PRODUCTIVITY AND PROFITABILITY OF BUSH BEAN AS INFLUENCED BY VARIETY AND SPACING

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BY

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CERTIFICATE

*This is to certify that the thesis entitled, **"Productivity and Profitability of Bush bean as influenced by variety and spacing"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **Jannatun Naher**, Registration number: **08-02770** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: May, 2016

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DEDICATED

TO

MY BELOVED PARENTS

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PRODUCTIVITY AND PROFITABILITY OF BUSH BEAN (*Phaseolus Vulgaris* L.) AS INFLUENCED BY DIFFERENT VARIETY AND SPACING.

BY

JANNATUN NAHER

ABSTRACT

The experiment was carried out at Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from November 2014 to January 2015 to study the productivity and profitability of bush bean as influenced by different variety and spacing. Two different varieties viz. V_1= BARI bush bean-1, V_2 = BARI bush bean-2 and six levels of spacing i.e. S_1= 30 cm x 20 cm, S_2 = 30 cm x 15 cm, S_3 = 30 cm x 10 cm. S_4 = 25 cm x 20 cm. S_5 = 25 cm x 15 cm and S_6 =25 cm x 10 cm. were used for the present study. The experiment was laid out in RCBD with three replication. The analyzed results showed that highest plant height (56.07 cm), early 1^{st} flower initiation (37.67 days), pod yield per plot (3054.30 g) as well as pod yield (16.97 t/ha) were achieved from V_1S_6 treatment combination. Furthermore, the second highest plant height (52.18 cm), early 1^{st} flower initiation (38.67 days), pod yield per plot (2978.66 g), pod yield (16.55 t/ha) were achieved from V_1S_3 treatment combination. However, the lowest pod yield (8.31 t/ha) was found from V_2S_1 treatment combination .From the present study it was found that the combined effect of V_1S_6 considered as best treatment combination in respect of yield. From economic point of view, V_1S_3 treatment combination gave the highest net return and benefit cost ratio value (Tk. 220,619.25 Tk. /ha and 2.14, respectively).

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LIST OF ABBRIVIATIONS

AEZ	=	Agro Ecological Zone
Agric.	=	Agriculture
Agril.	=	Agricultural
ANOVA	=	Analyses of Variances
BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit of Cost Ratio
cm	=	Centimeter
CV (%)	=	Co–efficient of Variance
^{0}C	=	Degree Centigrade
DAS	=	Days after sowing
DMRT	=	Duncan Multiple Range Test
et al.	=	and others *(at elli)*
FAO	=	Food Agriculture Organization
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
g	=	gram (s)
HRC	=	Horticulture Research Centre
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
NS	=	Non Significant
P^{H}	=	Hydrogen ion concentration.
ppm	=	Parts per million
RCBD	=	Randomized Complete Block Design
SRDI	=	Soil Resources Development Institute
SAU	=	Sher-e-Bangla Agricultural University
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
Viz.	=	Namely
%	=	Percent

Chapter - I

INTRODUCTION

Bush bean (*Phaseolus vulgaris* L.) is an important vegetable crop belonging to the family Leguminosae which originated in the Central America and Mexico (Swiader *et al.*, 1992). It is also known as French bean, kidney bean, snap bean, pinto bean, basic bean, haricot bean, pole bean, wax bean, string bean, green bean, raj bean and bonchi (Duke, 1983; Salunkhe *et al.*, 1987; Tindall, 1988). In our country it is also known as Farashi sheem (Rashid, 1993) and Jhar sheem. Bush bean plants are indeterminate, short, bushy and becoming popular for its tender pods and shelled beans. French bean is nutritionally rich. Each 100 g of pods contain on an average 36 calories food energy, 89% moisture, 2.7g of protein, 0.2 g of lipid, 7.9 g of CHO, 43 mg of Ca, 29 mg of Mg, 28 mg of P, 1.4 mg of Fe, 0.8 mg of Thiamin and *8.5* mg of Niacin. On the other hand, dry bean contains 336 calories food energy with 12% moisture, 21.7 g of proteins *1.5* g of lipid, 60.9 g of CHO, 120 mg of Ca, 8.2 mg of Fe, 0.37 mg of Thiamin and 2.4 mg of Niacin (Sehoonhoren and Rovset, 1993). Protein from beans and seeds are easily transportable and absorbed in human body than animal protein. In Bangladesh there is no statistics about the area and production of this crop and grown in Sylhet, Chittagong hill tracts, Cox's Bazar and Comilla. According to the recent FAO statistics, French beans including other related species of genus *Phaseolus* occupied 25.69 million hectares of the world's cropped area and produced about 17.62 million tons green vegetables with the average yield or 686 kg/ha (FAO, 1998).

It is early donated vegetable crop, it can be grown successfully during winter season after harvest of transplanted Amman paddy and it would allow the growing of Boro rice after the harvest of green pods (Anon., 2000). It can also be intercropped with maize, wheat, sunflower and sugarcane. Moreover, Bangladesh has a great opportunity to earn foreign exchange by exporting this crop. Because of its high nutritive value, good taste and wide range of use, the popularity of field bean is increasing day by day in Bangladesh like many countries of the world. Production of a crop depends on many factors such as variety, proper management practices including sowing time, spacing, intercultural operations etc.

Variety is one of the most important factors that influence on the productivity and profitability of bush bean. Farmers normally used to cultivate a few well adopted local varieties such as (Sylhet local, Chittagong local) varieties etc. for pod production in limited areas of Bangladesh. Some works have been conducted in Bangladesh Agricultural Research Institute (BARI) on the development of this crop, Only two varieties viz. BARI bush bean-1 (BARI Jhar sheem-1), and BARI bush bean-2 (BARI Jhar sheem-2) have so far been released from BARI. Although some sporadic works have been conducted regarding performance and characterization of bush bean varieties, more attention should be paid on these aspects to improve yield. All the varieties do not produce same quantity and quality of pod. So it is essential to identify specific variety which is more productive than others.

Plant spacing is also important aspect of crop production to maximize the yield. Optimum plant spacing ensures judicious use of natural resources, makes the intercultural operation easier, which help increase the number of leaves and branches. The farmers cultivate this crop according to their own conception due to absence of standard production technique. As a result they do not get satisfactory yield and ultimately become financially loser. In our country there are very few research works for focusing on the spacing and variety performance of bush bean production in Bangladesh. The maximum pod was recorded with the highest plant density (Moniruzzaman *et al.* 2009). These results are in agreement with the findings of Chakravorty *et al.* (2009) and Singh *et al.* (1996). Optimum plant spacing is essential for attaining desired yield because high plant density results in reduction of number of pods per plants and seeds per pod. So, optimum plant density is essential for maximizing the productivity of bush bean.

Considering the above facts, the present study is undertaken with following objectives

1. To find out varietal performance on the productivity and profitability of bush bean.
2. To observe optimum spacing on the productivity and profitability of bush bean.
3. To find out suitable combination of variety and spacing for ensuring the higher productivity and profitability of bush bean.

Chapter - II

REVIEW OF LITERATURE

French bean (*Phaseolus vulgaris* L.) is an important legume vegetable grown during Rabi season and the Bangladesh Agricultural Research Institute (BARI) has developed two potential French bean varieties like BARI bush bean-1 & BARI bush bean-2. Plant spacing is another important factor of crop production. Practically, a suitable combination of plant spacing and varieties is very important in producing higher yield of French bean. Thus, the present investigation was undertaken to determine proper variety and spacing to maximum yield productivity of French bean as well as increased to profitable. However, on the base of this topic very little information is available regard on Bangladesh perspective and present study is presenting here the following heads.

2.1 Effect of variety on productivity of Bush Bean

Kakon *et al.* (2015) conducted an experiment into agronomy research field of Bangladesh Agricultural Research Institute (BARI), Joydebpur under Gazipur districts of Bangladesh during the period from November 2009-10 and 2010-11. The experiment site was located Chhiata Series under Agro-Ecological Zone-28 (AEZ-28) and found that effect of flowering pattern and floral abscission on the yield and yield attributed characters of French bean varieties. There nine varieties were treated- (1) BARI Jharsheem-l (2) BARI Jharsheem-2 (3) Sylhet local 1 (4) Sylhet local 2 (5) Sylhet local 3 (6) Sylhet local 4 (7) Syihet local 5 (8) Sylhet local 6 and (9) Sylhet local 7. The duration of flowering was dependent on growing periods and varieties. All local varieties started flowering at 37-40 DAS and high yielding variety BARI Jharsheem-1 and BARI

Jharsheem-2 were taken 5-6 days more than local variety. In both the years, the longest among the treatment the highest number of flower was recorded within 5 to 8 days in BARI Jharsheem-2. Although, the maximum flower opened within *5* to 8 days and following ceased within 15 to 20 days after first flowering. The total number of flowers per plant varied between 19.36 to 45.06 and 22.0 to 47.20 in two consecutive years while percentage of pod abscission varied between 70.53 to 82.26 and 73.46 to 80.75 in two consecutive years. The flowering pattern and percent abscission as well greater number of pod were found to be the influential character for the highest yield of French bean.

Noor *et al.* (2014) reported that eleven genotypes variety of French bean (*Phaseolus vulgaris* L.) including BARI bush bean-1 and BARI bush bean-2 which were screened to select a suitable one which could provide optimum yield of fresh pod. The maximum fresh pod yield (14.25 t/ha) was found for BARI bush bean-1 followed by BARI bush bean-2 (13.23t/ha). BARI bush bean-1 required the minimum time of 88.33 days while BB 3 the maximum of 110.00 days to attain 90% pods maturity. The highest number of diseased plants was observed in BB 5 (30.33%) and the lowest were in BARI bush bean-1 (7.33%) whereas BARI bush bean-2 was highest disease incident 16.67%. No significant difference ($P < 0.05$) in maximum protein content among the studied genotypes was observed, for example BB 15 (21.60%) and BARI bush bean-1 (21.57%). Maximum crude fiber (5.53%) was obtained from BARI bush bean-1 followed by BB 6 (5.50%), BB 20 (5.50%) and BB5 (5.47%) which all were statistically similar. Among all the genotypes, BARI bush bean-1 showed highest pod yield and superior quality of French bean that was recorded in BARI bush bean-1 (64.13 g and 14.25 t/ha) followed by BARI bush bean-2 (59.53 g and 13.23 t/ha) ($P < 0.05$) which are more suitable for human consumption. BARI bush bean-1 took minimum time for 90% flowering (34.67

days), 90% pod setting (37.33 days), and 90% maturity of pods (88.33 days). Moreover, the maximum crude protein (21.57%) and crude fiber (5.53%) were obtained from BARI bush bean-1. Therefore, BARI bush bean-1 was selected as best for its quality and yields (fresh pod) among eleven genotypes of French bean.

Moniruzzaman *et al*. (2009) reported that French bean comprising two varieties i.e. BARI bush bean-1 and BARI bush bean-2 by application of 120 kg N/ha coupled with the highest plant density such as the lowest plant spacing gave the maximum pod yield of 34.3 t/ha and 30.2 t/ha in BARI bush bean-1 and BARI bush bean-2 respectively. The data on the effect of varieties, plant density, and nitrogen levels on the yield attributers and pod yield have been projected with the following. There was no significant difference in two varieties with respect to branches per plant, pod length, and number of green pods per plant. However, the plant heights, pod width, green pod weight per plant and pod yield were significantly higher in BARI bush bean-1 as compared to BARI bush bean-2. The pod yield varied due to effect of variety of bush bean are 23.3 and 21.4 t/ha respectively.

Moniruzzaman *et al*. (2007) experimented on French bean having three varieties (BARI Jhar sheem-1, BARI Jhar sheem-2 and Local) and six sowing dates at 10 days interval from November 01 to December 20) was conducted at the Agricultural Research Station, Raikhali, Rangamati Hill District during the Rabi seasons of 2004-05 and 2005-06 to find out the suitable variety and optimum sowing date for getting higher pod yield. Varieties showed significant variation in plant height, number of branches per plant and dry weight per plant. Variety BARI Jhar sheem-2 produced significantly smallest plant in both the years, whereas the plant height was highest in local variety though at par with BARI Jhar sheem-1 during 2005-06. However, branches/plant and dry weight/plant was significantly lowest in local variety compared to BARI Jhar sheem-2 and BARI Jhar sheem-1 during both the years. Bari Jhar sheem-1 significantly produced maximum number of branches/plant closely followed by BARI Jhar seem-2 and highest dry weight/plant in both the years. Varieties had significant effect on the yield attributes (pod length, pod width, pods/plant and weight of 10 pods) and yield of French bean. The variety BARI Jhar sheem-2 significantly produced longer pods having lowest diameter during both the years. November 10 sowing was statistically at par with November 20 sowing gave the highest pod yield of French bean. Two variety are produced maximum pod yield 16.57 t/ha and 16.5 t/ha respectively.

Roy *et al.* (2006) found the relationship between yield and its component characters of twenty seven bush bean (*Phaseolus vulgaris* L.) genotypes during November 2002 to February 2003. Ten characters were studied to identify suitable traits for yield improvement of this crop. The yield difference was attributed mainly due to variation in yield components such as days to 50% flowering, duration of flowering, plant height, pod length, pod breadth, pod per plant among genotypes (BB 1, BB 2, BB 3, BB 4, BB 5, BB 6, BB 7, BB 8, BB 9, BB 10, BB 11, BB 12, BB 13, BB 14, BB 15, BB 16, BB 17, BB 18, BB 19, BB 20, BB 21, BB 22, BB 23, BB 24, BB 25, BB 26 and BARI bush bean-1). Genotypes varied from 34.33 to 54.67 days to initiate 50% flowering. The number of pods per plant was the highest in BB 15 (22.64) followed by BB 3 (17.87) whereas BARI bush bean (7.97).

Hussain (2005) reported an experiment in Bangabandhu Seikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur on yield and quality of improvement of bush bean as influenced by date of sowing and marked differences in diseased plants were observed in all eleven genotypes of French bean. The highest number of diseased plant was recorded in BB 5 (30.33%) and the lowest in BARI bush bean-1 (7.33%). It has been reported that percentages of disease plants were influenced by sowing time of bush bean and this percentage increased the yield of the French bean. Early sowing (15 November) was found better than late sowing (15 December) that is yield and quality decreased gradually with the delay of sowing. BARI bush bean-1 took the shortest time (86.67 days), while BB 3 the longest time (101.83 days) to maturity.

Roy (2004) found an experiment in Bangabandhu Seikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur on Characterization and yield variation in bush bean (*Phaseolus vulgaris* L.) genotypes and observed variation (15.00 to 21.67 days) among the genotypes in respect of days required to attain 4 leaves stage. BARI bush bean-1 took the shortest time to attain 4 leaves stage (17.33 days), whereas the genotype BB 3 took the longest (23.00 days). BB 4 (33.01) took minimum days to first flowering followed by BB 22 (35.31), BB 5 (36. 10) and BB 24 (36.77). The maximum day was required for the genotype BB 9 (53.80). Number of leaves at first flowering ranged between 7.00 (BARI bush bean-1) and 17.39 (BB 9). Regarding days to 50% flowering the genotype BB 9 (54.67) took maximum days closely followed by BB 14 (54.33). The longest pod (12.34 cm) was recorded in BB 18 followed by BB 10 (11 .92 cm), BB 22 (11 .82 cm) and BB 19 (11.41 cm), respectively while BARI bush bean-1 was recorded (8.94 cm).

Joshi *et al.* (1987) reported that the varieties required 45-46 days to attain 50% flowering, which was in consonance with the majority of varieties under investigation. Days to 90% pod setting was significantly varied ($P< 0.05$) in different genotypes. The genotypes BB 3 (58.67) and BB 15 (57.33) required maximum days; whereas BARI bush bean-1 (37.33) required minimum days for

90% pod setting. Minimum days for 90% maturation of pods (88.33 days) were recorded in BARI bush bean-1 and maximum in BB 3 (110 days) ($P < 0.05$).

