YIELD AND SEED QUALITY AS INFLUENCED BY PRUNING AND PLANT SPACING OF FRENCH BEAN

MD. FARIDUL ISLAM

INSTITUTE OF SEED TECHNOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE, 2017

YIELD AND SEED QUALITY AS INFLUENCED BY PRUNING AND PLANT SPACING OF FRENCH BEAN

By

MD. FARIDUL ISLAM

REGISTRATION NO. 11-04618

A Thesis

Submitted to the Institute of Seed Technology,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE

IN

SEED TECHNOLOGY

SEMESTER: JANUARY-JUNE, 2017

Approved by:

(Assoc. Prof. Dr. Jasim Uddain)	**(Prof. Dr. A. K. M. Ruhul Amin)**
Supervisor	**Co-supervisor**

(Prof. Dr. Mohammad Ali)
Chairman
Examination Committee

INSTITUTE OF SEED TECHNOLOGY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **" YIELD AND SEED QUALITY AS INFLUENCED BY PRUNING AND PLANT SPACING OF FRENCH BEAN"** *submitted to the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.)*** *in* ***SEED TECHNOLOGY,*** *embodies the results of a piece of bona fide research work carried out by* ***MD. FARIDUL ISLAM,*** *Registration. No. 11-04618 under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated:

Dhaka, Bangladesh

(Assoc. Prof. Dr. Jasim Uddain)
Supervisor

ACKNOWLEDGEMENT

At first the author expresses his gratefulness to the Almighty Allah who has helped me in pursuit of my education in Agriculture and for giving the strength of successful completion of this research work.

The author is highly grateful and greatly obliged to his supervisor, ***Dr. Jasim Uddain****, Associate Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his continuous encouragement, innovative suggestions and affectionate inspiration throughout the study period.*

With deepest emotion the author wishes to express his heartfelt gratitude, indebtedness, regards and sincere appreciation to his benevolent research Co-supervisor ***Prof. Dr. A. K. M. Ruhul Amin****, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his intellectual guidance, intense supervision, affectionate feelings and continuous encouragement during the entire period of research work and for offering valuable suggestions for the improvement of the thesis writing and editing.*

Cordial thanks are extended to all the respected teachers of the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh and the entire staff member of the Institute of Seed Technology (SAU).

The author would like to thank to his younger brothers and sisters of this university for their valuable and sincere help in carrying out some research work in the Farm of Sher-e-Bangla Agricultural University, Dhaka.

The author also expresses his especial thanks to his well-wishers and friends for their help and support during his work.

Finally, the author expresses his heartfelt indebtedness to his beloved father and mother, brother and sisters for their sacrifice, encouragement and blessing to carry out his study which can never be forgotten.

YIELD AND SEED QUALITY AS INFLUENCED BY PRUNING AND SPACING OF FRENCH BEAN

ABSTRACT

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the rabi season from November 2016 to March 2017 to study the quality seed production of french bean as influenced by spacing and pruning. The experiment comprised of two of which factors, factor A. Pruning (P_0= no pruning, P_1= one time stem pruning, P_2= two times stem pruning) and factor B. Spacing (S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing). The experiment was conducted following the randomized complete block design (RCBD) with three replications. Result revealed that the number of pods plant^{-1} (27.27), pod weight plant^{-1} (135.68 g) and pod yield (13.86 t ha^{-1}) showed the highest value resulting best seed yield (11.27 t ha^{-1}) due to pruning P_1. Similarly, the number of pods plant^{-1} (26.98), pod weight plant^{-1} (133.06 g) and pod yield (12.27 t ha^{-1}) attained the highest seed yield (9.97 t ha^{-1}) the wider spacing S_2. Result also demonstrated that, seed quality (i.e. germination (%), shoot length and root length) was higher for the treatment P_1 and S_2. Thus, the findings indicated that the one time pruning with wider spacing (30×15 cm) could be used for yield maximization of French bean in Bangladesh.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd.)

LIST OF CONTENTS (Cont'd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
ANOVA	Analysis of Variance
BA	Boric Acid
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
CV%	Percentage of coefficient of variance
cv.	Cultivar
DAE	Department of Agriculture Extension
DAS	Days after sowing
^{0}C	Degree Celsius
et al	And others
FAO	Food and Agriculture Organization
g	gram(s)
ha^{-1}	Per hectare
HI	Harvest Index
kg	Kilogram
mg	Milligram
MP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Not significant
%	Percent
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resource Development Institute
TSP	Triple Super Phosphate
Wt.	Weight

CHAPTER I

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is one of the most important vegetable crops belongs to the family fabaceae which originated in the Central and South America (Swiader *et al*., 1992). French bean is grown as a mono crop mostly by small scale farmers. It is extensively grown commercially as well as in the home garden. In Bangladesh, it is known as’’Farashi shim’’ (Rashid, 1993) and are mainly used as green vegetables. Its edible immature pods supply protein, carbohydrate, fat, fiber, thiamin, riboflavin, Ca and Fe (Shanmugavelu, 1989) and the seed contains significant amount of thiamine, niacin, folic acid as well as fiber (Rashid, 1999). Major French bean growing districts in Bangladesh are Sylhet, Cox's Bazar, Chittagong Hill Tracts. Recently cultivation of French bean is going popularity in Bangladesh mainly because of its demand as a commodity for export). Production of French bean depends on many factors such as quality of seed, variety, fertilizer management, soil moisture, plant spacing and proper management practices.

French bean is an important legume vegetable grown during *rabi* season for its tender green pods with high protein, calcium and iron contents. The Bangladesh Agricultural Research Institute (BARI) has developed two potential French bean varieties. Among the various factors that contribute towards the attainment to potential yield of french bean, optimum plant spacing or plant population is one of the important factors (Pawar *et al*., 2007). Plant density and sowing date are the two important factors of crop production. Several authors have reported that pod yield of French bean increases with the increase of plant density (Ali 1989: Dhanjal *et al.,* 2001; Mozumder *et al.,* 2003; Shivakumar *et al.,* 1996; Singh *et al.,* 1996). Mozumder*et al.,* (2003) obtained the highest yield of French bean from the plants spaced at 25 cm x 10 cm, while Dhanjal *et al.,* (2001) and Shivakumar *et al*., (1996) in their experiments observed the highest yield at the spacing of 30 cm x 10 cm and 30 x 15 cm, respectively. . Among the various factors, optimum sowing date and best variety are of primary importance to obtain potential yield (Amanullah *et al*., 2002). Furthermore; site-specific factors, such as cultural practices and sowing date influence yield, yield characteristics and quality parameters of French bean. Therefore, selection of the most suitable variety, determining suitable sowing date and applying appropriate cultural practices are very important for increasing quality and yield of French bean.

Plant spacing is an important factor that affects the yield contributing characters and yield which can be manipulated to maximize yield. With higher spacing vegetative growth enhances because of less competition of nutrients, light, moisture and space but yield potential decreases. Population density modifies the canopy structure and influence light interception, dry matter production and yield of the crop (Parwar *et al*., 2007; Fukai *et al*., 1990). Optimum plant spacing is essential for attaining desired yield because high planting density results in reduction in number of pods per plant and seeds per pods reported by Kueneman *et al*. (1979).

