plant^{-1} of blackgram as influenced by combined effect of variety and plant spacing

Source of variation	df	Mean square of above ground dry weight plant^{-1} at different days after sowing (DAS)			
		20	35	50	At harvest
Replication	2	0.001	0.57	2.44	52.65
Variety (A)	2	0.57*	8.56*	55.69*	412.62*
Error	4	0.001	0.22	1.71	4.32
Plant spacing (B)	4	0.003*	1.08*	20.25*	474.69*
Variety(A) X Plant spacing (B)	8	0.008*	0.32*	0.66*	23.27*
Error	24	0.001	0.11	0.67	8.33

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on crop growth rate of blackgram as influenced by combined effect of variety and plant spacing

Source of variation	df	Mean square of crop growth rate at different days after sowing (DAS)		
		35-20	50-35	At harvest-50
Replication	2	0.18	0.06	13.57
Variety (A)	2	2.15*	9.26*	76.81*
Error	4	0.08	0.16	0.71
Plant spacing (B)	4	0.47*	5.93*	143.96*
Variety(A) X Plant spacing (B)	8	0.12*	0.51*	11.52*
Error	24	0.05	0.10	2.34

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Analysis of variance of the data on relative growth rate of blackgram as influenced by combined effect of variety and plant spacing

Source of variation	df	Mean square of relative growth rate at different days after sowing (DAS)		
		35-20	50-35	At harvest-50
Replication	2	0.000	0.00	0.000
Variety (A)	2	0.004^{NS}	0.000^{NS}	0.000^{NS}
Error	4	0.000	0.000	0.000
Plant spacing (B)	4	0.000^{NS}	0.000^{NS}	0.000^{NS}
Variety(A) X Plant spacing (B)	8	0.000^{NS}	0.000^{NS}	0.000^{NS}
Error	24	0.000	0.000	0.000

*Significant at 5% level of significance

^{NS} Non significant

Appendix X. Analysis of variance of the data on yield contributing characters of blackgram as influenced by combined effect of variety and plant spacing

Source of variation	df	Mean square value of			
		Pods $plant^{-1}$	Seeds pod^{-1}	Pod length	1000 seed weight
Replication	2	80.53	0.49	0.06	0.80
Variety (A)	2	1031.84*	0.28*	0.06*	376.93*
Error	4	20.22	0.27	0.13	2.15
Plant spacing (B)	4	3731.13*	0.27*	0.06*	5.36*
Variety(A) X Plant spacing (B)	8	78.04*	0.03*	0.01*	2.94*
Error	24	18.50	0.08	0.03	1.31

*Significant at 5% level of significance

^{NS} Non significant

Appendix XI. Analysis of variance of the data on yield characters of blackgram as influenced by combined effect of variety and plant spacing

Source of variation	df	Mean square value of				
		Seed yield plant^{-1}	Seed yield	Stover yield	Biological yield	Harvest index
Replication	2	3.05	0.008	0.00	0.01	2.77
Variety (A)	2	84.81*	0.81*	0.84*	0.89*	736.56*
Error	4	0.91	0.001	0.001	0.003	0.68
Plant spacing (B)	4	124.76*	0.72*	0.57*	2.54*	56.21*
Variety(A) X Plant spacing (B)	8	1.45*	0.02*	0.01*	0.02*	7.02*
Error	24	0.72	0.01	0.01	0.02	4.39

*Significant at 5% level of significance

^{NS} Non significant