2.2 Effect of spacing on productivity of bush bean

Elhag and Hussein (2014) conducted a field experiment during the winter season of the year 2011-2012, at the College of Agricultural studies, University of Science and Technology, Sudan. Two sowing dates 7th November and 26th November, respectively and six plant populations obtained by three plant spacing (10, 15 and 20cm plant spacing) and two planting densities (2 and 3 plants/hill). The results showed that early sowing date had positive effects on both growth and pod yield and quality compared to late sowing, irrespective of plant population. Increasing of plant population increased plant height but decreased pod yield. The highest pod yield (105.9 g) was obtained at early sowing by 2plants/hill and 20cm plant spacing which was almost double that (56.3 g) obtained at the same plant population at late sowing. Pod yield /ha was higher at early sowing at all plant population than late sowing. However, the highest pod yield/ha was obtained at early sowing by the highest plant population (3plant/ hill at 10cm spacing) and the lowest at late sowing by the lowest plant population (2plants/hill at 20cm spacing).Plant spacing affects plant growth and pod yield due to increased competition with increased plant population. Increasing of plant density to 3 plants per hill and at medium plant spacing of 15cm or 2plants/hill at the narrowest spacing 10cm gave maximum pod yield per unit area and quality.

Getachew *et al.* (2014) carried out an experiment into the Jimma, southeast of Ethiopia in the 2010/2011 main cropping season. The treatments were five level of spacing (50 cm x 7 cm, 40 cm x 15 cm, 40 cm x 10 cm, 40 cm x 7 cm, 30 cm x 15 cm) on two pipeline varieties, namely Melka1 and Melka 6. The different sowing dates, green bean sown on the 3rd of July resulted in the highest total marketable pod yield (4326 kg /ha) and the lowest total marketable pod yield (906 kg/ha) was obtained from green bean sown on the 17th of August. Among the spacing combinations, 40 cm x 7 cm gave in the highest total marketable pod yield (3.47 kg /ha) of green beans and the lowest total marketable pod yield (2.53 kg/ha) was obtained from green bean spaced at 50 cm x 7 cm which was on par with 40 cm x 15 cm and 40cm x l0cm spacing. Hence, the longest pod (13.5 cm) with a wide diameter (0.9 cm) was obtained from variety Melka 1. Pod yield of green bean was higher observed in the narrow spacing than in the wider spacing.

Mureithi *et al* (2012) studied to evaluate the effect of intra-row spacing on growth of French bean (*Phaseolus vulgaris* L.) in Maseno Division, Kenya. The study was carried out at Maseno University Horticultural Farm about intra-row spacing or 10, 15, 20 and 30 cm were evaluated in a randomized complete block design. Growth parameters of plant height, leaf number and branch number were measured on a weekly basis starting two weeks after sowing up to the sixth week. Leaf area and plant dry weight were measured once at six weeks after sowing. Increasing intra-row spacing from 10 cm to 15 cm to 20 cm resulted in significant ($p<0.05$) increase in all the growth parameters that were measured except plant height. Increasing the spacing further to 30 cm between plants resulted in significant decrease in growth rate. Although intra-row spacing 20 cm produced the highest growth rate, cost benefit analysis could be ideal to justify its recommendation over intra-row spacing of 15 cm. Leaf number increased with time in all the four treatments with significant differences being observed as from the fourth week after sowing. The closest intra-row spacing of 10 cm and 15 cm produced statistically equal number of leaves until after six weeks when the latter recorded significantly higher number of leaves (10.2) than the former (8.7). The widest intra-row spacing of 30 cm produced the least number of leaves while the highest leaf number was observed at a spacing of 20 cm between plants.

Moniruzzaman *et al*. (2009) exploited a field experiments with French bean comprising two varieties (BARI bush bean-1 and BARI bush bean-2), three plant densities (500 x 10^3 plants/ha, 333 x 10^3 plants/ha , 250 x 10^3 plants/ha as maintained by 20 cm x 10cm, 30 cm x 10cm, and 40 cm x 10 cm spacing, respectively) were conducted at the Agricultural Research Station, Raikhali in the district of Rangamati during the winter (Rabi) seasons of 2004-05 and 2005-06. Highest plant density 500 x l0^3 plants/ha where spacing is 20 cm x 10 cm, maximum pod yield is 34.3 t/ha and 30.2 t/ha in BARI bush bean-1 and BARI bush bean-2, respectively. Plant height increases with the increase of plant density because of competition of light. Maximum plant height (44.5 cm) was obtained from the highest plant density (500 x 10^3 plants/ha) and the lowest from the lowest plant density (250 x 10^3 plants/ha where plant spacing is 40 cm x 10 cm). Yield components - branches per plant, pod length, pod width, number of green pods per plant and green pod weight per plant recorded the highest values at lower plant density. However, it was not reflected in pod yield per ha, because higher (500 x 10^3 plants/ha) and medium plant density (333 x 10^3 plants/ha where plant spacing is 30 cm x 10 cm) out yielded the lower plant density. The maximum pod was recorded with the highest plant density (24.5 t/ha) and the lowest pod yield with the lowest plant density (20.0 t/ha). These results are in agreement with the findings of Mozumder *et al.* (2003) and Singh *et al.* (1996).

Chakravorty *et al.* (2009) conducted by the Department of Crop Improvement, Horticulture & Agriculture Botany under red and lateritic belt of West Bengal, a field experiment during Rabi season or 2005-06 and 2006-07 to study the effect of spacing on growth and yield of French bean viz. 10 cm x 10cm, 15 cm x 10cm, 15 cm x 15 cm, 20 cm x 15cm, 20 cm x 20cm, 25 cm x 20 cm, 25 cm x 25 cm, 30 cm x 25 cm and 40 cm x 20 cm. Different spacing significantly influenced the various growth, yield attributes and pod yield in French bean. Closely spaced plants attained maximum height, but simultaneously recorded minimum number or branches and leaves per plant. Narrow spacing influenced most of the yield attributes positively by recording higher values. Closer spacing accommodated more number or plants per unit area that might contribute towards higher production and 15 cm x 10 cm spacing was found to be optimum to achieve higher pod yield in French bean.

Samih (2008) reported from an experiment into department of Plant Production and Protection, Al Balqa Applied University in the southern part of Jordan during 2007 about six different planting densities (10 cm x 30 cm, 20 cm x 30 cm, 30 cm x 30cm, 40 cm x 30 cm, 50 cm x 30 cm, 60 cm x 30 cm) of French bean (*Phaselous vulgaris* L.). However, number of days for 50% of plants to be flowered was significantly affected by different planting densities. Lower planting densities needed higher number of days for blooming. The highest planting density (10 cm x 30 cm) gave the highest percent of early yield (93%) in comparison to the total yield which was among the lowest yielding ability and tended to pods. The highest planting density (10 cm x 30 cm) was among the lowest yielding. The highest yields of French beans were obtained under the 20 cm x 30 cm (12.55 t / ha) and 30 cm x 30 cm (12.09 t/ ha) respectively. Moreover, total yields obtained from the two densities were statistically similar. The lowest yielding was given from the lowest density (60 cm x 30cm) which produced 6.98 t/ha.

Pawar *et al.* (2007) conducted an experiment about variety and plant density relation into department of Agronomy Marathwada Agricultural University, India. The four varieties namely HPR 35, PDR 14, HUR 15 and VL 63 and three spacing i.e. 30 cm x 10 cm (3.33 lakh plants/ha), 45 cm x 10 cm (2.22 lakh plants/ha) and 45 cm x 15 cm (1.48 lakh plants/ha) were allotted randomly in each replication. The significantly highest number of branches per plant (6.63) and functional leaves per plant (3.36) was recorded under the variety PDR 14 over the other treatments. There was no significant effect of parameter between the varieties and plant density.

Mozumder *et al.* (2003) was conducted an experiment in the eastern hilly area of Bangladesh where split plot design with six spacing and three planting time of dwarf French bean (*Phaseolus vulgaris* L.) during the period from October to March, 2000. Earlier (October, 15) planting took longer time for flowering and fruiting while late planting (December, 15) gave early flowering but number of pod and pod yield decreased. Wider spacing gave higher number of pod and pod yield per plant but closer spacing gave higher number of pod and pod yield per unit area. The highest pod yield (24.16 t/ha) was obtained from 25 cm x 10 cm spacing of mid-November planting. Plant height, number of branches, foot and root rot disease infestation was higher in earlier planting and was minimum in late planting.

Dhanjal *et al.* (2001) was conducted during the winter seasons of 1996-97 and 1997-98 at Baraut in Uttar Pradesh, and studied the response of French bean (*Phaseolus vulgaris* L.) to plant density. Lowest plant density of 250 x 10^3 plants/ha recorded markedly higher values of growth and yield attributes, except plant height which was the maximum with the highest plant density to 500 x 10^3 plants/ha.

Horn *et al.* (2000) conducted an experiment into 1992-93 season at Agricultural Center of Palma (CAP), University of Federal Peolotas (UFPel) in Brazil to evaluate the effect of spacing variations between rows and plant populations on agronomic characteristics related to mechanized harvest for dry bean (*Phaseolus vulgaris* L.) . Three different row spacing (25, 50 and 75 cm) and four different plant populations/ha (100, 200, 350 and 500 thousand) were used. The reduction in the row spacing, in spite of reducing the plant height, the pod insertion height and the grain yield, resulted in an increase of the lowest pod tip height and in a reduction of the percentage of plants with pods touching the soil surface. The increase in the plant population, despite of not affecting the majority of the agronomic characteristics of the plant, resulted in a reduction of the percentage of plants with pods touching the soil and did not cause any alteration in the pod yield.

Latifi and Navabpoor (2000) conducted an experiment in Gorgan, Iran to evaluate the effect of 3 row spacing levels (40, 50 and 60 cm) and 3 plant densities (20, 30 and 40 plans/m^2) and observed that row spacing of 50 cm positively affected the different crop characters, particularly those of line 11816. Decrease in row spacing resulted in reduction of yield in French bean cv. Pampa.

Samontra *et al.* (1998) stated that the row spacing had significant influence on growth and pod yield of French bean. They said that yield was decreased with increasing row spacing (45-75cm).

Singh (2000) conducted an experiment in Bihar, India during 1991 and 1992 to study the response of French bean cv. Arka Komal to plant spacing or 40 cm x 40 cm, 40 cm x 15 cm and 40 cm x 20 cm. The decreasing plant spacing from 40 cm x 20 cm to 40 cm x 10 cm improved the yield significantly without adversely affecting the pod quality. The highest net returns along with higher rate of net profits were also observed for the closest spacing.

Akher (1999) conducted an experiment on the growth and yield of French bean and found that plant height, TDM, CGR and dry matter accumulation increased with the decreased in spacing. However, the number of branches per plant, pod length, number of pods per plant significantly increased with increase of spacing. Also maximum stem dry matter, leaf dry matter, pod dry matter and pod yields were found in the narrowest spacing.

Another experiment was conducted to observe the effect of plant spacing on the yield of edible pod bean. It was found that at any specific line to line spacing, yield of vegetable bean decreased with the increase in plant to plant spacing. At any plant to plant spacing the bean yield decreased with the increase in line to line spacing. The maximum green pod yield was obtained with a plant spacing of 30 cm x 10 cm (11.84 t/ha).

Blackshaw *et al.* (1999) conducted a field experiment in Alberta, Canada with *Phaseolus vulgaris* cv. Centralia and L9384 grown at row spacing of 23, 46 and 69 cm and densities of 24 or 48 plants /m^2. They observed that reduction in row-spacing increased yield in all years when grown at a density of 48 plants /m^2 but only increased yield in 1 of 3 years when grown 24 plants /m^2. Narrow rows reduced plant biomass and increased bean yield.

Singh and Behera (1998) carried out an experiment in India to study the response of French bean to spacing and found the closer spacing (35 cm x 25 cm) produced significantly the maximum green pod yield.

Chatterjee and Som (1991) conducted a field experiment in west Bengal, India with plant spacing of 40 cm x 10 cm, 40 cm x 15 cm, or 40 cm x 20 cm. Reducing the inter row spacing of French bean (*Phaseolus vulgaris* L.) From

40 to 20 cm, yield was increased from 10.5 to 12.3 t/ha. Argerich and Calvar (1986) observed that closest spacing gave the higher pod yield.

Dhanju *et al.* (1995) conducted a field experiment for 2 years (1991-92) to study the effect of barrier crops (maize, shorghum, okras, sunflowers or *Amaranthus caudatus)* and different spacing on the virus incidence and green pod yield of *Phaseolus vulgaris* cv. Jawala. Of the barrier crops, maize was the most effective as it reduced mosaic virus incidence by about 16% compared with controls with a corresponding increase in yield or about 25%. Among the planting densities, the lowest and highest virus incidences were recorded at spacing of 30 cm x 10 cm and 45 cm x 30 cm, respectively. However the highest green pod yield (7.70 t/ha) was obtained at a spacing of 30 cm x 10 cm.

Jadhao (1993) observed from an experiment conducted in Maharashtra, India that 30 cm x 10 cm spacing (2,20,000 plants/ha) showed better performance than plant spacing of 30 cm x 15 cm and 30 cm x 20 cm. Another observation was found that the incidence or virus diseases or French bean (*Phaseolus vulgaris* L.*)* increased by wider row to row and plant to plant spacing.

Azmi and Rathi (1991) reported that the higher yield with lowest diseases incidence was obtained at a spacing of 30 cm x 10cm.

Grafton *et al.* (1988) carried out a field experiment in the northern Great Plains, USA to investigate the effects of row spacing and plant population of French bean (*Phaseolus vulgaris* L). Row spacing was decreased from 0.75 m to 0.25 m yield was increased in cv. UI 114 and Seafarer by 52 and 44%, respectively. They also observed that row spacing x plant population had no interaction for yield in both cultivars.

Anon., (1995) observed an experiment with edible podded bean, the maximum green pod yield obtained with a plant spacing of 30 cm x 10 cm (11.84 t/ha) the result suggested that a closer spacing was better for a higher vegetable. An experimental result was found that the maximum total and early pod yield in pea at closer spacing. Wider spacing gave longer (El-Habbasha *et al.,* 1996). Plant growth and pod quality were the highest with sowing on two sides of the ridge (28 plant/ m^2) and the highest total pod yield was given by sowing three lines ridge (42 plants/ m^2). Another report was found that the highest planting density (40 plants/ m^2) produced the highest green pod (9.26 t/ha) as in edible podded pea (Rahman *et al.,* 2000).

Vulsteke (1985) observed from a trial in Belgium that *Phaseolus vulgaris* cultivars Belami and Prifin and observed that *33* cm inter row-spacing gave an average of 37 plants/m^2 by planting 45 seeds/m^2 and gave the most economic yields of green beans.

Lima *et al.* (1983) reported that spacing had little effect on yield except during the wet season when yield was significantly higher at wider spacing.

Mangual and Torres (1979) stated that different varieties needed different spacing for growth and yield of French bean. In a trial with French bean (*Phaseolus vulgaris* L.) planted at 30, 45 and 60 cm between rows and found that pod weight and pod number per plant were highest with the widest planting distance.

Bull (1977) conducted an experiment with three pea varieties with 17, 34, 51 and 68 cm spacing between rows and stated that closely spaced plants yielded higher than that of wide spaced plants of Phaseolus *vulgaris* L. bean. They also observed that decreasing row spacing and higher plant density generally increased yields or green peas (Guzal *et al.* 1976).

Isasi *et al.* (1985) found significant interaction between variety and spacing regarding yield of *Phaseolus vulgaris* L.

Gretzmacher (1975) conducted a spacing trial with bush bean using plant densities of 316, 192, 170 or 115 plants /m². The beat single plant harvest results were obtained at the lower density and triangle pattern.

Shekhawat *et al.* (1967) compared row spacing of green peas of free branching variety W29. They found that 45.7cm row spacing gave better yields than 30.5 cm, 61 cm or 91.4 cm rows. They also observed that the inability of plant growth to compensate for the loss of yield may be due to reduced population at spacing above 45.7 cm with rows 30.5 cm apart. The increased population with closer row could not offset the per plant yield reduction.

Koli and Akashe (1995) carried out an experiment on plant density of French bean (*Phaseolus vulgaris* L.). Seeds were sown in rows 22.5 cm or 30 cm apart at plant densities of 222222, 333333 or 44444 plant/ha. They observed the 20, 40 and 60 days after sowing and the highest pod yield at harvest with crops sown at row 30 cm apart and 222222 plants/ha.

Chapter - III

MATERIALS AND METHODS

The field experiment was conducted to find out the productivity and profitability. In this chapter, a short description of the location of experimental site, soil and climate condition of the experimental plot, materials used for the experiment, design of the experiment, data collection procedure and statistical analysis and economic analysis have been presented.

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the Rabi season from November 2014 to January 2015.

3.1.2 Experimental site

The experiment was conducted at the Horticulture research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in 24.09^0 N latitude and 90.26^0 E longitudes. The altitude of the location was 8 m above the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207.