French bean production in Bangladesh is very low due to lower pollen production, fertilization and yield reduction. The growth of plants and other factors can be modified by pruning according to human desires (Jarrick, 1986). There are many purposes for branch pruning treatments in french bean, such as mechanical harvesting, hybrid seed production, to easily control insect and diseases, to use the higher plant population without significant yield reduction, and to obtain uniform fruits (Humphries, 1994). Stem pruning directly helped in the growth and yield of crop in acid soil (Mardhiana *et al*., 2017). The stem pruning increased total yield, yield per plant, number of fruits per plant, average fruit weight per plant in horticultural crops (Khoshkam, 2016). Data on fruit number, fruit mass, unmarketable yield, marketable yield and total yield was higher in stem pruning area of crops (Maboko *et al*., 2011). McFadyen *et al*. (2011) stated that total stem, fruit set and non-structural carbohydrates (TNSC) over time, and yield were maximum in stem pruning treated plots. The unpruned plants produced the highest total number of fruits, marketable and non-marketable fruits while the weight, length and diameter of fruits were highest on one stem pruning (Ekwu and Utobo, 2010). Utobo *et al*. (2010) reported that the significant differences in some vegetative growth parameters were found due to stem pruning.

The present study, therefore, was undertaken to test the influence of pruning and plant spacing on the growth and yield of french bean.

OBJECTIVES

1. To study the influence of plant spacing on quality seed production of french bean,
2. To study the influence of stem pruning on quality seed production of french bean and
3. To identify the combined effect of stem pruning and spacing on growth, yield and quality seed production of french bean.

CHAPTER II

REVIEW OF LITERATURE

3.1 Effect of spacing

Ahmed *et al*. (2016) was carried out the experiment at Mansehra during cropping season of 2013. There were three French bean cultivars and four different plant spacings. The experiment was laid out on a Randomized Complete Block Design (RCBD) with three replications. Different cultivars, plant spacings and their interactions significantly influenced all the parameters studied. Maximum days to flowering (59.33) and seed maturity (97.66) were recorded in cultivar Komal Green grown at 15 cm spacing, while, maximum 100-grain weight (42.20 g) was noted in cultivar Peshawar Local grown at 60 cm spacing. However, maximum fresh pod yield • plant^{-1} (109.67 g), number of seed • pod^{-1}(7.99) and seed yield • hm^{-2} (1 437.3 kg) were recorded in cultivar Paulista grown at spacing of 45 cm. Whereas, maximum plant height (40.50 cm) was noticed in cultivar Paulista grown at 15 cm plant spacing. While, the least number of days to flowering (50.33) and to seed maturity (85.66) were taken by cultivar Paulista grown at 60 cm plant spacing. Likewise, minimum seed yield (311.9 kg • hm^{-2}) was recorded in plants of cultivar Komal Green spaced at 60 cm plant spacing. While, minimum fresh pod weight • plant^{-1} (67.00 g) and number of seed • pod^{-1} (4.66) were attained in cultivar Peshawar Local grown at 15 cm plant spacing. Whereas, minimum plant height (27.59 cm) and 100-grain weight (15.60 g) were recorded for cultivar Komal Green grown at 45 and 15 cm, respectively.

Sahariar *et al*. (2015) was conducted a field experiment at the Horticulture Farm of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh to investigatethe effect of mulching and plant spacing on the growth and yield of French bean during the period from November 2014 to January 2015. The experiment consisted of three types of mulchingnamely (i) control (without mulch), (ii) water hyacinth and (iii) black ploythene much and three levels of spacing viz., (i) 30 cm x 25 cm (ii) 30 cm x 20 cm and (iii) 30 cm x 15 cm. The experiment was laid out in randomized complete block design with three replications. Results showed that both mulching and plant spacing significantly influenced the growth and yield components of French bean. Black polythene mulch produced the highest yield (5.82 t/ha) and the lowest yield (4.92 t/ha) was recorded fromno mulch treatment. The maximum yield (6.22 t/ha) was obtained from 30 cm x 15 cm plant spacing and the lowest (4.58 t/ha) was obtained with 30 cm x 25 cm plant spacing. The combined effects of mulching and plant spacing were statistically significant. The combination of black polythene mulch with 30 cm x 15 cm spacing gave the highest yield (6.97 t/ha) and the lowest yield (3.94 t/ha) was received from without mulching at spacing of 30 cm x 25 cm treatment combination. Considering the above findings, the black polythene mulch with 30 x 15 cm plant spacing may be recommendfor French bean cultivation.

Tuarira and Moses (2014) reported that seed is the basic unit for any agricultural production system. Without quality seed, no one can even think of good harvest and green been (Phaseolus vulgaris L.) production. Seed producers have to meet farmers seed demand by adopting appropriate plant population and arrangement pattern which would give them satisfactory seed yield of good quality. Previous researches on the same subject indicate that square arrangement results in high yield while others found no clear differences yet others advocate the use of higher plant densities during production. Several plant population densities (125,000 plants/ha, 163,265 plants/ha, 222,222 plants/ha and 320,000plants/ha) and three planting arrangement patterns (square, R50 and R40) were investigated in this study. Comparison of bush bean seed yield was highest (0.50t/ha) at population of 222,222 plants/ha and when planted in square arrangement pattern and least (0.13t/ha) at population of 360,000 plants/ha. Seed size was only influenced by plant population and not affected by plant arrangement pattern. Plant population density strongly influenced the percent of good seeds developed with populations of 125,000 and 163,265 plants/ha producing 97.01% and 96.15%, respectively. Germination of the harvested seeds was insignificant at all plant densities. The highest speed of germination (77.62%) of seeds was observed from a population density of 320,000 plants/ha. Therefore, green bean seed producers can adjust their planting density to 222,222 plants/ha in square arrangement to maximize seed yield.

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 15cm. 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 numbeof 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.

Mureithi *et al*. (2012) was conducted an experiment 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. Intra-row spacing of 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. The data was subjected to Analysis of Variance (ANOVA) and differences declared significant at 5% level. Increasing intra-row spacing from 10 to 15 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 of 20 cm produced the highest growth rate, cost benefit analysis could be ideal to justify its recommendation over intra-row spacing of 15 cm.

Moniruzzaman *et al*. (2009) was conducted a field experiments with French bean comprising two varieties (BARI bush bean- 1 and BARI bush bean-2), three plant densities (500 x 103, 333 x 103, and 250 x 103 plants/ha as maintained by 20 x 10, 30 x 10, and 40 x 10 cm spacings, respectively) and three levels of N (0, 60, and 120 kg/ha) were conducted at the Agricultural Research Station, Raikhali in the district of Rangamati during the winter (rabi) seasons of 2004-05 and 2005-06. BARI bush bean-1 outyielded BARI bush bean-2. The lowest plant density (250 x 10 plants/ha) recorded significantly higher values of growth and yield attributes, except plant height which was the maximum with the highest plant density of 500 x 103 plants/ha. The highest plant density of (500 x 103 plants/ha) resulted in the highest pod yield in comparison with the lower and medium plant densities. Application of 120 kg N/ha coupled with the highest plant density (500 x l03 plants/ha) gave the maximum pod yield of 34.3 t/ha and 30.2 t/ha in BARI bush bean-I and BARI bush bean-2, respectively.

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

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.

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 rows 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.

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.

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).

Akhter (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.

El-Habbasha, *et al.* (1996) 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.

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.

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.

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.

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 two seasons. The distribution of pod sizes, particularly as it affected the uniformity of pod maturity, was examined. Individual plants were more variable in their contribution to yield as density increased. In a glasshouse experiment, a more detailed description of plant form and the distribution of flowering and pod sizes according to positions on the plants were recorded. The nodes which bore the majority of the early flowers became the main yielding nodes. This information allowed an interpretation of yield responses in the field to plant density in terms of patterns of flowering.

Daniells and Wilson (1987) reported that, four cultivars of French beans (*Phaseolus vulgaris* L.) were grown in the field at different spacing. Wider spacing gave highest yield.

Field and Nkumbula (1986) reported that the yield and quality of green beans (*Phaseolus vulgaris* L. cv. Gallatin 50) was determined after sowing the crop at 150, 300, 380, and 450 mm between-row distances and within-row distances of 70 or 140 mm. Total pod yield and the yield of processable pods (> 50 mm in length) showed significant quadratic responses to increasing plant population density. A plant population density> 40 plants m^{-2} produced a total pod yield in excess of 3.0 kg m^{-2}. Plant population density was a more important determinant of yield than planting arrangement. There was no significant difference in pod size distribution between treatments, with at least 92.5% of total fresh weight being processable pods. Similarly, the distance between the soil and the first pod was not influenced by plant population. Pod colour, as determined by chlorophyll measurements, was not affected by population density but some pod bleaching occurred at all but the ISO mm between-row treatments.

Argerich *et al.* (1986) observed that closest spacing gave the higher pod yield.

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

Goulden (1976) stated that, navy beans, cv. ‘Sanilac’, were grown in rows 0.2 m and 0.4 m apart, and at 48, 71, and 104 mm within rows. Number of seeds per pod and 100-seed weights were not affected by the treatments used. Pods per plant and yield per plant were inversely correlated with yield per ha. Yield per ha generally increased with increasing plant density, especially with a decrease in row width, and the highest yields were obtained with the closest spacing in the narrow rows.

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.

2.2 Effect of pruning

Sabaruddin *et al*. (2013) reported that the soil fauna plays an important role in decomposition and nutrient mineralization. The objective of this research was to study the effect of "komba-komba" compost and planting time of mungbean intercropped with maize on yield and soil fauna. The research was conducted in research station of Agricultural Faculty, Haluoleo University. The experiment was laid out using split plot design with two factors ("komba-komba" compost and planting time of mungbean intercropped with maize). The result indicated that the highest net assimilation rate (NAR) of mungbean

5.78 g per cm^2 per week was obtained in the komba-komba compost 10 ton per ha with planting time of mungbean at 14 days after planting (DAP) maize whereas NAR of maize 5.50 g per cm^2 per week was obtained in the planting time of mungbean at 14 DAP maize. Coleoptera and Hymenoptera (Formicidae) were dominant and Shannon's diversity index ranged between 0.32 and 1.28. LER values tended to increase with the addition of "komba-komba" compost in soil and time variation of planting mungbean intercropped with maize. The relation between Shannon's diversity and LER values was variable.

Sebetha *et al*. (2010) was carried out a three-factorial field experiment at the University of Limpopo experimental Research farm during two planting seasons (2005/06 and 2006/07) to examine the effect of cowpea-leaf removal on cowpea performance. Three treatment factors namely cowpea varieties (Pan 311 and Red Caloona), cropping systems (sole and intercropping) and cowpea-leaf pruning regimes (pruned and un-pruned) were combined and arranged in a randomized complete block design (RCBD). Sole cowpea and sweet corn treatments were included and all treatments replicated four times. Fully expanded cowpea leaves on all cowpea plants in the two middle rows were harvested once at seven weeks after seed sowing prior to flowering. Growth and yield component data were collected from component crops while the protein content of harvested leaves and green pods as well as those of grains and the fodders at harvest were determined. The results of the study revealed that cowpea leaf protein content ranged from 24.1 to 28.1% and 26.0 to 30.7% for Red Caloona and Pan 311, respectively. The protein content of green cowpea pods obtained from Pan 311 cowpea variety ranged from 18.8 to 25.1% while that of Red Caloona varied between 17.9 and 20.7%. Similarly, the protein content of the fodder obtained after grain harvest varied between 9.3 and 9.4% and 9.9 and 12.3%, respectively for Pan 311 and Red Caloona during the two seasons. The protein content of cowpea grain obtained from intercropped plots (23.7 to 26.3%) was similar to that from sole plots (23.7 to 25.7%). In 2005/06, grain yield was 1704 kg ha^{-1} and 1480 kg ha^{-1}

respectively for Pan 311 and Red Caloona while 1291 and 512 kg ha^{-1} were obtained for Pan 311and Red Caloona, respectively in 2006/07. There was a significant season x varietal effects on pod and seed protein content. These results reveal that Pan 311 would be better suited for both vegetable and grain production purposes for human consumption while Red Caloona would better serve as a fodder crop for animal production. The results also show that neither cropping system nor cowpea leaf pruning did have consequential effects on the nutritional value of cowpea plant parts and grains.

Awodun *et al*. (2007) were conducted field trials in Southwest Nigeria to determine fertilizing effect of pruning of Gliricidia sepium on cowpea (*Vigna unguiculata* Walps). Pruning of gliricidia was applied at 0, 2, 4, 6, 8 and 10 t ha-1 as mulch. Soil fertility status and nutrient status and yield of cowpea given by the treatments were evaluated. Soil organic matter, N, P, K, Ca Mg and leaf N, P, K, Ca Mg and pod and grain yield of cowpea increased with amount of pruning. Relative to control 2, 4, 6, 8 and 10 t ha^{-1} pruning increased seed weight by 23, 97, 165, 201 and 218%, respectively.

Ayoola and Agboola (2004) were conducted field operations at the University of Ibadan, Nigeria on the effect of cassava (*Manihot esculenta* Crantz) planting pattern and pruning methods on cassava yield and yield of mixed crops, namely, maize (*Zea mays* L.), melon (*Colocynthis vulgaris* L.) and cowpea (*Vigna unguiculata*) in a cassava-based cropping system. Cassava planting patterns had significant effects on maize and melon yield in the 1995 but had no effect in 1996. Cowpea yield values under triangular planting pattern were 15 and 19% higher than regular planting pattern in 1995 and 1996, respectively. Its yield components differed under the two planting patterns. Number of cassava tubers and tuber weight plant^{-1} were superior under triangular planting pattern to regular planting pattern. The overall yield of cassava was, however, higher than regular planting pattern than triangular planting. The least cowpea yield and yield were recorded under unpruned cassava. Yield and yield components of cassava reduced when pruned irrespective of the type of pruning method.