3.1.3 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I. During the experimental period the maximum temperature (25.8^0C) was recorded from November, 2015 and the minimum temperature (12.4^0C) from January, 2015, highest relative humidity (78%) was recorded from November, 2015, whereas the lowest relative humidity (68%) was recorded in January, 2015.

3.1.4 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agro-ecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace soil. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of silty clay with P^H and organic matter 6.1 and 1.13, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay, which have been presented in Appendix II.

3.2 Experimental details

3.2.1 Planting materials

In this experiment two bush bean variety seeds (BARI bush bean-1 and BARI bush bean-2) were used. Seeds were collected from Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.2.2 Land Preparation

The selected plot of the experiment was opened in the 1st week of November 2014 with a power tiller, and left exposed to the sun for a week. Subsequently cross-harrowing was done five times with a country plough followed by laddering to make the land suitable for planting the seed tubers. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilt was achieved. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.2.3 Manuring and fertilization

The sources of N, P_2O_5, and K_2O are found compositing into Urea, TSP and MP which were applied, respectively. The entire amounts of Cowdung, TSP and Gypsum were applied as a basal dose during final land preparation whereas total amount of Urea and MP were applied in three splits. 1/3 amount of Urea and MP were applied during final land preparation and rest was applied at 15 & 30 days after sowing of seeds. The following manures and fertilizers that were used in the experimental plot suggested by BARI, 2011 have been presented in the appendix III.

3.2.4 Experimental design and layout

The experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. Total area 127.4 m^2 (6.5 m x 19.6 m) was divided into three equal blocks. Each block was divided into 12 plots where 12 treatment combinations were allotted at randomly. There were 36 unit plots altogether in the experiment. The size of the each unit plot was 1.5 m × 1.2 m. Furthermore, plot to plot distance was 0.4m and replication to replication distance was 0.5m. The layout of the experiment is shown in Fig 1.

3.2.5 Treatment of the experiment

The experiment was considered as two factors. Factor A comprised of two varieties and Factor B comprised of six population density such as spacing.

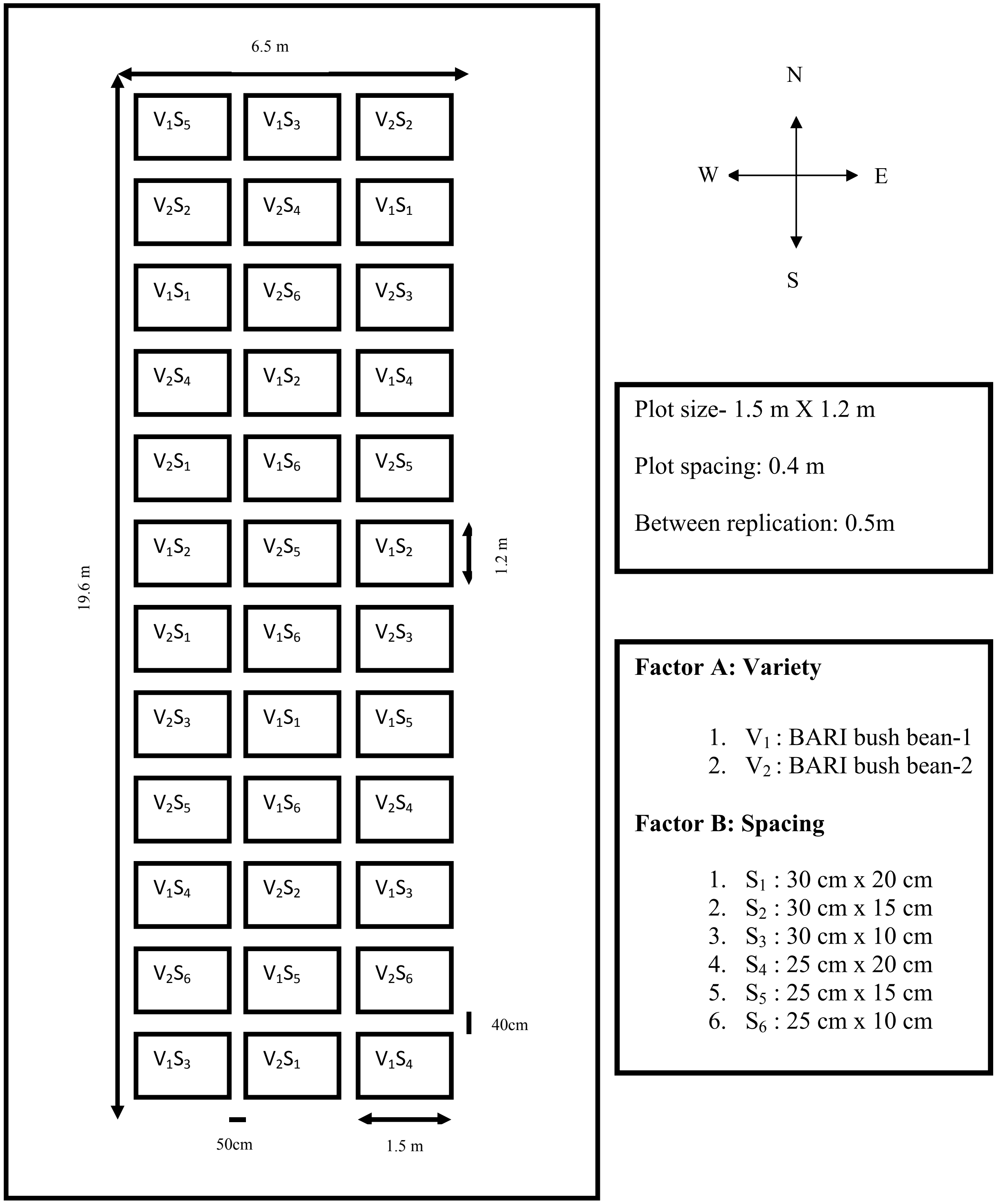


Fig. 1. Layout and design of experimental site

Factor A. Two type of variety (V):

V_1 = BARI bush bean-1; V_2 = BARI bush bean-2;

Factor B. Six level of spacing (S):

S_1 = 30 cm x 20 cm; S_2 = 30 cm x 15 cm; S_3 = 30 cm x 10 cm;

S_4 = 25 cm x 20 cm; S_5 = 25 cm x 15 cm; S_6 = 25 cm x 10 cm;

There were on the whole 12 (2 × 6) treatment combinations such as V_1S_1, V_1S_2, V_1S_3, V_1S_4, V_1S_5, V_1S_6, V_2S_1, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6.

3.2.6 Sowing of seeds

Before seed sowing the seeds were soaked in water to enhance germination. Seeds were also treated with Bavistin @ 2g per kg of seeds before sowing. Two seeds were sown in rows according to the treatments by hand on 10th November, 2014. To allow uniform sowing in rows seeds were mixed with loose soil. The sowing was done with the following spacing 30 cm x 20 cm, 30 cm x 15 cm, 30 cm x 10 cm, 25 cm x 20 cm, 25 cm x 15 cm, 25 cm x 10 cm.

3.3 Intercultural operation

When the seedlings started to emerge in the beds it was always kept under careful observation. After emergence of seedlings, various intercultural operations i.e. Gap filling, thinning out, irrigation and drainage, weeding and mulching, plant protection measurement and harvesting were accomplished for better growth and development of BARI bush bean seeds.

3.3.1 Gap filling

When seeds failed to germinate, the seedlings were transferred to filling the gap. Gap filling was done in second week after the sowing seed. Seedlings about 15 cm in height were transplanted during evening and watering were done to protect the seedlings from wilting.

3.3.2 Thinning Out

One seedling was kept in each hill and remaining was uprooted after 15 days of emergence.

3.3.3 Irrigation and drainage

Over-head irrigation was provided with a water can to the plots once immediately after germination in every alternate day in the afternoon. Stagnant water was effectively drained out at the time of heavy rains.

3.3.4 Weeding and mulching

Weeding and mulching were done three times as and when necessary. Weeding done to keep the plots free from weeds, easy aeration of soil, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully after complete emergence of seedlings whenever it is necessary. Breaking the crust of the soil was done accordingly. The crop was infested by Fusarium wilt at early stage of growth and controlled by applying Ridomil @ 2.58 per liter at the base of the plant. Fungicide and insecticide were applied as and when necessary.

3.3.5 Plant protection measurement

At early stage of growth, some plants were attacked by insect pests (mainly aphids) and hairy caterpillar attacked the young plant. For controlling leaf caterpillars Bavistin @ 2 g/L water was applied 2 times at an interval of 10 days starting soon after the appearance of infestation. Some plants were attacked by the bean common Mosaic virus (BCMV). Those plants were removed from the plots and destroyed.

3.3.6 Harvesting

Green pods were harvested at tender stage. At harvest, pods were nearly full size, with the seeds still small (about one-quarter developed) with firm flesh. These pods were weighed to estimate fresh pod yield. Harvesting pod collected in different stage, specially accumulated pod three times in three weeks. The pods were harvested at 9-15 days after pollination based on the crude method of fiber development (Snapping technique).

3.4 Data collection

Data were recorded on the following parameters from the sample plants during the course of experiment. Five plants were randomly selected from each unit plot for the collection of data.

3.4.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at 15 days interval from 15 DAS to 45 DAS. The height was measured meter scale from the attachment of the ground level up to the tip of the growing point. Five plants of each plot were used to count the average plant height.

3.4.2 Number of compound leaves per plant

The number of compound leaves per plant was counted at 15 days interval from 30 DAS to 60 DAS seed in the plants of experimental plot. Five plants of each plot were used to measure the average number of leaves.

3.4.3 Number of branches of plant

Five plants of each plot were collected to evaluate the average number of branches per plant. The number of branches per plant was documented at 15 days distance from 30 DAS to 60 DAS seed in the plants of experimental plot.

3.4.4 Leaf length (cm)

Five plants of each plot were exercised to compute the average leaf length. The Leaf length of plant was counted in centimeter (cm) at 15 days times from 30 DAS to 60 DAS seed in the plants of experimental plot. It was measured meter scale from the attachment of shoot to the tip of the leaf point.

3.4.5 Leaf breadth (cm)

The Leaf breadth of plant was recorded in centimeter (cm) by at 15 days times from 30 DAS to 60 DAS seed in the plants of experimental plot. It was measured meter scale that 90^0 angle of leaf length which was the maximum diameter of the leaf. Five plants of each plot were used to determine the average leaf breadth.

3.4.6 Days to first flower initiation

The number of days after sowing (DAS) to first flower opening was recorded and five randomly selected plants per plot were used to measure the average days for initiation.

3.4.7 Days to 50% and 90% flower initiation

The number of days after sowing (DAS) to 50% and 90% flower opening was recorded and five randomly selected plants per plot were exercised to evaluate the average days for initiation.

3.4.8 Number of pods per plant

Total number of pods was recorded and five randomly selected plants per plot were used to measure the average number of pods per plant in three different harvesting.

3.4.9 Pod length (cm)

Five pods of the selected plants of were counted randomly. Length of pod selected plants was measured and their mean value was calculated. The pod length was recorded in centimeter (cm).

3.4.10 Pod diameter (cm)

The pod diameter of plant was recorded in centimeter (cm). From five randomly selected plants with the help of slide calipers and their mean value was calculated.

3.4.11 Pod yield per plant (g)

Fresh green pods from five randomly selected plants were counted and their average was found out. The pod yield of plant was recorded in gram (g).

3.4.12 Pod yield per plot (g)

Green pods were harvested from each unit plot at seven days interval and their weight was recorded. Harvesting was done at three times and their total weight was recorded in each unit plot and expressed in gram (g).

3.4.13 Pod yield (t/ha)

The green pod yield per plot was finally converted to yield ton per hectare and was expressed in ton (t).

3.4.14 Dry matter of shoot (%)

Shoot (100 g) from selected plants was taken. The material was then cut with a fine knife, thereafter dried under room condition and kept in an oven at 70^0C till the constant weight was reached. The percentage of shoot was calculated by using the following formula.

$$\text{Dry matter of shoot (\%)} = \frac{\text{Dry weight of shoot}}{\text{Fresh weight of shoot}} \times 100$$

3.5 Static analysis

The experimental data obtained for different parameters were statistically analyzed by using MSTAT computer program. The mean values of all the recorded characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the individual and treatment combinations means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability.

3.6 Economic analysis

Economic analysis was done in order to find out the most profitable treatment combinations.

i. Analysis or total cost of production of bush bean

All the non-material input cost, interest on fixed capital of land and total input cost and miscellaneous cost were considered for computing the total cost of production. The interest of land rent and capital for 12 month was calculated 10% for three-month and 12% for 12 month respectively as well as miscellaneous cost was considered as 5% of the total input cost.

ii. Gross Income or gross return

Gross income was calculated on the sale of marketable green pod of bush bean.

iii. Net Return

Net return was calculated by deducting the total production cost from the gross income for each treatment combination.

iv. Benefit cost ratio:

The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

Plate1: Flowering stage of BARI bush bean-1

Plate 2: Flowering stage of BARI bush bean-2

Plate 3: Pod setting of BARI bush bean-1

Plate 4: Pod setting of BARI bush bean-2

Plate 5: Pod of BARI bush bean-1

Plate 6: Pod of BARI bush bean-2

Chapter - IV

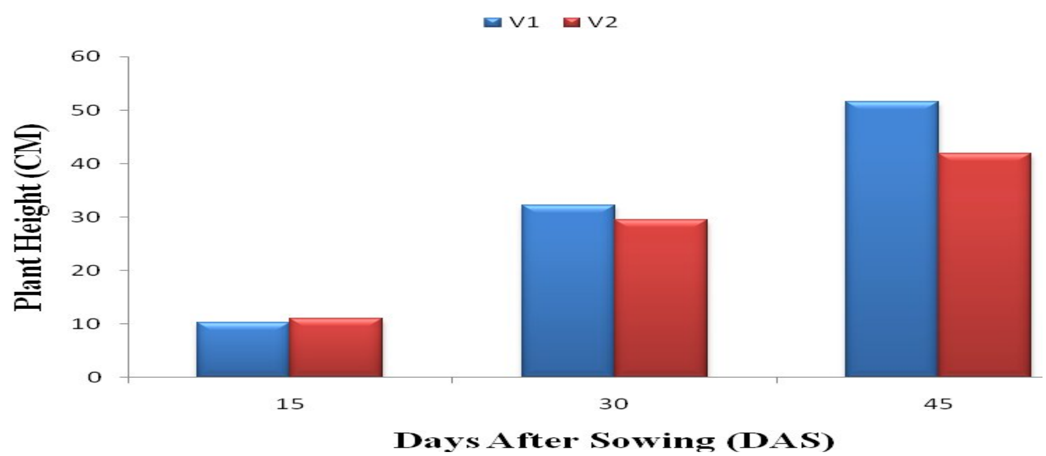
RESULT AND DISCUSSION

The present experiment was conducted to investigate the Productivity and profitability of bush bean *(Phaseolus vulgaris* L.*)* as influenced by different variety and spacing. The analyses of variances (ANOVA) of the data on different characters and yield of bush bean have been presented in Appendix IV. The results of the experiment as influenced by variety, different levels of plant spacing and their different combinations have been presented and discussed in this chapter under the following headings.