Sulistyono (2000) reported that, an attempt to increase the yield of Snap bean/French bean (*Phaseolus vulgaris* L.) was practiced by pruning and Ethephon applications. This experiment was conducted at the farmer field in Mulyoagung village, Dau, Malang district from September to Nopember 1997. Three levels of pruning and four levels of Ethephon concentrations were arranged according to the Randomized Block Design in factorial pattern with three replications. The results of this experiment showed that pruning increased the growth and yield of fresh pod. The used of Ethephon increased number of food, pod yield per plant and pod yield per hectare, but it did not influence all of growth parameters. Pruning as much as two times at 15 days and 35 days after planting and application of Ethephon with 600 ppm concentrations, present the best growth and pod yield, with 2.66 t/ha and 2.68 t/ha fresh pod yield, respectively.

Karinge (1991) were conducted a series of trials at the International Institute of Tropical Agriculture, Ibadan, Nigeria, between January and December 1988 to evaluate the potential of calljandra for alley cropping. In a field experiment, the growth, biomass production and nutrient yield of calljandra and the growth and yield performance of sequentially grown maize and cowpea were assessed. Six treatments were used comprising three nitrogen rates (0, 45 and 90 kg N ha^{-1}) factorially combined with and without prunings in a randomized complete block design. Concurrently, a comparison of the decomposition rates and nitrogen release of calliandra and maize stover, and that of green and dry wood of calliandra, leucaena, calliandra, cassia and acioa was made using the same experimental field and design. In a greenhouse study, the N-manuring value and residual effects of dry and green leaves of calliandra and calliandra maize production were also investigated and compared with inorganic N-source in a randomized complete block design. Nitrogen from legume leaves and calcium ammonium nitrate (CAN) was supplied at 0, 50 ppm and 100 ppm N rates and the plant height, dry matter production and N-content in tops determined. Calljandra recorded an impressive one year's growth of 306.7 em, a maximum of 35 coppices per tree and a biomass production of 5.0 tons Dm ha^{-1} from four prunings contributing an estimated nutrient yield of 185 kg N, 13.3 kg P, 64.2 kg K, 55.2 kg Ca and 16 kg Mg ha^{-1}. Maize plant height and leaf area index were increased (xv) by pruning and inorganic N application, but not significantly. Levels of N, P and Mg in maize earleaves increased with increasing nitrogen and with pruning application, but only N was significant while K and Ca remained largely unaffected. Without prunings, the application of 45 and 90 kg N ha^{-1} increased total grain yield by 108 and 176% respectively. With pruning application, however, the respective yield increases were only 6 and 12%. Prunings alone double maize yield while the addition of 45 kg N increased yields by 12% and that of 90 kg N depressed yields by 8%. The effect of pruning applicaiton was approximately equivalent to the application of 45 kg N ha-1. Hedgerows significantly reduced per plant grain yield of plants grown adjacent to them, but the latter accumulated more N in grain than the former. Pruning application, residual Nand calliandra hedgerows did not significantly influence cowpea plant height or leaf area index. Plants near hedgerows' showed higher nutrient status than those in middle of alleys. Application of prunings significantly affected weed growth and flora in cowpea crop. Prunings slightly increased total seed yields and the proximity of cowpea to hedgerows had a significant positive effect on both number of pods and yield, with a significant interaction with residual N. Calliandra prunings decomposed four times faster than maize stover and green wood faster than dry wood, rates which were proportional to their respective C:N ratios. The order of decomposition was leucaena > gliricidia > calliandra > cassia> (xv i) acioa. The decomposition rates of cassia and acioa were significantly different from the rest. Under greenhouse conditions, inorganic N was a better Nsource than dry leaves of calliandra at same N-rates while calliandra was inhibitory at increasing application rate. Incubation of green and dry leaves for periods of

9, 6 and 3 weeks did not improve performance significantly, but green leaves were better than both inorganic N and dry leaves and gave a greater residual effect on subsequent maize crop.

Duguma *et al*. (1988) were carried out field trials on an Oxic Paleustalf in the humid zone of southwestern Nigeria with *Leucaena leucocephala* (Lam.) de Wit, *Gliricidia sepium* (Jacq.) Steud. And *Sesbania grandiflora* (L.) Pers. alley cropped with maize and cowpea. The three leguminous woody species were grown in hedgerows spaced at 2 m. Trials were carried out one year after establishment of the hedgerows using a split-plot design with four replications. The *Leucaena* trial had twenty pruning combinations consisting of five pruning heights (25, 50, 75, 100 and 150 cm) and four pruning frequencies (monthly, bi-, tri- and six-monthly). The *Gliricidia* and *Sesbania* hedgerows were subjected to nine pruning intensities consisting of three pruning heights (25, 50 and 100 cm) and three pruning intensities (monthly, tri- and six-monthly). For the three woody species, biomass, dry wood and nitrogen yield from the hedgerow prunings increased with decreasing pruning frequency and increasing pruning height. Biomass, dry wood and nitrogen yields were in the following order *Leucaena* >*Gliricidia* >*Sesbania*. The various pruning intensities had no effect on survival of *Leucaena* plants. Pruning frequency had a larger effect than pruning height on survival of *Gliricidia* and *Sesbania* plants. With monthly pruning, about 25 percent of the *Gliricidia* and all of the *Sesbania* plants died within six months of repeated pruning. Even with lower pruning frequency *Sesbania* plants showed lower survival rates than *Gliricidia* or *Leucaena*. The various pruning intensities of all the hedgerow species had more pronounced effects on the grain yield of the alley cropped cowpea than on maize grain yield. Higher maize and cowpea yields were obtained with increasing pruning frequency and decreasing pruning height.

Enyi (1975) reported that the defoliation reduced the dry weight of stems, pods, grains and size of individual grains in all four of the legume crops studied and the dry weight of flowering inflorescence stalk in the case of cowpeas and green gram only. The adverse effect of defoliation was more pronounced when defoliation was complete than when half of the number of leaves were removed. The greatest reduction in grain yield occurred when the plants were defoliated during the early podding stage, the percentage reduction being 59.7, 79.0, 86.4 and 95.3 in groundnut, cowpeas, soyabeans and green gram respectively when completely defoliated at this stage and 43.3, 14.0, 42.4 and 46.1 respectively when only half defoliated. The results show that assimilates produced by the leaves during the early stages of growth are used in the growth of stems and leaves, but the assimilates produced during the reproductive stage are used mainly for the growth of the pods. In groundnut, pod number and grain weight were positively correlated with stem weight. It appears that defoliation reduced pod number by depressing the growth of stems and this in turn reduced the number of flowering nodes. The reasons for the differences between the crops in their response to the defoliation treatments and the practical implications of the findings in relation to pest and disease control and plucking of leaves for human consumption are discussed.

CHAPTER III

MATERIALS AND METHOD

This chapter deals with the major information that was considered to conduct the experiment.

3.1 Experimental site

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Dhaka. The experiment was carried out during the period from November 2016 to March 2017. The location of the site in 23°74" N latitude and 90°35" E longitude with an elevation of 8.2 meter from sea level the experimental site is showed in appendix I.

3.2 Climate

The experimental site is located in subtropical region where climate is characterized by heavy rainfall during the months from May to August and scanty rainfall during rest of the month (Rabi season). The maximum and minimum temperature, humidity rainfall and soil temperature during the study period are collected from the Sher-e-Bangla Mini weather station at Sher-e-Bangla Agricultural University (Appendix II).

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract. Soil analysis report of the experimental area was collected from Khamarbari, Dhaka which was determined by SRDI, Soil testing Laboratory. The analytical data have been presented in appendix-II. The experimental site was a medium high land and pH of the soil was 5.4 to 5.6. The morphological characters of the soil as indicated by FAO (1988) are given here. AEZ No. 28 Soil series- Tejgaon General soil - Non -calcareous dark gray. The soil test report was shown in Appendix III.

3.4 Plant materials

The french bean cultivar i.e. BARI Jhar Sheem1 was used as a test crop.

3.5 Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A: Spacing

a. S_1=30 × 10 cm
b. S_2=30 × 15 cm
c. S_3=30 × 20 cm

Factor B: Pruning

a. P_0=No stem pruning
b. P_1= Stem pruning one times
c. P_2= Stem pruning two times

Treatments combinations S_1P_0, S_1P_1, S_1P_2, S_2P_0, S_2P_1, S_2P_2, S_3P_0, S_3P_1, S_3P_2

3.6 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Each block was divided into 9 plots. First blocks were included in first replication (R_1) and 2nd block was in second replication (R_2) and last blocks was in third replication (R_3). Every replication had twelve plots where 9 treatments were allotted at random. The size of each plot was 1.2 × 1.0 m. The distance between two blocks and two of plots both were l.0 m.

3.7 Land preparation

The selected land for the experiment was opened 5 November, 2016 with the help of a power tiller and then it was kept open to sun for 4 days prior to further ploughing. Then the land was prepared well by ploughing and cross ploughing followed by well by laddering at 9 November, 2016. Weeds and stubble were removed and the basal doses of fertilizers were applied and mixed thoroughly with soil before final land preparation. The unit plots were prepared by keeping l m spacing in between two plots and 50 cm drain was dug around the land. The space between two blocks and two plots were made as drain having a depth of about 30 cm.

3.8 Application of manures and fertilizers

Following doses of manures and fertilizers were recommended for cucumber production fertilizer recommendation guide (2012).

Fertilizers	**Doses ha^{-1}**
Cowdung	10 ton
Urea	50 kg
TSP	100 kg
MoP	55 kg
BA(Boric acid)	1 kg

All the fertilizers along with urea were applied by broadcasting and was mixed with soil thoroughly at the time of final land preparation after making plot. The furadan 5g at was also applied during land preparation to avoid the pest attack.

3.9 Sowing of seeds and selection of seedlings

The seeds were sown directly in the main plot on 21th November 2016. Two to three seeds were sown in each pit of 2 to 3 cm depth. When the seedlings attained 10-15 cm high and hard enough then one healthy seedling was selected to remain in each pit and others were thinned out. During seed sowing spacing was maintained as per the treatment.

3.10 Application of pruning treatment

Primary branches on main stem were prunned according to treatments. When the branches were appeared from the main stem of the plant and became 2-3 cm long then that was pruned. Pruning was done from the basal nodes of the plants according to treatments. Pruning was done on 13th December, 2016.

3.11 Intercultural Operations

3.11.1 Weeding

Weeding was done whenever necessary to keep the crop free from weeds.

3.11.2 Staking

When the seedlings were established, staking was given to each plant. Stick of bamboo stick was given to support the growing twig.

3.11.3 Stem management

For proper growth and development of the plants the stems were managed upward with the help of bamboo and plastic rope. So, the rainy and stormy weather could not damage the growing vines and fruits into the plants.

3.11.4 Irrigation

The experiment was done in rabi season. So, irrigation was given when it is necessary. Sometimes rain was supplied sufficient water then irrigation was no need. Irrigation was done through drains of the plots.

3.11.5 Plant protection

French bean is a very sensitive plant to various insect pests and diseases. So, various protection measures were taken. Melathion 57 EC and Ripcord was applied @ 2 ml against the insect pests like beetle, fruit fly, fruit borer and other. The insecticide application was made fortnightly from 10 days after seed sowing to a week before first harvesting. During cloudy and hot weather precautionary measures against viral disease like mosaic of cucumber was taken by spraying. Furadan 5 G was also applied during plot preparation as soil insecticide.

3.12 Harvesting

When the green fruits were in marketable condition then they were harvested.

3.13 Data collection

Data was collected for the following parameters

I. Plant height (cm)
II. Number of branches plant^{-1}
III. Total number of pods plant^{-1}
IV. Pod length (cm)
V. Pod diameter (cm)
VI. Number of seeds pod^{-1}
VII. Individual pod weight (g)
VIII. Pod weight plant^{-1} (g)
IX. Pod weight plot^{-1} (kg)
X. Pod yield (t ha^{-1})

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

XII. Germination (%)

XIII. Shoot length (cm)

XIV. Root length (cm)

3.14 Data collection procedure

3.14.1 Plant height (cm)

Plant height was taken at three times and measured in centimeter from ground level to tip of the main stem from each plant of each treatment and mean value was calculated.

3.14.2 Number of branches per plant

Total number of branches was counted at three times at 30, 45 DAS and at harvest from each plant of the treatment and mean value was calculated. The pruned branches number was also included in counting.

3.14.3 Number of pods $plant^{-1}$

Total number of pod $plant^{-1}$ from five plants were counted at harvest time from each plant of the treatment.

3.14.4 Pod length (cm)

Individual pod length was measured using the measuring tape and recorded as centimeter (cm).

3.14.5 Pod diameter (cm)

Pod diameter was measured using the measuring tape and mean value was recorded as centimeter (cm).

3.14.6 Number of seeds pod^{-1}

Five selected pods from each plant of each treatment was used for counting the number of seeds pod^{-1}. Finally, the mean value of the number of seeds pod^{-1} was counted.

3.14.7. Pod weight (gm)

The pod weight value i.e. individual pod weight (g), pod weight $plant^{-1}$ (g) and pod weight $plot^{-1}$ (kg) was measured from each of the treatment.

3.14.8 Yield of pods and seeds

To estimate yield, all the plants in every plot and all the fruits in every harvest were considered. Thus, the average yield per plot was measured. The yield per hectare was calculated considering the area covered by the all plants. Finally, the seed yield was calculated as t ha^{-1}.

3.14.9 Germination percentage

After harvesting germination test was done in the laboratory of Department of Agronomy. Twenty five seeds were placed in each petri dish and germinated seedling was counted. Finally, total number was converted as percentage.

3.14.10 Shoot length and root length

From the germinated seedling, shoot length and root length was measured using measuring tape and recorded as centimeter (cm).

3.15 Statistical analysis

The recorded data on different parameters were statistically analyzed using Statistix 10 software and mean separation was done by DMRT test at 5% level of probability.