4.1 Plant height

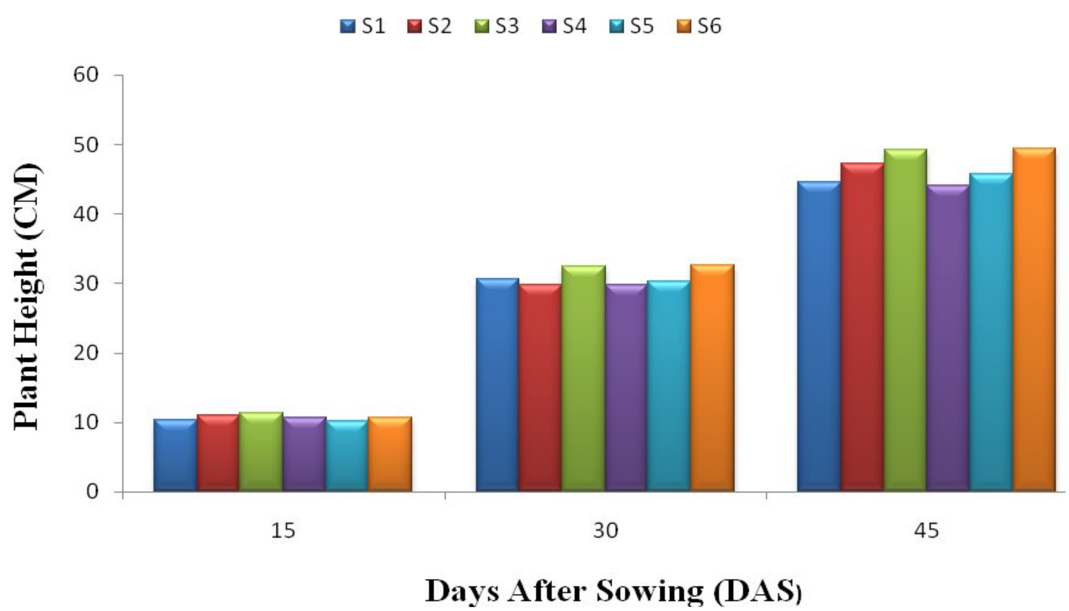
Plant height is an important character, which is very essential parameter for plant growth and development. Plant height was significantly influenced by variety (Appendix IV). Plant height was found to be statistically significant at 15 DAS, 30 DAS and 45 DAS. At 45 DAS, the maximum plant height (51.50 cm) was found from BARI Bush bean-1 and the minimum (41.93 cm) was observed from BARI bush bean-2 (Fig. 02). Probably the genetic makeup of varieties was responsible for the variation in plant height. This result is in agreement with findings of Moniruzzaman *et al.* (2009) that reported at the same days, the plant height for BARI bush bean-1 and BARI bush bean-2 were 45.3 cm and 41.8 cm, respectively.

Optimum plant height can be achieved during growth and development stage with proper management practice. Plant height is influenced by growing condition such as spacing. Effect of different plant spacing on plant height at 15 DAS was found to be statistically non significant but after 15 DAS plant height was statistically significant up to 45 DAS (Appendix IV). At 45 DAS, the tallest plant



V_1=BARI bush bean-1, V_2= BARI bush bean-2

Fig. 2. Effect of variety on plant height at different days after sowing of bush bean (*Phaseolus vulgaris* L.).



S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Fig. 3. Effect of spacing on plant height at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Table 1. Combined effect of variety and spacing on plant height at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Treatments	Plant height (cm)		
	15DAS	**30DAS**	**45DAS**
V_1S_1	10.32	34.27	50.78 bc
V_1S_2	10.85	30.13	52.70 ab
V_1S_3	10.94	33.93	53.30 ab
V_1S_4	9.99	31.17	47.83 de
V_1S_5	9.57	31.3	49.03 cd
V_1S_6	10.23	31.93	55.40 a
V_2S_1	10.32	28.93	38.27 i
V_2S_2	11.16	29.81	41.97 gh
V_2S_3	11.61	33.13	45.20 ef
V_2S_4	11.27	29.53	40.20 hi
V_2S_5	10.65	29.3	42.50 fgh
V_2S_6	11.04	31.07	43.47 fg
LSD(0.05)	NS	1.02	3.24
CV%	9.36	9.11	10.34

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

(49.43 cm) was found from S_6 (25 cm x 10 cm) treatment, which was statistically identical to S_3 (49.25 cm) and statistically similar to S_2 (47.33 cm) treatments and the shortest plant (44.02 cm) was found from S_4 (25 cm x 20 cm) treatment, which was statistically similar to S_1 and S_5 treatments. Plant height increased with decreased plant spacing (Fig.03). Plant height was influenced by spacing might be due to the competition for nutrient, space, moisture and light among the plants grown at different plant spacing. The variation in plant height as influenced by plant spacing might be due to the elongation of internodes for light in a crowded population . However, Alemayehu *et al.* (2015) reported the similar findings at 266,667 plant/ha (10cm spacing) and 133, 333 plants/ha (20cm spacing) were 48.67 cm & 40.58 cm respectively.

Combined effect of variety and spacing was found to be statistically non significant at 15 DAS to 30 DAS but after 30 DAS plant height was found statistically significant at 45 DAS on plant height (Appendix IV). At 45 DAS, the maximum plant height (55.40 cm) was found from V_1S_6 (BARI Bush bean-1 with 25 cm x 10 cm) treatment combination, which was statistically similar to V_1S_3 (53.30 cm) and V_1S_2 (52.70 cm) treatment combination, while the minimum height (38.27cm) was recorded from V_2S_1 (BARI bush bean-2 with 30 cm x 20 cm) treatment combination, which was statistically similar to V_2S_4 (40.20 cm) treatment combination (Table 1). Plant height Moniruzzaman *et al.* 2009 found the treatment combination of highest plant height 46 cm for BARI bush bean-1 at 40 cm x 10 cm spacing and the lowest height 40 cm for BARI bush bean-2 at spacing 40 cm x 10 cm.

4.2 Number of compound leaves per plant

Number of compound leaves per plant is a vital parameter and an important part of crop plant because of its physiological role in photosynthetic activities. Number of leaves is directly related to the yield of bush bean. Effect of variety on number of compound leaves was found to be statistically non significant influenced at 30 DAS but after 30 DAS to 60 DAS were found to be statistically significant (Appendix IV). At 60 DAS, highest number of leaves per plant (18.84) was recorded from BARI bush bean-2 while lowest number of leaves (12.23) was found from BARI bush bean-1 (Table 2). Noor *et al.* (2014) founded that the number of leaves per plant of both varieties were 11.67 at 50% pod setting.

Table 2. Effect of variety on number of compound leaves and branch per plant at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Treatment	Number of compound leaves per plant			Number of branches per plant		
	30DAS	45DAS	60DAS	30DAS	45DAS	60DAS
V_1	5.65	7.79 b	12.23 b	1.12	1.27	4.68 b
V_2	5.37	8.42 a	18.84 a	1.21	1.24	6.94 a
LSD (0.05)	NS	0.58	4.61	NS	NS	1.89
CV%	9.1	13.99	13.84	8.21	7.35	8.66

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2

Table 3. Effect of spacing on number of Compound leaves and branch per plant at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Treatments	Number of compound leaves per plant			Number of branches per plant		
	30DAS	45DAS	60DAS	30DAS	45DAS	60DAS
S_1	5.36	9.033 a	18.40 a	1.2	1.36	6.35 ab
S_2	5.28	7.76 abc	16.81 ab	1.06	1.25	4.74 c
S_3	5.79	7.742 bc	14.85 bc	1.28	1.26	5.35 bc
S_4	5.4	8.80 ab	16.59 ab	1.31	1.13	7.08 a
S_5	5.7	8.26 abc	13.66 c	1.08	1.26	6.04 ab
S_6	5.53	7.03 c	12.91 c	1.06	1.26	5.32 bc
LSD(0.05)	----	1.26	2.57	----	----	1.28
CV%	9.1	13.99	13.84	8.21	7.35	8.66

*Means in a column followed by the same letter do not differ significantly at 5% level;
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Table 4. Combined effect of variety and spacing on number of leaves and branch per plant at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Treatments	Number of compound leaves per plant			Number of branches per plant		
	30DAS	45DAS	60DAS	30DAS	45DAS	60DAS
V_1S_1	5.73	8.06 cd	13.87 ef	1.06	1.26	5.37 bcd
V_1S_2	5.56	7.80 cde	12.65 f	1.2	1.24	4.07 d
V_1S_3	5.8	7.48 cde	12.62 f	1.13	1.13	3.96 d
V_1S_4	5.333	8.13 cd	13.50 f	1.23	1.26	6.28 bc
V_1S_5	5.733	8.00 cd	10.31 g	1.03	1.33	4.60 cd
V_1S_6	5.733	7.26 de	10.44 g	1.06	1.4	3.84 e
V_2S_1	5	10.00 a	22.93 a	1.33	1.46	7.32 a
V_2S_2	5	7.73 cde	20.98 b	0.93	1.26	5.42 bcd
V_2S_3	5.78	8.00 cd	17.09 c	1.43	1.4	6.73 b
V_2S_4	5.46	9.46 ab	19.69 b	1.4	1	7.89 a
V_2S_5	5.66	8.53 bc	17.00 cd	1.13	1.2	6.30 bc
V_2S_6	5.33	6.80 e	15.38 de	1.06	1.13	6.80 b
LSD(0.05)	NS	1.26	2.57	NS	NS	1.28
CV%	9.1	13.99	13.84	8.21	7.35	8.66

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Effect of spacing on number of compound leaves per plant was observed statistically significant at 45 DAS and 60 DAS except at 30 DAS (Appendix IV). At 60 DAS, the highest number of compound leaves per plant was recorded (18.40) from S_1 (30 x 20 cm) treatment, which is statistically similar to S_2 (16.81), S_4 (16.59) treatments while the lowest number of leaves per plant (12.91) was counted from S_6 (25 x 10 cm) treatment, which was statistically identical to S_5 (13.66) and S_3 (14.85) treatment (Table 3). The trend of increasing number of compound leaves with increasing plant spacing was perhaps due to the fact that the plants at wider spacing had less competition for plant nutrients water, light and air thereby could grow luxuriantly with more number of leaves per plant. The results are in conformity with Chakrovatry *et al.* (2009) reported about leaves per plant (highest no of leaves 19.03 and lowest 12.20 at 30 cm x 25 cm and 20cm x 15 cm respectively).

Combined effect of variety and plant spacing should significant differences on number of compound leaves per plant except 30 DAS (Appendix IV). The number of compound leaves per plant was gradually increased with time up 30 to 60 DAS. At 60 DAS, the highest number of compound leaves was recorded (22.93) at V_2S_1 (BARI bush bean-2 with 30 x 20 cm) treatment combinations and the lowest number of compound leaves was recorded (10.31) from V_1S_5 (BARI bush bean-1 with 25 x 15 cm) treatment combination, which was statistically identical to V_1S_6 (10.44 cm) (Table 4).

4.3 Number of branches per plant

Number of branches per plant was found to be statistically non significant at 30 DAS to 45 DAS but it was found statistically significant at 60 DAS (Appendix V). At 60 DAS, the maximum number of branches per plant (6.94) was obtained from V_2 (BARI bush bean-2) whereas minimum branches per plant

(4.68) was recorded from V_1 (BARI bush bean-1) treatment (Table 2). The probable reason of this difference could be the genetic make-up of the variety. Moniruzzaman *et al.* (2007) studied that the number of branch per plant of BARI bush bean-1 and BARI bush bean-2 were 4.21 and 4.24 respectively.

Number of branches per plant was influenced by plant spacing. Number of branches per plant was found statistically non significant at 30 DAS and 45 DAS but statistically significant at 60 DAS (Appendix V). At 60 DAS, the maximum number of branches per plant was recorded (7.08) from S_4 (25 x 20 cm) treatment which, was statistically similar to S_1 and S_5 treatments. The minimum number of branches per plant was counted (4.74) from S_2 (30 x 15 cm) treatment, which was statistically similar to S_3 and S_6 treatments (Table 3). It might be due to the fact that in case of wider spacing plant obtained more plant nutrients, light and other resources for better vegetative growth and producing more branching in plants. The similar result stated by Chatterjee *et al.* 1991 and Pawar *et al.* 2007 that a number of branches/plant increased with increased intra row spacing.

Combined effect of variety and spacing of number of branches per plant was found statistically non significant at 30 DAS to 45 DAS but after 45 DAS it was found statistically significant (Appendix V). (Table 4) The number of branches per plant was gradually increased with time up 30 to 60 DAS. At 60 DAS, the maximum number of branches per plant (7.89) was found from V_2S_4 (BARI bush bean-2 with 25 x 20 cm) treatment combination, which was statistically identical to V_2S_1 treatment combination and the minimum number for branches per plant was recorded (3.84) fromV_1S_6 (BARI bush bean-1 with 25 x 10 cm) treatment combination (Table 4). This result might be due to cause of varietal performance i.e. genotype character and also association with population density.

4.4.1 Leaf length

Due to the effect of variety, a significant variation was found on leaf length at 45 DAS and 60 DAS except at 30 DAS (Appendix V). At 60 DAS, the highest leaf length (26.54 cm) was found from V_2 (BARI bush bean-2) treatment while the lowest leaf length (23.33 cm) was recorded from V_1 (BARI bush bean-1) treatment (Table 5). Probably the genetic make-up of varieties was responsible for the variation in leaf length of plant.

Plant spacing on leaf length at 30 DAS and 45DAS was found to be statistically non significant but leaf length was statistically significant at 60 DAS (Appendix V). In case of plant spacing, leaf length showed increasing trend up to 60 DAS in all treatment (Table 6). At 60 DAS, the highest leaf length (26.86 cm) was recorded from S_1 (30 x 20 cm) treatment, which was statistically identical to S_4 treatment (Table 6). The lowest leaf length was recorded (23.56 cm) from S6 (25 x 10 cm) treatment, which was statistically identical to S_3 treatment and statistically similar to S_5 treatment. The plants grown under wider spacing received more nutrients, light and moisture around compared to plants of closer spacing, which was probably the cause of better performance in leaf length and pod yield of bush bean.

Combined effect of variety and plant spacing showed on leaf length statistically non significant at 30 DAS and 45 DAS but statistically significant at 60 DAS (Appendix V). At 60 DAS, the highest leaf length (29.40 cm) was found from V_2S_1 (BARI bush bean-2 with 30 x 20 cm) treatment combination and it was statistically identical to V_2S_4 (Table 7). On the other hand, the lowest leaf length (21.63 cm) was recorded from V_2S_3 (BARI bush bean-2 with 30 x 10 cm) treatment combination, which was statistically identical to V_1S_6 , V_2S_2 and V_2S_6

treatment combination. The combined effect showed that variety and spacing were significantly and positively affected leaf length of bush bean.

Table 5. Effect of variety on leaf length and leaf breadth at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Treatment	Leaf length (cm)			Leaf breadth (cm)		
	30DAS	45DAS	60DAS	30DAS	45DAS	60DAS
V_1	20.47	21.53 b	23.33 b	6.50 a	8.81 a	8.07 a
V_2	20.36	22.48 a	26.54 a	5.40 b	6.83 b	6.92 b
LSD (0.05)	NS	0.87	1.82	0.95	1.02	0.92
CV%	12.12	10.87	7.22	7.75	8.05	10.65

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2

Table 6. Effect of spacing on leaf length and leaf diameter at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Treatments	Leaf length (cm)			Leaf breadth (cm)		
	30DAS	45DAS	60DAS	30DAS	45DAS	60DAS
S_1	21.10	23.20	26.86 a	6.14	7.03	8.19 a
S_2	21.08	24.53	25.27 b	5.76	7.11	7.48 b
S_3	19.97	22.47	23.83 c	5.97	6.05	6.65 c
S_4	21.35	23.05	26.80 a	6.04	7.01	8.06 a
S_5	19.33	22.44	24.74 bc	5.97	6.92	7.23 bc
S_6	19.7	22.37	23.56 c	5.83	6.17	6.85 c
LSD (0.05)	NS	NS	1.57	NS	NS	0.72
CV%	12.12	10.87	7.22	7.75	8.05	10.65

*Means in a column followed by the same letter do not differ significantly at 5% level;
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Table 7. Combined effect of variety and spacing on leaf length and leaf breadth at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Treatments	Leaf length (cm)			Leaf breadth (cm)		
	30DAS	45DAS	60DAS	30DAS	45DAS	60DAS
V_1S_1	20.47	22.63	26.00 b	6.77	9.43 a	8.99 ab
V_1S_2	21.4	22.23	24.73 bc	6.45	9.25 ab	7.58 cde
V_1S_3	19.9	22.37	24.68 bcd	6.3	8.27 c	6.56 ef
V_1S_4	21.7	23.53	26.09 b	6.54	8.63 abc	9.24 a
V_1S_5	19.8	22.07	25.02 bc	6.5	8.47 bc	7.95 bcd
V_1S_6	19.6	21.38	22.38 e	6.41	6.62 de	6.74 ef
V_2S_1	21.73	24.77	29.04 a	5.5	8.82 abc	8.13 abc
V_2S_2	20.77	21.83	22.63 de	5.07	6.68 de	7.17 de
V_2S_3	20.03	21.14	21.63 e	5.63	6.98 de	6.83 def
V_2S_4	21	24.73	28.40 a	5.54	7.38 d	7.38 cde
V_2S_5	18.87	22.5	25.20 bc	5.44	6.96 de	7.12 def
V_2S_6	19.8	22.67	23.48 cde	5.26	6.39 e	6.34 f
LSD(0.05)	NS	NS	2.05	NS	0.84	1.21
CV%	12.12	10.87	7.22	7.75	8.05	10.65

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

4.5 Leaf breadth

Leaf breadth is also an important determinant of yield potential. There is a general consensus that the higher is the leaf breadth, higher is the yield. There was found a statistically significant variation between the varieties in case of leaf breadth at different days after sowing (Appendix VI). The maximum leaf breadth (8.07 cm) was recorded from V_1 (BARI bush bean-1) treatment whereas the minimum leaf breadth (6.92 cm) was found from V_2 (BARI bush bean-2) treatment (Table 5).