CHAPTER IV

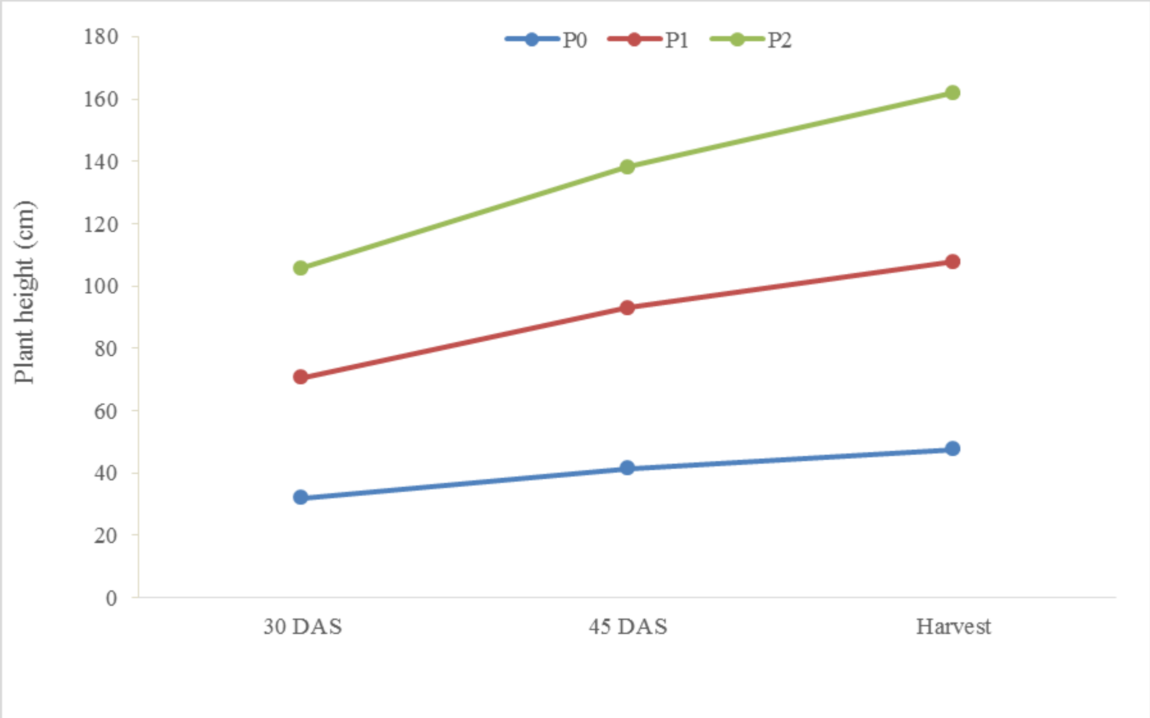
RESULTS AND DISCUSSION

The present experiment was conducted to determine the quality seed production of french bean influence as pruning and spacing. Data on growth, yield contributing characters, yield and seed quality characters were recorded to find out the suitable cultivar and optimum planting time. The analyses of variance (ANOVA) of the data on different yield contributing characters, yield is presented in Appendices IV-XXI. The results have been presented and discussed, and possible interpretations given under the following headings-

4.1 Plant height (cm)

Effect of pruning

Plant height of french bean at different growth stages varied significantly due to different pruning treatments (Figure 1 and Appendix IV, V, VI). Results signified that the tallest plant (38.63, 51.42 and 60.22 cm at 30, 45 DAS and at harvest respectively) was found from P_1 which was significantly different from other treatments where the smallest plant (32.01 cm, 41.43 cm and 47.60 cm at 30, 45 DAS and at harvest respectively) was found from P_2. This might be due to that pruning helped in vegetative growth of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

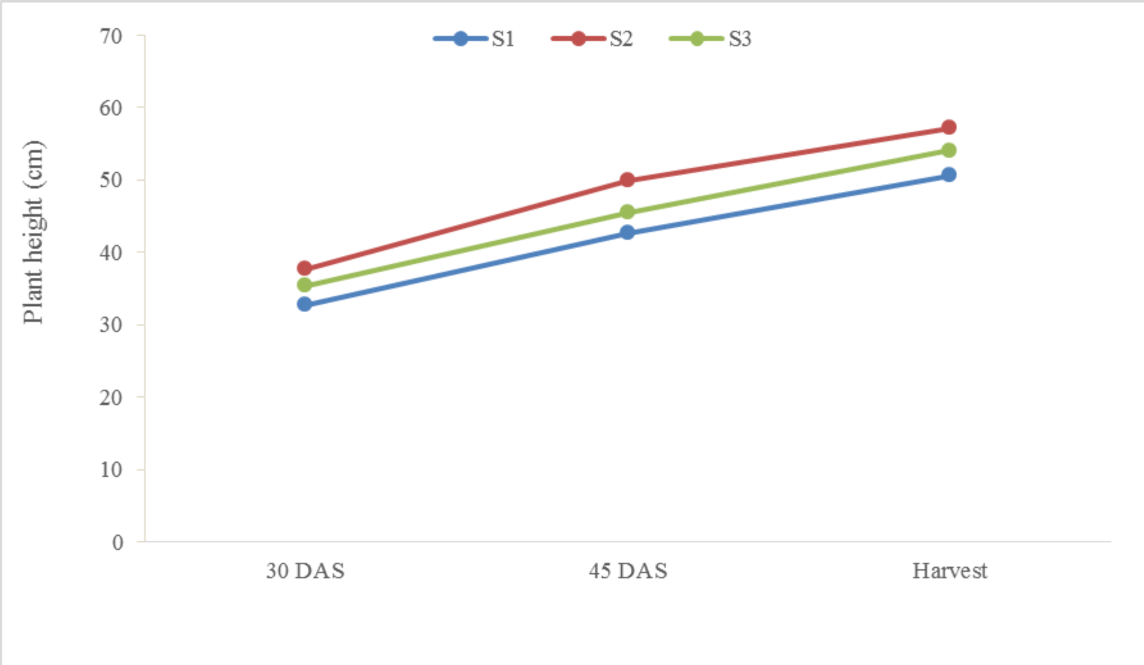


DAS= Days after sowing, P_0= no pruning, P_1= one time pruning, P_2= two times pruning

Figure 1. Effect of pruning on plant height of french bean

Effect of spacing

Different spacing treatments showed significant variation on plant height of french bean at different growth stages (Figure 2 and Appendix IV, V, VI). It was found that wider spacing (30×15 cm) gave higher plant growth. The tallest plant (37.69, 49.92 and 57.18 cm at 30, 45 DAS and at harvest respectively) was found from S_2 while the shortest plant (32.70, 42.65 and 50.67 cm at 30, 45 DAS and at harvest respectively) was found from S_1. Probably wide spacing facilitated proper growth and development of plant. Ahmed *et al.* (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.



DAS= Days after sowing, S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

Figure 2. Effect of spacing on plant height of french bean

Combined effect of pruning and spacing

Significant influence was examined on plant height of french bean at different growth stages affected by combined effect of pruning and spacing except at harvest (Table 1 and Appendix IV, V, VI). Results indicated that the tallest plant (45.25, 57.91 and 63.47 cm at 30, 45 DAS and at harvest respectively) was found from the treatment combination of P_1S_2. The treatment combination of P_0S_1 produced shortest plant (29.80, 38.58 and 44.74 cm at 30, 45 DAS and at harvest respectively) compared to others combinations.

Table 1. Combined effect of spacing and pruning on plant height of french bean

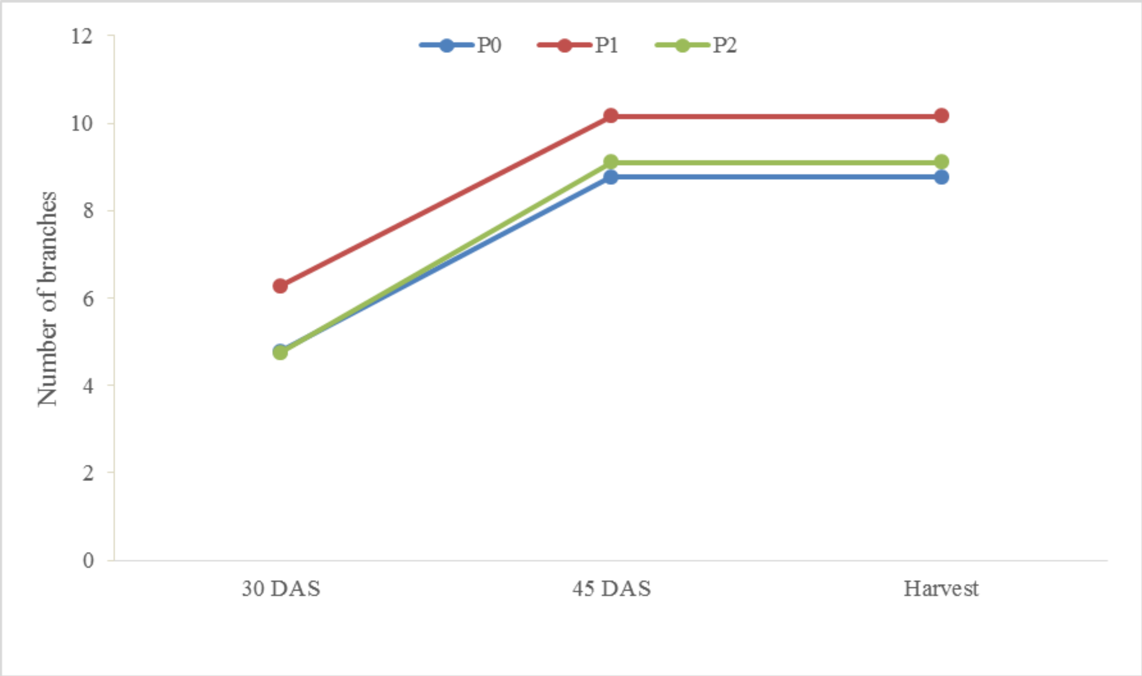
Treatments	Plant height (cm) at		
	30 DAS	45 DAS	Harvest
P_0S_1	29.80 e	38.58 f	44.74 e
P_0S_2	33.90 d	44.33 cde	50.54 d
P_0S_3	32.33 de	41.38 ef	47.54 de
P_1S_1	34.27 cd	46.26 cd	56.80 c
P_1S_2	42.25 a	57.91 a	63.47 ab
P_1S_3	39.36 ab	50.09 b	60.38 a
P_2S_1	34.03 cd	43.11 de	50.48 d
P_2S_2	36.93 bc	47.52 bc	57.54 bc
P_2S_3	34.40 cd	44.94 cd	54.34 c
SE (±)	**0.849**	**0.908**	**0.912**

DAS= Days after sowing, P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

4.2 Number of branches plant^{-1}

Effect of pruning

Number of branch/plant of french bean showed statistically significant variation due to different pruning treatment at different growth stages (Figure 3 and Appendix VII, VIII, IX). The maximum number of branches plant-^{1} (6.27, 10.16, 10.16 at 30, 45 DAS and at harvest, respectively) was recorded from P_1 (one time pruning). The minimum number of branches plant^{-1} (4.77, 8.77 and 8.77 at 30, 45 DAS and at harvest, respectively) was recorded from the control treatment (no pruning). This might be due to that pruning helped in vegetative growth of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

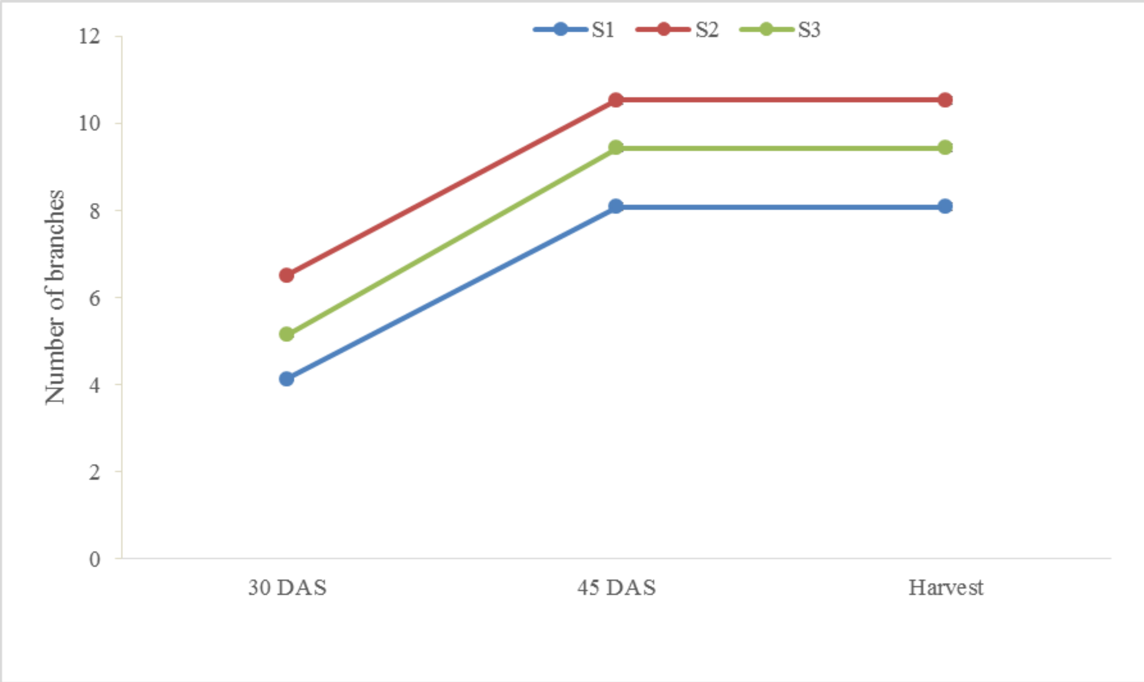


DAS= Days after sowing, P_0= no pruning, P_1= one time pruning, P_2= two times pruning

Figure 3. Effect of pruning on number of branches plant^{-1} of french bean

Effect of spacing

Different spacing of french bean cultivation had significant influence on number of branches plant^{-1} (Figure 4 and Appendix VII, VIII, IX). Results revealed that the maximum number of branches plant^{-1} (6.51, 10.53 and 10.53 at 30, 45 DAS and at harvest, respectively) was recorded from wider spacing S_2 (30×15 cm). While the minimum number of branches plant^{-1} (4.13, 8.08 and 8.08 at 30, 45 DAS and at harvest, respectively) was recorded from the closer spacing S_1 (30×10 cm). Probably wide spacing facilitated proper growth and development of plant. Ahmed *et al*. (2016), Sahariar *et al*. (2015), Tuarira and Moses (2014) and Getachew *et al*. (2014) reported the similar finding for the spacing experiment of french bean.