Plant spacing showed non-significant effect on leaf breadth at 30 DAS to 45DAS was found to be statistically non significant but leaf breadth was statistically significant at 60 DAS. In case of plant spacing, leaf breadth showed increasing trend up to 60 DAS in all treatment (Appendix VI). The maximum leaf breadth (8.19 cm) was recorded in S_1 (30 x 20 cm) treatment which was statistically identical to S_4 treatment (Table 6). The lowest leaf breadth (6.65 cm) was recorded from S_3 (30 x 10 cm) treatment, which was statistically identical to S_6 treatment and statistically similar to S_5 treatment. From the result it was found that wider the spacing, higher the leaf breadth. The plants grown under wider spacing received more nutrients, light and moisture around compared to plants of closer spacing, which was also probably the cause of better performance in leaf breadth and pod yield of bush bean.

Combined effect of variety and plant spacing on leaf breadth was found to be statistically non significant differences on leaf breadth except 30 DAS (Appendix VI). At 60 DAS, the maximum leaf breadth (9.24 cm) was recorded from V_1S_4 (BARI bush bean-1 with 25 x 20 cm) treatment combination, which was statistically similar to V_1S_1 and V_2S_1 combination treatment. The lowest leaf breadth (6.34 cm) was recorded from V_2S_6 (BARI bush bean-2 with 25 x 10 cm) treatment combination, which was statistically similar to V_1S_3, V_1S_6, V_2S_3 and V_2S_5 treatment combination (Table 7). This result might be due to cause of varietal performance i.e. genotype character and also association with population density. The combined effect showed that variety and spacing were also significantly and positively affected leaf breadth of bush bean.

4.6 Days to first flower initiation

Day to first flower initiation was showed statistically significant variation due to the effect of variety (Appendix VI). BARI Bush bean-1(V_1) took the shortest period (39.28) days and BARI Bush bean-2 (V_2) took the longest time (50.02) days (Fig. 3). The time taken from flower initiation to fruit set is important phonological character, which is not only dependent on environmental factors but also on the intrinsic factors like, variety, plant spacing, translocation of metabolites etc. Flowering time is the most important time because it plays a vital role in life span of plant. The result was showed similar by findings of Kakon *et al.* (2015) and stated BARI bush bean-2 took 5 to 6 days more than BARI bush bean-1 for first flowering initiation.

Significant variation was found due to the effect of spacing at days to first flower initiation (Appendix VI). The shortest period 43.74 days was required for first flowering from S_5 (25 x 15 cm) treatment, which was statistically identical to S_6 treatment and the longest period 45.47 days was required for S_1 (30 x 20 cm) treatment, which was statistically similar to S_4 treatment(Fig. 4). This might be due to the fact that in case of wider spacing vegetative growth was higher than those of closer spacing which took longer time for flower initiation.

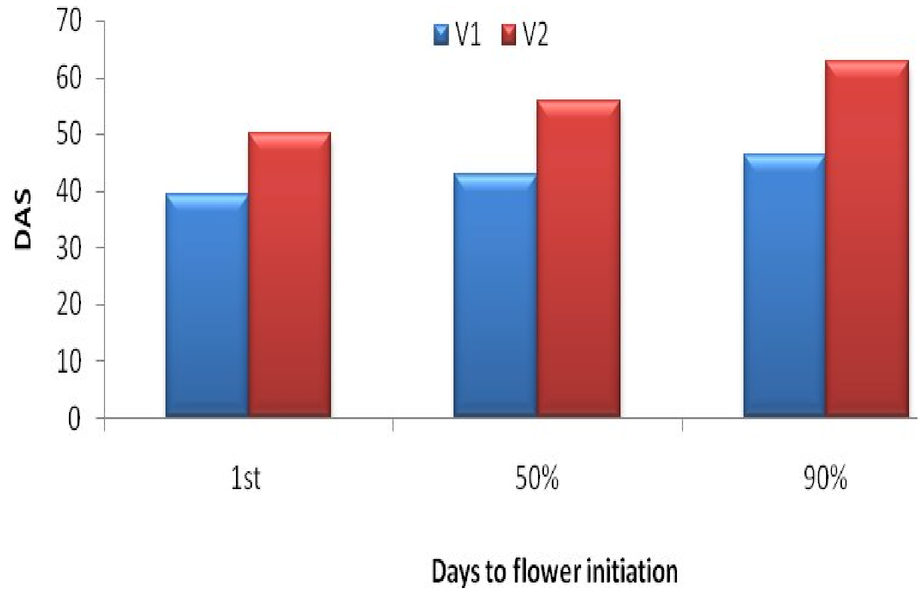
Combined effect of variety and spacing on days to first flower initiation was found to be statistically significant (Appendix VI). The shortest period 37.67 days was required for first flower initiation from V_1S_6 (BARI bush bean-1 with

25 x 10 cm) treatment combination, which was statistically similar to V_1S_3 (BARI bush bean-1 with 30 x 10 cm) treatment combination. The longest period 52.27 days was required from first flower initiation for V_2S_4 treatment combination (Table 8).

4.7 Days to 50% and 90% flower initiation

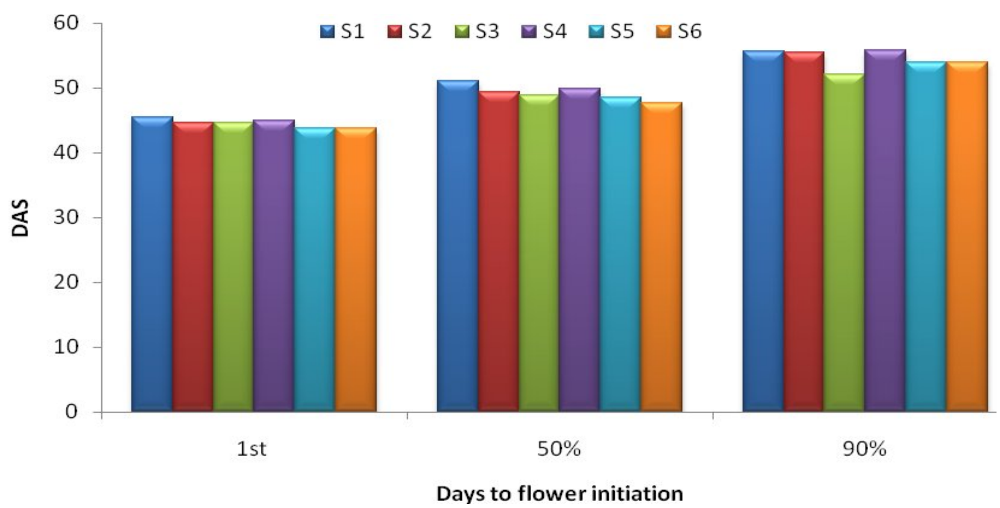
Days to 50% and 90% flower initiation was showed statistically significant variation on variety (Appendix VI). BARI bush bean-1 took the shortest period 42.73 DAS for 50% flowering, 46.23 DAS for 90% flowering. On the other hand, longer period 55.78 DAS was taken from the BARI bush bean-2 to 50% flower initiation and 62.69 DAS to 90% flower initiation (Fig.4) Kakon *et al.* (2015) was showed the longest duration of flowering (range 17-20 days) was observed in BARI bush bean-1 and BARI bush bean-2. Joshi *et al.* (1987) also reported that the varieties required 45-46 days to attain 50% flowering.

Plant spacing on flower initiation at 50% and 90% was also found to be statistically significant (Appendix VI). At 50% flower initiation, shortest period 47.57 days was required from S_6 (25 x 10 cm) treatment, which was statistically similar to S_5 treatment and the longest period 51.10 was recorded from S_1 (30 x 20 cm) treatment, which was statistically similar to S_4 treatment. However, at 90% flower initiation, shortest period 52.10 days was required from S_3 (30 x 10 cm) treatment and the longest period 55.76 days was required from S_4 (25 x 20 cm) treatment, which was statistically identical to S_1 and statistically similar to S_2 treatments (Fig. 5). The similar findings resulted by Samih (2008) who was stated 50% flowered was significantly affected by different planting spacing treatment and lower planting spacing needed lower number of days for blooming.



V_1=BARI bush bean-1, V_2= BARI bush bean-2

Fig. 4. Effect of variety on days to flower initiation at different days after sowing of bush bean (*Phaseolus vulgaris* L.).



S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Fig. 5. Effect of spacing on days to flower initiation at different days after sowing of bush bean (*Phaseolus vulgaris* L.).

Table 8. Combined effect of variety and spacing on days to flower initiation, number of pod per plant of bush bean (*Phaseolus vulgaris* L.).

Treatments	Days to flower initiation			Number of pod
	1st	50%	90%	
V_1S_1	39.87 d	44.00 e	46.53 d	24.69 a
V_1S_2	39.33 de	43.13 f	47.53 d	23.02 ab
V_1S_3	38.67 ef	41.60 g	45.87 de	21.03 bc
V_1S_4	39.37 de	43.53 ef	46.97 d	22.24 bc
V_1S_5	39.27 de	42.80 f	44.20 e	20.43 cde
V_1S_6	37.67 f	41.33 g	46.33 de	17.77 f
V_2S_1	49.47 b	58.20 a	65.40 a	20.30 cde
V_2S_2	49.93 b	55.67 bc	63.45 ab	18.43 ef
V_2S_3	50.35 b	55.00 c	57.67 c	14.88 g
V_2S_4	52.27 a	56.20 b	64.55 a	20.82 bcd
V_2S_5	49.82 b	55.50 bc	63.53 ab	18.70 def
V_2S_6	48.30 c	53.80 d	61.57 b	14.77 g
LSD (0.05)	1.03	0.78	2.26	2.32
CV%	8.37	7.24	7.46	12.45

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Combined effect of variety and spacing on 50% and 90% flower initiation were statistically significant (Appendix VI). The highest 58.20 days was counted from V_2S_1 (BARI bush bean-2 with 30 x 20 cm) treatment combination and the lowest 41.33 days was recorded from V_1S_6 (BARI bush bean-1 with 25 x 20 cm) treatment combination, which was statistically identical to V_1S_3 treatment combination at 50% flower initiation. However, at 90% flower initiation, the highest 65.40 DAS was recorded from V_2S_1 treatment combination which was statistically identical to V_2S_4 treatment combination and statistically similar to V_2S_5, V_2S_2 whereas the lowest 44.20 DAS was counted from V_1S_5 treatment combination which was statistically similar to V_1S_6 and V_1S_3 treatment combination (Table 8).

4.8 Number of pods per plant

The variation in number of pods per plant was found statistically significant due to variety (Appendix VII). The number of pods per plant is one of the most important yield contributing characters in bush bean. The maximum number of pods (21.53) was found from V_1 (BARI bush bean-1) and the minimum (17.98) was obtained from V_2 (BARI bush bean-2) treatment. It might be concluded that genetically BARI bush bean-1 gave more yield than BARI bush bean-2 (Fig. 6). Moniruzzaman *et al.* (2009) found that pod number of BARI bush bean-1 and BARI bush bean-2 was 20.5 and 20.1 respectively**.**

Statistically significant variation in number of pods per plant was observed due to plant spacing (Appendix VII). The maximum number of pods per plant (22.50) was obtained from S_1 (30 x 20 cm) treatment which was statistically similar to S_4 treatment while the lowest number of pod per plant (16.27) was found from S_6 (25 x 10 cm) treatment (Fig. 7).The increase in pods per plant in wider spacing might be attributed due to the less inter plant competition which resulted in better vegetative and reproductive growth of plants. This is in agreement with the findings of Arf *et al.* (1996) stated that higher number of pod per plant attained by increasing plant spacing of bush bean.

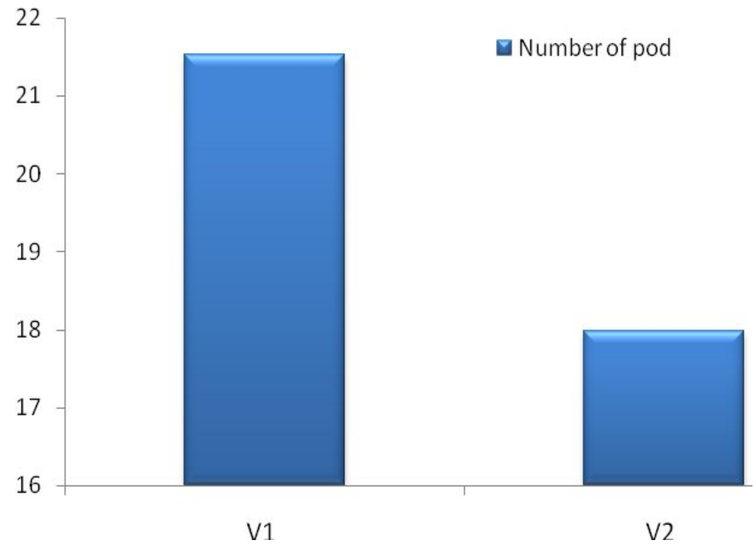
Combined effect of variety and plant spacing showed significant effect on number of pod (Appendix VII). The maximum number pod per plant (24.69) was found from V_1S_1 (BARI bush bean-1 with 30 x 20 cm) treatment combination, which was statistically similar to V_1S_2 treatment combination and the minimum number of pod per plant (14.77) was counted from V_2S_6 (BARI bush bean-2 with 25 x 10 cm) treatment combination, which was statistically identical to V_2S_3 treatment combination (Table 8). This result indicated the differences due to differences in varietal characteristics happened due to genotype variation and also in association with population densities. Moniruzzaman *et al.* (2009) resulted the same finding of combination treatment.

4.9 Pod length (cm)

Pod length was found to be statistically non significant effect due to variety (Appendix VII and Table 9).

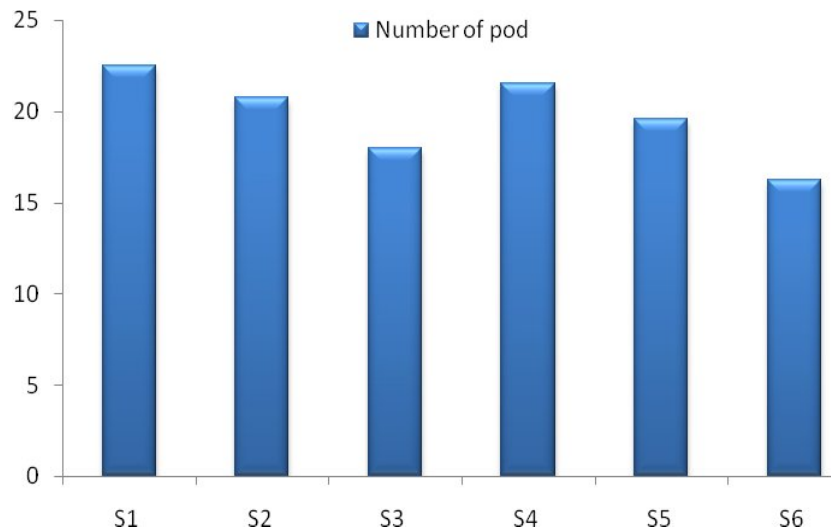
The length of green pod was also statistically significant by using different plant spacing (Appendix VII). The longest pod (13.34 cm) was obtained from S_1 (30cm x 20cm) treatment which was statistically similar to S_2 and S_4 treatments, while the shortest pod length (12.75cm) was found from S_3 (30 x10 cm) treatment, which was statistically similar to $S_{2,}$ S_5 and S_6 treatments (Table 10).

The combined effect of variety and plant spacing on pod length was found to be statistically non- significant (Appendix VII). The longest pod length was found (13.40cm) from V_2S_1 treatment combination. However, the shortest length of pod was (12.70 cm) was found from V_2S_3 treatment combination (Table 11).



V_1=BARI bush bean-1, V_2= BARI bush bean-2

Fig. 6. Effect of variety on number of pods per plant of bush bean (*Phaseolus vulgaris* L.).



S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Fig. 7. Effect of spacing on number of pods per plant of bush bean (*Phaseolus vulgaris* L.).

4.10 Pod diameter

The diameter of green pod was found statistically significant by variety (Appendix VII). The maximum diameter of green pod was found (0.874cm) from V_1 (BARI bush bean-1) treatment and the minimum diameter of pod was found (0.777cm) from V_2 (BARI bush bean-2) treatment (Table 9). Moniruzzaman *et al.* (2009) found that pod diameter of BARI bush bean-1 and BARI bush bean-2 was 0.73 cm and 0.66 cm respectively. Roy *et al.* (2006) found that pod diameter of BARI bush bean-1 was 0.939 cm.

Pod was found to be statistically non-significant due to different plant spacing (Appendix VII and Table 10).

The combined effect of plant spacing was found to be statistically non-significant (Appendix VII).The highest diameter of pod was recorded (0.91 cm) from V_1S_2 treatment combination and the lowest diameter of pod was found (0.736 cm) from V_2S_2 treatment combination (Table 11).

4.11 Pod yield per plant

Pod yield per plant was significantly influenced by variety (Appendix VII). Number of pods per plants is one of most important yield contributing character in bush bean. It was recorded that the maximum pod yield (98.41 g/plant) was obtained from V_1 (BARI bush bean-1) treatment while the minimum pod yield was recorded (64.87 g/plant) from V_2 (BARI bush bean-2) treatment (Table 9). Varietal differences in pod yield per plant might be due to the morpho-physiological and genetic differences between the varieties. Moniruzzaman *et al.* (2009) found that pod yield per plant of BARI bush bean-1 and BARI bush bean-2 were 80.5 g and 71.4 g respectively.

Table 9. Effect of variety on pod length, pod diameter, pod yield per plant, pod yield per plot, pod yield per hectare and dry matter of shoot (%) of bush bean (*Phaseolus vulgaris* L.)

Treatments	Pod length (cm)	Pod diameter (cm)	Pod yield per plant (g)	Pod yield per plot (g)	Pod yield (t/ha)	Dry matter of shoot (%)
V_1	13.04	0.874 a	98.41 a	2719.05 a	15.11	24.28
V_2	13.02	0.777 b	64.87 b	2155.33 b	11.97	24.27
LSD (0.05)	NS	0.091	28.53	532.6	3.47	NS
CV%	9.13	11.21	15.19	16.09	18.09	10.65

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2

Table 10. Effect of spacing on pod length, pod diameter, pod yield per plant, pod yield per plot, pod yield per hectare and dry matter of shoot (%) of bush bean (*Phaseolus vulgaris* L.).

Treatments	Pod length (cm)	Pod diameter (cm)	Pod yield per plant (g)	Pod yield per plot (g)	Pod yield (t/ha)	Dry matter of shoot (%)
S_1	13.34 a	0.813	99.48 a	1817.84 d	10.09 d	26.05 a
S_2	13.16 abc	0.823	83.23 bc	2552.50 b	14.18 b	23.44 bc
S_3	12.75 c	0.815	71.37 de	2662.16 a	14.79 a	22.91 c
S_4	13.25 ab	0.828	92.17 ab	2241.05 c	12.45 c	25.73 a
S_5	12.85 bc	0.843	77.63 cd	2642.00 ab	14.68 ab	24.33 b
S_6	12.80 bc	0.83	66.00 e	2710.25 a	15.06 a	23.23 c
LSD(0.05)	0.48	NS	9.61	103.6	0.56	1.4
CV%	9.13	11.21	15.19	16.09	18.09	10.65

*Means in a column followed by the same letter do not differ significantly at 5% level;
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Table 11. Combined effect of variety and spacing on pod length, pod diameter, pod yield per plant, pod yield per plot, and dry matter of shoot (%) of bush bean (*Phaseolus vulgaris* L.).

Treatments	Pod length (cm)	Pod diameter (cm)	Pod yield per plant (g)	Pod yield per plot (g)	Dry matter of shoot (%)
V_1S_1	13.28	0.843	110.00 a	2138.01 g	26.67 a
V_1S_2	13.13	0.91	108.10 a	2721.33 cd	23.33 cde
V_1S_3	12.81	0.87	97.07 ab	2978.66 ab	23.04 de
V_1S_4	13.3	0.891	102.80 a	2589.01 de	25.56 abc
V_1S_5	12.9	0.873	88.00 bc	2834.00 bc	24.44 cd
V_1S_6	12.8	0.867	84.53 bc	3054.30 a	22.67 e
V_2S_1	13.4	0.783	89.00 bc	1496.67 i	25.44 abc
V_2S_2	13.2	0.736	58.33 de	2382.06 f	23.55 cde
V_2S_3	12.7	0.761	45.67 e	2347.13 f	22.78 e
V_2S_4	13.2	0.766	81.53 c	1893.00 h	25.89 ab
V_2S_5	12.8	0.816	67.27 d	2450.00 ef	24.22 cd
V_2S_6	12.8	0.825	47.47 e	2356.00 f	23.78 cde
LSD (0.05)	NS	NS	13.59	146.5	2.45
CV%	9.13	11.21	15.19	16.09	10.65

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

The pod yield per plant in different plant spacing was found to be statistically significant (Appendix VII). The highest pod yield of bush bean (99.48 g/plant) was obtained from S_1 (30 x 20 cm) treatment which was statistically similar to S_4 treatment. However, the lowest pod yield (66 g/plant) was found from S_6 (25 x 10 cm) treatment, which was statistically similar to S_3 treatment (Table 10). It was found from above result that wider the spacing higher the amounts of pod yield per plant because in wider spacing there was less competition for plant nutrients water, light and air thereby could grow better pod yield per plot. Mangual *et al.* (1979) stated that pod yield per plant were highest with the widest planting distance.

The combined effect of variety and different plant spacing on pod yield per plant was found to be statistically significant (Appendix VII). The maximum pod yield (110 g/plant) was found from V_1S_1 (BARI bush bean-1 with 30 x 20 cm) treatment combination, which was statistically identical to V_1S_2, V_1S_4 and V_1S_4 treatment combination whereas the lowest pod yield per plant (45.67 g/plant) was obtained from the V_2S_3 (BARI bush bean-2 with 30 cm x 10 cm) treatment combination, which was statistically identical to V_2S_6 and statistically similar to V_2S_2 treatment combination (Table 11). Elhag and Hussein (2014) observed that the highest pod yield (105.9 g) was obtained by 2plants/hill and 20cm plant spacing.

4.12 Pod yield per plot

The variation in pod yield per plot was found to be statistically significant due to variety (Appendix VII). The highest pod yield per plot (2719.05g) was recorded from V_1 (BARI bush bean-1) treatment and the lowest pod yield per plot (2155.33g) which was found from V_2 (BARI bush bean-2) treatment (Table 9).

The pod yield per plot was significantly influenced by different plant spacing (Appendix VII). The highest pod yield per plot (2710.25 g) was found from S_6 (25 x10 cm) treatment, which was statistically identical to S_3 treatment and statistically similar to S_5 treatments. The lowest pod yield per plot (1817.84 g) was obtained from S_1 (30 x 20 cm) treatment (Table 10). It was observed that the closest spacing produced the highest yield. The highest pod yield per plot at closer spacing is mainly due to higher plant density per unit area.

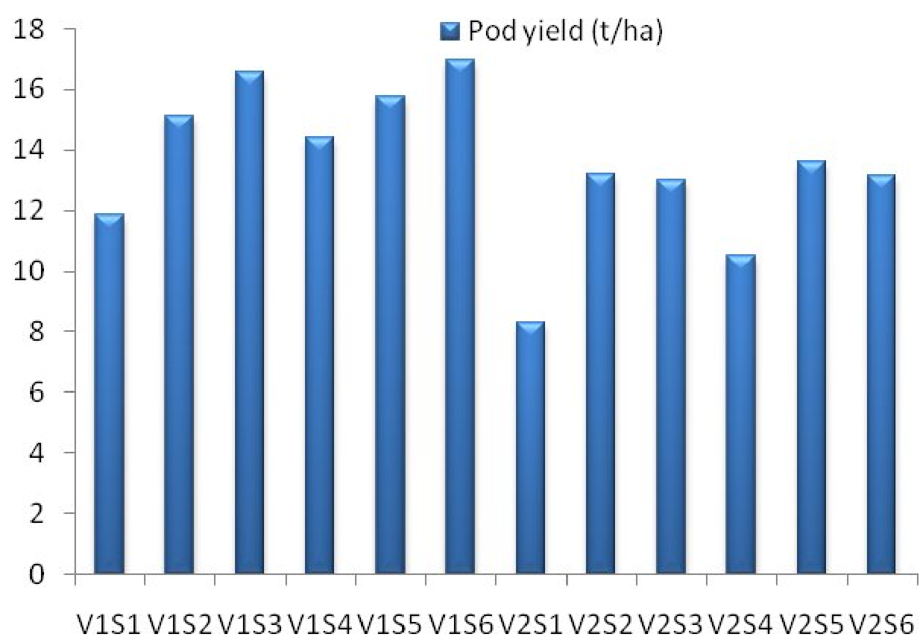
The combined effect of variety and plant spacing was significantly influenced by pod yield per plot (Appendix VII). The maximum pod yield per plot (3054.30 g) was found to V_1S_6 (BARI bush bean-1 with 25 x 10 cm) treatment combination, which was statistically similar to V1S3 treatment combination. The lowest pod yield per plot (1496.67 g) was recorded from V_2S_1 (BARI bush bean-2 with 30 x 20 cm) treatment combination (Table11).

4.12 Pod yield (t/ha)

The variation in pod yield per hectare was found to be statistically significantly by different variety (Appendix VII). BARI bush bean-1 was produced the highest pods yield (15.11 t/ha) while the lowest pod yield (11.97 t/ha) was found from BARI bush bean-2 (Table 9). Noor *et al*. (2014) found that the maximum fresh pod yield (14.25 t/ha) was observed from BARI bush bean-1 and BARI bush bean-2 was followed by 13.23t/ha.

The pod yield per hectare was significantly influenced by plant spacing (Appendix VII). The highest pod yield (15.06 t/ha) was obtained from S_6 (25 x 10 cm) treatment, which was statistically identical to S_3 and statistically similar to S_5 treatment. However, the lowest pod yield (10.09 t/ha) was found from S_1 (30 x 20 cm) treatment (Table 10). It might be concluded that decreasing plant spacing reduced pod number per plant but increased total pod yield per hectare. Anon *et* *al.* (1995) stated that the maximum green pod yield obtained with a plant closer spacing was better for a higher vegetable.

Combined effect of variety and plant spacing by pod yield per hectare was found statistically significant (Appendix VII). The highest pod yield (16.97 t/ha) was found from V_1S_6 (BARI bush bean-1 with 25 x 10 cm) treatment combination, which was statistically similar to V_1S_3 treatment combination. The lowest yield of pod (10.52 t/ha) was recorded from the V_2S_4 (BARI bush bean-2 with 25 x 20 cm) treatment combination (Fig.8). Moniruzzaman *et al.* (2009) found that the highest pod yield (t/ha) with lower spacing (20 cm x10 cm).



V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Fig. 8. Combined effect of variety and spacing on pods yield (t/ha) of bush bean (*Phaseolus vulgaris* L.).

4.13 Dry matter percentage of shoot

No significant effect was found on dry matter percentage of shoot due to the effect of variety (Appendix VII and Table 9).

The dry matter of shoot percentage was statistically significant by using different plant spacing (Appendix VII). The highest dry matter shoot (26.05%) was found from S_1 (30 x 20 cm) treatment, which was statistically identical to S_4 treatment while the lowest dry matter shoot (22.91%) was found from S_3 (30 x 10 cm) treatment, which statistically identical to S_3 treatment and which were statistically similar to S_2 treatment (Table 10).

The combined effect of spacing and variety was varied significantly (Appendix VII). The highest dry matter percentage of shoot (26.6%) was found from V_1S_1 (BARI bush bean-1 with 30 x 20 cm) treatment combination, which was statistically similar to V_1S_4, V_2S_1 and V_2S_4 treatment combinations. However, the lowest dry matter percentage of shoot (22.67%) was found from V_1S_6 (BARI bush bean-1 with 25 x 10 cm) treatment combination, m 7ations (Table 11).

4.14 Economic analysis

Input costs for manpower, land preparation, seed cost, irrigation, pesticide, fertilizer required for all the operations from planting to harvesting of were recorded for unit plot and converted into cost per hectare. Price of pod was considered as per market rate. The economic analysis presented under the following headings-

4.14.1 Gross return

The combination treatment of variety and spacing showed different gross return. The highest gross return was obtained from V_1S_6 (424,208.33Tk./ha) treatment combination and the second highest gross return was found in V_1S_3 (413,563.89 Tk./ha) treatment combination. The lowest gross return was obtained from V_2S_1 (207,731.94 Tk./ha) treatment combination (Appendix XI-B).

4.14.2 Net return

In case of net return different treatments combination showed different net return. The highest net return was found from V_1S_3 (220,619.25Tk./ha) treatment combination and the second highest net return was obtained from V_1S_6 (215,106.89Tk./ha) treatment combination. The lowest net return was obtained V_2S_1 (30310.50Tk./ha) treatment combination (Appendix XI-A-B).

4.14.3 Benefit cost ratio

In the combination treatment of variety and spacing, the highest benefit cost ratio was noted from V_1S_3 (2.14) treatment combination and the second highest benefit cost ratio was estimated from V_1S_6 (2.03) treatment combination. The lowest benefit cost ratio was obtained from V_2S_1 (1.17) treatment combination. From economic point of view, it was apparent from the above results that the treatment combination of V_1S_3 was more profitable than rest of the treatment combination (Appendix XI-A-B).

Table 12. Cost and return analysis of bush bean considering variety and spacing.

Treatment	Pod Yield (t/ha)	Gross return	Total cost of production	Net return	BCR (Benefit cost ratio)
V_1S_1	11.88	296945.83	174887.04	122058.79	1.7
V_1S_2	15.12	377962.5	187981.44	189981.06	2.01
V_1S_3	16.54	413563.89	192944.64	220619.25	2.14
V_1S_4	14.38	359584.72	190093.44	169491.28	1.89
V_1S_5	15.74	393611.11	197485.44	196125.67	1.99
V_1S_6	16.97	424208.33	209101.44	215106.89	2.03
V_2S_1	8.31	207731.94	177421.44	30310.5	1.17
V_2S_2	13.23	330787.5	187981.44	142806.06	1.76
V_2S_3	13.04	325926.39	198013.44	127912.95	1.65
V_2S_4	10.52	262916.67	193261.44	69655.23	1.36
V_2S_5	13.61	340277.78	201709.44	138568.34	1.69
V_2S_6	13.14	328472.22	215437.44	113034.78	1.52

*Means in a column followed by the same letter do not differ significantly at 5% level;
V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Chapter - V

SUMMARY

A field experiment was conducted at the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during Rabi season of November 2014 to January 2015 to study the yield and profit of bush bean (*Phaseolus Vulgaris* L.) in response to variety and Spacing. In the experiment, the treatments consist of two varieties and six levels of spacing viz. V_1=BARI bush bean-1, V_2= BARI bush bean-2 and six level of spacing S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm. The experiment was laid out in randomized complete block (RCBD) design having twelve treatments with 3 replications. The size of unit plot was 1.5m x 1.2m. The total number of treatments was 12 and the numbers of plots were 36. Data were collected on the following parameters- plant height, number of leaves per plant, number of branches per plant, leaf length, leaf breath, first flowering initiation, 50% and 90% flowering initiation, number of pods per plant, pod length, pod diameter, pod yield per plant, pod yield per plot, pod yield ton per hectare and dry matter content of shoot. The data were analyzed statistically by variances (ANOVA) of data on different characters and yield of bush bean.

Most of the parameters were significantly affected by the varietal differences except pod length and dry matter of shoot (%). Plant height, leaf breath, first flowering initiation, 50% and 90% flowering initiation, number of pods per plant, pod diameter, pod yield per plant, pod yield per plot and pod yield ton per hectare were significantly higher in BARI bush bean-l compared to BARI bush bean-2, excluding number of leaves per plant, number of branches per plant and leaf length. BARI bush bean-l produced yield of 15.11 t/ha where BARI bush bean-2 produced 11.97 t/ha.

The entire yield Parameters except pod diameter was significantly influenced by various spacing used in this experiment. Plant height was higher, flower initiation took shortest period, pod yield per plot, pod yield per ha at lower plant spacing. Wider spacing found to be beneficial for number of leaves, number of branches, number of pod, pod yield per plant also. At higher level of spacing plants faced less competition for nutrient, water and other components for that pod yield per plot was higher but at lower spacing number of plants per plot. For higher plant densities pod yield per was higher at lower spacing. The main yield contributing character pod yield (kg/ha) was better both in (30 cm x 10 cm) or (25 cm x 10 cm) spacing treatment.

The combined effect of variety and spacing was found significant for all of the growth and yield contributing parameters as well as for pod yield except pod length pod diameter. It was observed from the results that plant height highest at 45 DAS and 60 DAS V_1 (BARI bush bean-1) treated with lowest (30 cm x 10 cm) spacing. BARI bush bean-2 combined with wider spacing gave significantly higher number of leaves, number of branches per plant. BARI bush bean-1 with wider spacing gave good result in number of pod per plant, pod yield per plant but other important yield contributing parameters days to flower initiation, pod yield per plot, pod yield (t/ha) were found better in BARI bush bean-1 with lower spacing S_3 (30 cm x 10 cm) and S_6 (25 cm x 10 cm) .From BARI bush bean-1 with S_6 (25 cm x 10 cm) spacing was recorded highest yield 16.97 t/ha. Experimental data show a cost analysis with respect to the cost per plot and hectare, it was higher in V_1S_6 treatment combination than V_1S_3 due to higher plant density, their seed cost, labour cost and management cost. So as a view of cost analysis, BARI bush bean-1 with S_3 (30 cm x 10 cm) spacing might be better profitability which pod yield (16.55 t/ha) was not far away from S_6 (25 cm x 10 cm) spacing.

Chapter - VI

CONCLUSION AND RECOMMENDATION

Considering the above result of this experiment; the following conclusion and recommendation can be drawn:

1. BARI bush bean-1 performed better than BARI bush bean-2 in respect of growth, yield and yield contributing parameters.
2. The higher and better amount of pod yield was produced from 30 cm x10 cm spacing.
3. According to the Benefit Cost Ratio (BCR) it may be suggested that BARI bush bean-l in combination with 30 cm x 10 cm spacing gave maximum and profitable pod yield of bush bean.

The following recommendations can be made from the above results. For bush bean cultivation, BARI bush bean-l with 30cm x 10cm spacing may be adopted. The findings of the present investigation should be confirmed by conducting similar types of experiments in different AEZs of Bangladesh. Protein percentage and other quality parameters can be studied in further researches.

REFERENCE

Ahlawat, I.P.S. 1996. Response of French bean (*Phaseolus vulgaris.L*) varieties to plant density and phosphorus level. Indian J. Agril. Sci., 66: (6). 338-342.

Ali. M. 1989. Response of Frenchbean genotypes to planting dates during winter season. Indian J. Pulses Res. 2 (1): 59-63.

Ali, Q.S., Zeb. S., Jamil. E., Ahmed. N., Sajid. M., Siddique. S., Jan. N. and Shahid, M. 2015. Effect of various levels of nitrogen, phosphorus and potash on the yield of French Bean. Pure Appl. Biol., 4(3): 318-322.

Akther, N. 1999. Effeet of spacing and top removal on yield of bean. M.S. thesis, Dept. of Agronomy, BSMRAU, Salna, Gazipur. p.84.

Alemayehu, Y., Kaweti, M., and Boki, A., 2015. Effect of Intra-Row Spacing on Haricot Bean *(Phaseolus vulgaris* L.*)* production in humid tropics of Southern Ethiopia. *Journal of Natural Sciences Research,* Vol.**5:**15.

Anonymous, 2000. Krishi Projukti Hatboi (Handbook on Agro-technology) 2nd edition BARI, Gazipur., p.349.

Anomymnous, 1995.BARI (Bangladesh Agricultural Research Institute), Annual Report for 1993- 1994. BARI. Joydebpur, Gazipur, Bangladesh.

Anomymous, 2005. Fertilizer Recommendation Guide, Published by Bangladesh Agricultural Research Council, Firmgate, and New Airport Road.Dhaka- 1215.

Anonymous, 2000. Annual Report for 1999-2000. Bangladesh Agricultural Research institute (BARI), Joydebpur, Gazipur.

Arf, O., M.E.Sa., Olcita. C.S. and Tiba. M.A. 1996. Effect of different spacing and sowing rates on the development of bean (*Phaseolus vulgaris* L.) *Pesquisa Agropecuaria Brasileira.* **31**(9):629-634 [Cited from [Hort. Abstr., 67(8):877, 1997].

Argerich, C.A., Calvar. D.J and Sansinania. A. 1986. comparative-yield trial with bush bean cultivars. Field crop Abst., 39(4):325.

Azmi, O.R. and Rathi, Y.P.S. 1991. Influence of plant spacing on French bean crinkle stunt disease. *Indian J. Agron.,* **7**(1): 114-116.

Badilla-Feliceano, J., M.A. Lugo-Lopez. and T.W. Scott. 1978. Effect of planting distance on yield and agronomic characteristics of red and native white beans in an oxisol. J. Agri, Uni. Puerto-Rico. 62(2):145-148. [Cited from Hort. Abst., no. 1210. p. 102].

Begum, A., A. Ahad., M.O. Kaiser., M.M. Islam and M.K. Anam. 2003. Morphological and Reproductive Attributes in French Bean (*Phaseolus vulgaris* L.) as Influenced by Sowing Tine and Fertilizer Treutments. Pakistan Journal of Biological Sciences, 6 (22): 1902-1906.

Blackshaw, R.E., Muendel. H.H. and Saindon. G. 1999. Canopy architecture, row spacing and plant density effects on yield of dry bean *(Phaseolus vulgaris)* in the absence and presence of hairy night shade. *Canadian J. Plant Sci.,* **79**(4): 663- 669.

Bouriller, D.1989. Sowing beans, narrower row spacing. UNLEC, No. 63:16-l7 (Cited from Hort. Abst., 1990.60(5). Abst. No. 3398. p. 393].

Bull, P.B. 1977. Dwarf bean plant spacing. New Zealand Commercial Grower. 32(3): 23 [Cited from Hort. Abst.1977. 48(1). Abst. No. 455. p. 48].

Chakravorty, S., Ghosh, C., and Mandal, J., 2009. Effect of spacing on growth and yield of French Bean *(Phaseolus vulgaris L.)* in red and lateritic belt of West Bengal. *Env. And Ecol.* **27** (2) : 493-495.

Chandra. R., C.B.S. Rajput., K.P. Singh. and S.J.P. Singh. 1987. A nole on the effect of nitrogen, phosphorus and Rhizobium culture on the growth and yield of French bean Phaseolus vulgaris L.) cv. contentender. Haryana J. Hort. Sci., 16(8):l46-147.

Chatterjee, R. and Som. M.G. 1991. Response of French bean to different rates of phosphorus, potassium and plant spacing. *Crop Research,* **4:** 214-217.

Chowdhury, A.T.M.S. and Faruque. A.H.M. 1973. Pinto, a new variety of bean for Bangladesh. Bangladesh Hor. 1:37-38.

Dhanjal, R., Prakash, O., and Ahlawat, I. P. S., 2001. Response of French bean *(Phaseolus vulgaris* L.*)* variety to plant density and nitrogen application. *Indian J. Agron.* **46**:277-281.

Dhanju, K.S., Chowfla. S.C. and Handa. A.K. 1995. Effect of barrier crops and spacing on the incidence of mosaic diseases and yield of French bean. [Cited from Hort. Abst, 67(4) item no. 3074, 1997].

Duke, J. A. 1983. Hand Book of Legumes of World Economic Importance (Second Ed.), Plenum Press, New York. 341, p.

Dwivedi, D.K., H. Singh., K.M. Singh., D. Shahi. and J.N. Rai. 1994. Response of frcnch bean to population densities and nitrogen levels under medium upland situation in north-east alluvial plains of Bihar. Indian J. Agron., 39(4): 581-583.

Edge, O.T., L.K. Mughogho and U.W.U. Ayonoadu, 1975. Bean yield and yield components as affected by fertilizer and plant population. Turrialba 25(l): 79-84. [Cited from field crop Abst., 30(2):766, 1976].

El-Habbasha, K.M., Adam, S.M. and Rizk, F.A. 1996. Growth and yield of pea plants affected by plant density. Egypt J. Hort. 23(1): 35-51.

Elhag, A.Z., and Hussein. A.M., 2014. Effects of sowing date and plant population on Snap Bean *(Phaseolus vulgaris* L.*)* growth and pod yield in Khartoum State. *Universal J. Agri. Res.* **2:**115-118.

FAO. 1971. Soil Survey Project of Bangladesh. Food and Agriculture organization of United Nations soil Resources Technical Report pp 107-159.

FAO. 1998. Production year book. Food and Agricultural Organization of the United Nations. Rome. Italy. 52:94.

Getachew, E., Ali. M., Tesfaye. A. and Nebiyu. A. 2014.Growth and yield response of green beans *(Phaseolus vulgaris L.)* in relation to time of sowing and plant spacing in the humid tropics of Jimma, southwest Ethiopia. *Int. J. Soil. Crop. Sci,***2**(5): pp 061-067

Ghasempour, R. and Ashori. M. 2015. Impact of various planting spaces and different leveol of nitrogen fertilizer on yield and yield components of green beans under the weather of Gulian, Iran. Indian Journal of Fundamental and Applied Life Sciences, Vol. 4 (S4), pp. 2950-2956.

Gill, H. S., D. C. Pachauri, and S. R. Sharma. 1976. A note on the spacing requirement of french bean (Phaselous Vulgaris L.) for seed production Indian Hort., 33(2) 187-188.

Grafton, K.F., Schneiter, A.A. and Nagle, B.J. 1988. Row spacing, plant population and genotype x row spacing interaction effects on yield and yield components of dry bean. *Agron. J,* **80**(4): 631-634.

Gretzmacher, R. 1975. Spacing trials with bush bean. Studies on rectangular spacing's Teil. Unter suchungen an recheteckigen Standraumen Bodenkuttuer, **26**(2):163-164 (Cited from Hort. Abstr., 46(7): 578, 1975].

Guzal, M. B. L., C. K. Cafatl and G.B. Bascur. 1976. Effect of population density on yield and yield components in three varieties of pea (*Phaselous vulgaris* L.). Agricultura Technica., 36(3): 116- 121[Cited from Hort. Abstr., 46(8): 660, 1976].

Horn, F.L., Schuch. L.O.B. and Silveria. E.P. 2000. Assessment of spacing and plant density of bean for mechanical harvesting. *Pesquisa Agropecuaria Brasileira* **35**(1):41-46.

Hossain, M.A. and Salauddin, A.B.M. 1994. Growth and yield of sesame in relation to population density. Bangladesh J. Life sci., 6(1): *59-65.*

Hussain, M. M. 2005. Yield and quality of bush bean *(Phaseolus vulgaris* L*.)* genotypes as influenced by date of sowing. Master of Science (M.S.) Thesis, Department of Agronomy, Bangabandhu Seikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur.

Isasi, M.F. and Bustogaricia, I. 1985. The effect of plant spacing on the yield or common bean (*Phaselous Vulgaris*) cultivars with different growth types. *Ciencias de la Agricultura.,***23:** 127-129. [Cited from Hort. Abstr., 57(50):35-38].

Jadhao, S.L. 1993. Performance of French bean (*Phaselous vulgaris* L.) genotypes in relation to plant population. *Indian J. Agron.,* **38**(4):674-675.

Joshi, B. D., Sanwal, T. D. and Vidyasagar. 1987. French bean for the hills. *Indian Hort.* **31**: 5-8.

Kakon, S.S., Bhuiya. M.S.U., Hossain. S.M.A. and Sultana. N. 2015. Flowering behavior and seed yield of French bean as affected by variety. *Int J Appl Sci Biotechnol,* Vol **3**(3): 483-489.

Koli, B.D., Akashe, V.B., and Shaikh, A.A. (1996). Effects of row spacing, plant density and N-level on the yield and quality of French bean. PKV Res. J., 20:2, 174-175.

Koli, B.D. and Akashe,V.B., 1995. Dry matter production of French bean variety Waghya as influenced by row spacing, plant densities and nitrogen levels. Current Research, 24: 209 – 211.

Latifi, N. and Navabpoor, S. 2000. The response of growth indices and seed yield of two pinto bean to *row* spacing and plant population*. Iranian J. Agric Sci.,* **31**(2): *353*- 362 [CAB Abs 2002/04]

Lima, A.De.A., Cardoso, A.A., Veirn, C., Defehico, B.V., and Conde, A.R., 1983. Response of bean *(Phaseolus vulgaris* L.*)* cultivars to spacing and fertilizer rates. *Revista Ceres,* **30**(169): 245-248[Cited from Hort. Abst., 54(90): 600, 1984].

Mangual Crespo, G. and Torres, C.J. 1978. Response of snap beans to increasing plant density, *J. Agric. Univ. Puerto. Rico* **62:** 399-403.

Mangual-Crespo, G. and Torres. C.J., 1979. Response of pole beans *(Phaseolus vulgaris* L.*)* to various plant densities. **63**(4): 465- 468 [Cited from Hort. Abst., 50(4): 357-4234].

Moniruzzaman, M., Islam. M.R. and Hasan. J. 2008. Effect of N P K S Zn and B on yield attributes and yields of French bean in South Eastern Hilly Region of Bangladesh. J Agric Rural Dev 6(1&2), 75-82.

Moniruzzaman, M., S. M. L. Rahman., M.G. Kibria., M.A. Rahman. and Kaisar, M.O., 2007. Performances of vegetable French ban as influenced by varieties and sowing dates in Rabi season. *Int. J. Sustain. Crop Prod.* **2**(5):69-73.

Moniruzzaman, M., Halim. G.M.A. and Firoz. Z.A. 2009. Performances of French bean as influenced by plant density and nitrogen application. *Bangladesh J. Agril. Res.* **34**(1): 105-111.

Mozumder, S.N., Moniruzzaman, M., Islam, M. R. and Alam, S.N. 2003. Effect of planting time and spacing on the yield performance of bush bean *(Phaseolus vulgaris* L.*)* in the eastern hilly area of Bangladesh. *Legume Res* **26**(4): 242-247.

Mozumder, M.A., Rouf. M. A., Mollah. M. S. and Rashid. M.A. 1996. Collection and evaluation of bush bean germplasms. Research Report on Vegetable Crops, HRC, RARS, Hathazari. (Ed. M.A.Rashid): pp. 35-39.

Mozumder, S.N. 2002. Improved cultivation of Bush bean. BARI (Bangladesh Agricultural Research Institute) Folder No 03/2002.

Mureithi, D.M., Onyango. M.O.A., Jeruto. P. and Gichimu. B. M. 2012. Response of French Bean (*Phaseolus vulgaris* L.) to intra-row spacing in Maseno Division, Kenya. *J. Applied Sci.* **12**: 96-100.

Noor, F., Hossain, F., and Ara. U., 2014. Screening of French bean *(Phaseolus vulgaris* L.*)* genotypes for high yield potential. *Bangladesh J. Sci. Ind. Res.* **49**(4), 227-232.

Ozcan, L. and S. Ozdemir. 1996. Effects of plant density on the yield and yield components of bean (*PhaseoIus vulgaris* L). Anadolu., 6:1 17-24 [Cited from Hort. Abst., 67(4):382, 1997].

Pawar S.U., Kharwade, M.L., and Awari, H.W., 2007. Effect of plant density on vegetative growth and yield performance of different varieties of French bean under Irrigated Condition. *J. Agric. Sci.,* **20**(3):684-685.

Rana R.S., S.S. Rana, R.K. Chahota, G.D. Sharma and B.S. Mankotia. 2001. Influence of row spacing and fertility levels on the productivity and economics of rajmah *(Phaseolus vulgaris* L.*)* in dry temperate region of *H.P. Himachal J, Agric. Res.* **27**: 11-18.

Rahman M. O., Rabbani M. G., Nasiruddin K. M., Yesmin R. and Rahman M. M. 2002. Effect of different levels of nitrogen and plant spacing on the growth and yield of French bean. *Progress Agric.* ***13*** (1&2): 35-37.

Rahman MH, Q.A. Khaliq, A. Hamid, M.N.I. Miajh and M.M. Haque 2000. Irrigation and planting density effects on dry matter production and yield in edible podded pea. Bangladesh. *J. Agril. Res.* ***25***(1) : 161-167.

Rashid, A.S.M.H and Hossain, M.M. 2014.Yield and quality of green pod production of Bush bean *(Phaseolus vulgaris* L.*)* as Influenced by harvesting time. *American-Eurasian J. Agric. & Environ. Sci.,* **14** (11): 1221-1227.

Rashid, M. M. 1993. Sabji Biggan. In Bangla. 1st Ed., Bangla Academy Rashid Publishing House, Dhaka. pp. 387- 390.

Roy, S.K. 2004. Characterization and yield variation in bush bean *(Phaseolus vulgaris* L.*)* genotypes. M.S. Thesis, Department of Agronomy, Bangabandhu Seikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur.

Roy, S.K., Karim. M.A.; Islam. A.K.M.A., BARI. M.N., Mian, M.A.K., and Tetsushi, H., 2006. Re1ationship between yield and its component Characteristic of Bush Bean *(Phaseolus vulgaris* L.*)*. South Pacific Studies **27**(1): 13-23

Sa, M.E., S.De. Buzetti, S. Morello and N.D. Deziderio, 1982. Effects of plant density and phosphate fertilizer on bean production. *Centro Nacional de Pesquisa Arroz Feijao,* 101-103.[Cited from Field Crop Abstr., 28(2):4444,19831].

Salukhe, D.K., Desai, B.B. and Bhat, N.R.1987. Leguminous Vegetables (Peas and Beans). In Vegetabes and Flower Seed Production, Agricole Publishing Academy, New Delhi. 265-302, pp.

Samih, A. 2008. Effect of plant density on flowering date, yield and quality attribute of Bush beans *(Phaseolus vulgaris* L.*)* under center pivot irrigation system. *Am. J. Agric. Biol. Sci.,* **3**(4):666-668.

Samnotra, R.K., Gupta, A.K. and Verma, A. K. 1998. Effect of row spacing and varieties on the growth and yield of French bean (*Phaseolus vulgaris* L.). *Environ. Eco.,* **16**:3, 737-739.

Sehoonhoren, A.V. and Rovset. 1993. Common Beans: Research for Crop Improvement. CAB International, CIAT, Cali, Colombia.p.649.

Sen, R., M.A. Rahman.; A.K.M.S. Hoque.; S. Zaman and S. Noor, 2010. Response of Different Levels of Nitrogen and Phosphorus on the Growth and Yield of French Bean. *Bangladesh J. Sci. Ind. Res.* **45**(2), 169-172.

Shah, A., Lal. S.D., Seth. J.N. and Pant. C.C. 1996.Genetic variability and correlation studies in dwarf French bean *(Phaseolus vulgaris* L.*)* . *Prog. Hort.* **18:** 89-93.

Shaheb, M.R., M.N. Islam, A. Nessa, and M.A. Hossain. 2014. Effect of harvest times on the yield and seed quality of French bean. *SAARC J. Agri.,* **13**(1):01-13.

Shahid, M., A. Rehman, M.S. Khan and Zakaria, 2015. Effect of various levels of nitrogen, phosphorus and potash on the yield of French bean. *Journal of Natural Sciences Research,* **5:** 11.

Shekhawat, G.S., Shama. D.C. and Jain. R. K. 1967. Response of peas to Varying fertility and density Condition in chambal commanded area, Rajsthan. *Indian J. Agron.,* **121**: 103-107.

Singh R. V. 2000. Response of French bean to plant spacing, and nitrogen and phosphorus fertilization. *Indian J. Hort.* **57** (4): 338-341.

Singh, D.N. and Behera. A.K. 1998. Response of French bean (*Phaseolus vulgaris* L.) to fertilizers and spacing. *Indian J. Agron.,* **44**(3): 597- 600.

Singh, D.P., Rajput. A.L. and Singh. S.K. 1996. Response of French bean to spacing and nitrogen levels. *Indian J. Agron.,* **41**:4, 608- 610.

Singh, R.C., Singh. M. and Kumar. R. 1992. Performance of French bean genotypes on different sowing date in autumn. *Haryana Agric. Univ. J. Res.* **22** : 31-34.

Singh, R. C. and M. Singh. 1987. Response of French bean *(Phaseolus vulgaris* L.*)* varieties to sowing time. *Haryana Agric. Univ. J. Res.* **17**: 266-268.

Shivakumar, B.G.; C.S. Saraf and R.R. Path, 1996. Performance of winter French bean as influenced by varieties, spacing and time of sowing. *Ann. Agrie Res.* **17** (4): 407-410.

Stoker, R. 1975. Effect of plant population in yield of garden pea under different moisture regime. *Newzealand J. Exp. Agric.* **3** (4): 333-337.

Swaider, J.M.; Ware., G.W., and Mc Collum, J.P., 1992. Producing Vegetable Crops. 4th ed. Interstate Publishers, Inc. Danville, Illions, USA. pp. 233-249.

Thamburaj, S., Shanmugavelu, K.G., Chokalingam, P. and Pillai, O.A.A. 1980. Varietal evaluation in bush beans *(Phaseolus vulgaris* L.*)* . South Indian Hort. 28: 113-115.

Tindall, H.D. 1988. Vegetable in The Tropics. Mcmillan Education Ltd., p 527.

Tuarira, M. and Moses, M. 2014. Effects of plant density and planting arrangement in green bean seed production. J. Glob. Innov. Agric. Soc. Sci., 2(4): 152-157.

Vulsteke, G. 1985. The influence of spacing and seed rate on the yield of dwarf bean. PHM Revue Horticole. 255: 25-26 [Cited from Hort. Abstr., 55(7): 539, 1985].

Wahab, M.N.J., Dabbs, D.H. and Baker, R.J. 1986. Effects of planting density and design on pod yield of bush snap bean *(Phaseolus vulgaris* L.*). Can. J. Plant Sci*. **66**: 669-675.

Weber, C. R.; Shillers. R.M. and Byth. D.E. 1966. Effect of plant population and row spacing on soybean development and production Agron. J., 58: 99-102.

Welu, G. 2015. Effects of plant density on the yield components of Haricot bean (*Phaseolus vulgaris* L.) Journal of Natural Sciences Research, Vol.5, No.5.

APPENDICES

Appendix I. **Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2014 to January 2015.**

Month	*Air temperature (ºc)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2014	25.8	16.0	78	00	6.8
December, 2014	22.4	13.5	74	00	6.3
January, 2015	24.5	12.4	68	00	5.7

* Monthly average,
* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix II. **The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation**

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	6.1
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Dose and method of application of fertilizers in experimental field.

Fertilizers	Dose/ha	Basal	15 DAS	30 DAS
Cowdung	10 tons	100	--	--
Urea	220 kg	33.33	33.33	33.33
TSP	200 kg	100	--	--
MP	160 kg	33.33	33.33	33.33
Gypsum	220 kg	100	--	--

Appendix IV. Analysis of Variance data on plant height (cm) and number of leaves per plant on growth and yield of bush bean

Source of variation	Degrees of freedom (df)	Plant height (cm)			Number of compound leaves per plant		
		15DAS	30DAS	45DAS	30DAS	45DAS	60DAS
Replication	2	1.753	10.058	7.983	0.087	0.496	1.508
Variety (A)	1	4.319*	131.752**	824.943**	0.681 NS	4.578*	39.361**
Spacing (B)	5	1.101 NS	30.090*	32.627*	0.240 NS	4.319*	26.207**
A×B	5	0.336 NS	3.802 NS	23.359*	0.176 NS	1.171*	4.979*
Error	22	0.996	8.175	5.215	0.252	0.357	1.132

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant.

Appendix V. Analysis of Variance data on number of branches per plant and Leaf length (cm) on growth and yield of bush bean

Source of variation	Degrees of freedom (df)	Number of Branches per plant			leaf length (cm)		
		30DAS	45DAS	60DAS	30DAS	45DAS	60DAS
Replication	2	0.221	0.132	1.034	5.035	3.758	4.143
Variety (A)	1	0.080 NS	0.007 NS	45.833**	0.111 NS	8.085*	92.897**
Spacing (B)	5	0.077 NS	0.034 NS	4.280*	4.406 NS	1.111 NS	13.810**
A×B	5	0.065 NS	0.079 NS	4.741*	1.005 NS	1.778 NS	10.425*
Error	22	0.114	0.102	1.151	6.127	2.158	2.786

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant.

Appendix VI. Analysis of Variance data on 1st flower initiation, 50% and 90% flower initiation (days to flower initiation) and leaf breadth (cm) on growth and yield of bush bean

Source of variation	Degrees of freedom (df)	Days to flower initiation			Leaf breadth (cm)		
		1st	50%	90%	30DAS	45DAS	60DAS
Replication	2	0.695	1.919	1.193	0.285	0.388	1.525
Variety (A)	1	7.790**	10.700**	37.068**	10.737**	35.284**	11.926**
Spacing (B)	5	2.631**	8.723**	12.371**	0.121 NS	0.232 NS	1.730*
A×B	5	4.221**	6.051*	14.744**	0.091 NS	1.743*	1.535*
Error	22	0.37	1.213	1.789	0.213	0.247	0.511

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant.

Appendix VII. Analysis of Variance data on number of pods per plant, pod length (cm), pod diameter (cm), pod yield per plant (kg), pod yield (t/ha) and dry matter of shoot (%) on growth and yield of bush bean.

Source of variation	Degrees of freedom (df)	Number of pod	Pod length (cm)	Pod diameter (cm)	Pod yield per plant (g)	Pod yield per plot (g)	Pod yield (t/ha)	Dry matter of shoot (%)
Replication	2	2.647	0.158	0.007	102.86	8253.42	0.294	1.533
Variety (A)	1	113.210**	0.328 NS	0.084**	10123.37**	58213.67**	8.329**	0.341 NS
Spacing (B)	5	32.425**	0.689*	0.001 NS	957.454**	52421.53**	2.359**	11.578*
A×B	5	5.010**	0.015 NS	0.003 NS	320.587*	37443.92*	1.173*	10.049*
Error	22	1.883	0.167	0.002	64.452	7488.79	0.224	2.098

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant.

Appendix VIII. Effect of variety on plant height (cm) at different days after sowing, days to flower initiation, number of pods per plant of bush bean (*Phaseolus vulgaris* L.).

Treatment	Plant height (cm)			Days to flower initiation			Number of pod
	15DAS	30DAS	45DAS	1st	50%	90%	
V_1	10.31 b	32.28 a	51.50 a	39.28 b	42.73 b	46.23 b	21.53 a
V_2	11.02 a	29.46 b	41.93 b	50.02 a	55.78 a	62.69 a	17.98 b
LSD (0.05)	0.69	2.52	7.28	6.46	8.07	10.8	2.98
CV%	9.36	9.11	10.34	8.37	7.24	7.46	12.45

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant.
V_1=BARI bush bean-1, V_2= BARI bush bean-2

Appendix IX. Effect of spacing on plant height (cm) at different days after sowing, days to flower initiation, number of pods per plant of bush bean (*Phaseolus vulgaris* L.).

Treatment	Plant height (cm)			Flower initiation (Days)			Number of pod
	15DAS	30DAS	45DAS	1st	50%	90%	
S_1	10.32	30.60 b	44.52 bc	45.47 a	51.10 a	55.63 a	22.50 a
S_2	11.01	29.87 c	47.33 ab	44.63 b	49.40 b	55.49 ab	20.73 bc
S_3	11.27	32.47 a	49.25 a	44.67 b	48.90 b	52.10 d	17.95 d
S_4	10.63	29.77 c	44.02 c	44.86 ab	49.87 ab	55.76 a	21.53 ab
S_5	10.11	30.35 bc	45.77 bc	43.74 c	48.55 bc	53.95 bc	19.57 cd
S_6	10.64	32.62 a	49.43 a	43.78 c	47.57 c	53.87 c	16.27 e
LSD (0.05)	NS	1.02	3.24	0.72	1.31	1.6	1.64
CV%	9.36	9.11	10.34	8.37	7.24	7.46	12.45

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant.
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Appendix X. Combined effect of variety and spacing on pod yield (t/ha) of bush bean (*Phaseolus vulgaris* L.).

Treatment	Pod yield (t/ha)
V_1S_1	11.87 f
V_1S_2	15.12 bc
V_1S_3	16.55 a
V_1S_4	14.39 cd
V_1S_5	15.74 b
V_1S_6	16.97 a
V_2S_1	8.310 h
V_2S_2	13.23 e
V_2S_3	13.03 e
V_2S_4	10.52 g
V_2S_5	13.61 de
V_2S_6	13.14 e
LSD (0.05)	0.8
CV%	18.09

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant.
V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

Appendix XI: Cost of production of bush bean per hectare

i. Input cost (A)

Treatments	labour	Ploughing	Seed	Irrigation	Pesticides	Cowdung	Fertilizer				Subtotal Input cost (A)
							Urea	TSP	MP	Gypsum	
V_1S_1	51000	12000	9600	10000	8000	20000	3400	4600	2400	4840	125840
V_1S_2	57000	12000	16000	10000	8000	20000	3400	4600	2400	4840	138240
V_1S_3	58500	12000	19200	10000	8000	20000	3400	4600	2400	4840	142940
V_1S_4	63000	12000	12000	10000	8000	20000	3400	4600	2400	4840	140240
V_1S_5	66000	12000	16000	10000	8000	20000	3400	4600	2400	4840	147240
V_1S_6	69000	12000	24000	10000	8000	20000	3400	4600	2400	4840	158240
V_2S_1	51000	12000	12000	10000	8000	20000	3400	4600	2400	4840	128240
V_2S_2	57000	12000	16000	10000	8000	20000	3400	4600	2400	4840	138240
V_2S_3	58500	12000	24000	10000	8000	20000	3400	4600	2400	4840	147740
V_2S_4	63000	12000	15000	10000	8000	20000	3400	4600	2400	4840	143240
V_2S_5	66000	12000	20000	10000	8000	20000	3400	4600	2400	4840	151240
V_2S_6	69000	12000	30000	10000	8000	20000	3400	4600	2400	4840	164240

labour cost @ Tk. 300/Man/day

Cowdung @ Tk. 2/Kg		Cowdung	10 t/ha
Urea @ Tk. 17/Kg		Urea	200 Kg/ha
TSP @ Tk. 23/Kg		TSP	200 Kg/ha
MP @ Tk. 15/Kg		MP	160 Kg/ha
Gypsum @ Tk. 22/Kg		Gypsum	220 Kg/ha

V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.

ii. Overhead cost (B)

Treatment Combination	Miscellaneous cost (Tk. 5% of the input cost)	Cost of lease for 3 months land rent (10% of total Tk. 15,00000/year)	Interest of running capital for 12 month (Tk. 12% of cost/year)	Subtotal Overhead cost(B)	Total cost of production [Input cost (A) + Overhead cost (B)]	Pod Yield / Plot (t / ha)	Gross return Tk./ha (Marketable price 25Tk/pod)	Net Return= Gross return- cost of production	BCR= Gross return/ Cost of production
V_1S_1	6292	37500	5255.04	49047.04	174887.04	11.88	296945.83	122058.79	1.7
V_1S_2	6912	37500	5329.44	49741.44	187981.44	15.12	377962.5	189981.06	2.01
V_1S_3	7147	37500	5357.64	50004.64	192944.64	16.54	413563.89	220619.25	2.14
V_1S_4	7012	37500	5341.44	49853.44	190093.44	14.38	359584.72	169491.28	1.89
V_1S_5	7362	37500	5383.44	50245.44	197485.44	15.74	393611.11	196125.67	1.99
V_1S_6	7912	37500	5449.44	50861.44	209101.44	16.97	424208.33	215106.89	2.03
V_2S_1	6412	37500	5269.44	49181.44	177421.44	8.31	207731.94	30310.5	1.17
V_2S_2	6912	37500	5329.44	49741.44	187981.44	13.23	330787.5	142806.06	1.76
V_2S_3	7387	37500	5386.44	50273.44	198013.44	13.04	325926.39	127912.95	1.65
V_2S_4	7162	37500	5359.44	50021.44	193261.44	10.52	262916.67	69655.23	1.36
V_2S_5	7562	37500	5407.44	50469.44	201709.44	13.61	340277.78	138568.34	1.69
V_2S_6	8212	37500	5485.44	51197.44	215437.44	13.14	328472.22	113034.78	1.52

V_1=BARI bush bean-1, V_2= BARI bush bean-2
S_1 = 30 x 20 cm, S_2 = 30 x 15 cm, S_3 = 30 x 10 cm, S_4 = 25 x 20 cm, S_5 = 25 x 15 cm, S_6 = 25 x 10 cm.