DAS= Days after sowing, S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

Figure 4. Effect of spacing on number of branches plant^{-1} of french bean

Combined effect of pruning and spacing

Combined effect of pruning and spacing had a significant influence on number of branches plant^{-1} (Table 2 and Appendix VII, VIII, IX). Results exposed that the treatment combination of P_1S_2 exhibited the maximum number of branches plant^{-1} (7.36, 11.37 and 11.37 at 30, 45 DAS and at harvest, respectively). The minimum number of branches plant^{-1} (3.10, 7.16 and 7.16 at 30, 45 DAS and at harvest, respectively) was found from the treatment combination of P_0S_1.

Table 2. Combined effect of spacing and pruning on number of branches plant^{-1}

Treatments	Number of branches plant^{-1} at		
	30 DAS	45 DAS	Harvest
P_0S_1	3.10 e	7.16 e	7.16 e
P_0S_2	6.13 b	10.05 b	10.05 b
P_0S_3	5.10 c	9.10 c	9.10 c
P_1S_1	5.23 c	9.04 c	9.04 c
P_1S_2	7.36 a	11.37 a	11.37 a
P_1S_3	6.23 b	10.07 b	10.07 b
P_2S_1	4.06 d	8.04 d	8.04 d
P_2S_2	6.05 b	10.16 b	10.16 b
P_2S_3	4.11 d	9.11 c	9.11 c
SE (±)	**0.089**	**0.158**	**0.158**

DAS= Days after sowing, P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

4.3 Number of pods plant^{-1}

Effect of pruning

Number of pods plant^{-1} of french bean affected by different pruning treatment and showed statistically significant variation (Table 3 and Appendix X). It was found that the maximum number pods plant^{-1} (27.27) was recorded from P_1 (one time pruning) followed by P_2 (two time pruning) where the minimum number of pods plant^{-1} (23.58) was found from P_0 (no pruning). This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

Significant influence was observed for number of pods plant^{-1} affected by different spacing treatment of french bean (Table 3 and Appendix X). Results revealed that the maximum values of number of pods plant^{-1} (26.98) was recorded from the spacing of S_2 (30×15 cm) where the minimum value of the number of pods plant^{-1} (23.58) was recorded from spacing, S_1 (30×10 cm) followed by the spacing of S_3 (30×20 cm). Probably wide spacing facilitated proper reproductive development of plant. Ahmed *et al*. (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Table 3. Effect of pruning and spacing on number of pods, pod length and pod diameter

Treatments	Number of pods	Pod length (cm)	Pod diameter (cm)
Pruning			
P_0	23.58 c	12.19 c	1.30 c
P_1	27.27 a	14.18 a	1.58 a
P_2	24.93 b	13.09 b	1.38 b
SE (±)	**0.072**	**0.038**	**0.016**
Spacing			
S_1	23.58 c	12.16 c	1.26 c
S_2	26.98 a	14.17 a	1.59 a
S_3	25.20 b	13.13 b	1.39 b
SE (±)	**0.072**	**0.038**	**0.016**

P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

Combined effect of pruning and spacing

Number of pods plant^{-1} of french bean was significantly varied due to combined between pruning and spacing (Table 4 and Appendix X). Results demonstrated that the treatment combination of P_1S_2 exhibited the maximum number of pods plant^{-1} (29.36). The minimum value of number of pods plant^{-1} (22.16) was found from the treatment combination of P_0S_1.

4.4 Pod length (cm)

Effect of pruning

The pod length of french bean affected by different pruning treatment and showed statistically significant variation (Table 3 and Appendix XI). It was found that the highest value of pod length (14.18 cm) was recorded from P_1 (pruning one time) which was statistically different from all other pruning treatments where the lowest pod length (12.19 cm) was found from P_0 (control) which was also statistically different from all other pruning treatments. This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

Significant influence was observed for pod length affected by different spacing of french bean (Fig. 6 and Appendix IV). Results revealed that the highest pod length (14.17 cm) was recorded from the wider spacing of S_1 (30×15 cm) which was statistically different from the rest. The lowest pod length (12.16 cm) was recorded from closer spacing S_1 (30×10 cm) followed by the spacing of S_3 (30×20 cm). Probably wide spacing facilitated proper reproductive development of plant. Ahmed *et al.* (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Combined effect of pruning and spacing

The pod length of french bean was significantly varied due to combined of prunings and spacings (Table 4 and Appendix XI). Results showed that the treatment combination of P_1S_2 exhibited the highest pod length (15.18 cm) which was statistically different from other combinations. The lowest pod length (11.19 cm) was found from the treatment combination of P_0S_1 which was statistically differ from rest of the combinations.

Table 4. Combined effect of spacing and pruning on number of branches plant^{-1}

Treatments	Number of pods	Pod length (cm)	Pod diameter (cm)
P_0S_1	22.16 f	11.19 e	1.22 e
P_0S_2	25.29 d	13.24 c	1.37 cd
P_0S_3	23.28 e	12.14 d	1.33 d
P_1S_1	25.27 d	13.23 c	1.33 d
P_1S_2	29.36 a	15.18 a	1.94 a
P_1S_3	27.17 b	14.15 b	1.48 b
P_2S_1	23.32 e	12.07 d	1.31 de
P_2S_2	26.31 c	14.09 b	1.45 bc
P_2S_3	25.17 d	13.11 c	1.37 cd
SE (±)	**0.125**	**0.066**	**0.029**

P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

4.5 Pod diameter (cm)

Effect of pruning

Pod diameter of french bean affected by different pruning treatment and showed statistically significant variation (Table 3 and Appendix XII). It was found that the highest pod diameter (1.58 cm) was recorded from P_1 (pruning one time) followed by the pruning P_2 (two times pruning). Again, the lowest pod diameter (1.30 cm) was recorded from P_0 (No pruning). This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

Significant influence was observed for pod diameter of french bean affected by different spacing of french bean (Table 3 and Appendix XII). Results revealed that the highest pod diameter (1.59 cm) was recorded from spacing of S_1 (30×15 cm) Again, the lowest pod diameter (1.26 cm) was recorded from closer spacing, S_1 (30×10 cm). Probably wide spacing facilitated proper reproductive development of plant. Ahmed *et al*. (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Combined effect of pruning and spacing

The pod diameter of french bean was significantly varied due to combined of pruning and spacing (Table 4 and Appendix XII). Results demonstrated that the treatment combination of P_1S_2 exhibited the highest value pod diameter (1.94 cm) while the lowest value of pod diameter (1.22 cm) of French bean was recorded from the combination of P_0S_1.

4.6 Number of seeds pod^{-1}

Effect of pruning

Statistically significant variation was observed for number of seeds plant^{-1} of french bean by different pruning treatments (Table 5 and Appendix XIII). Results revealed that the maximum number seeds pod^{-1} (7.21) was recorded from P_1 (one time pruning) which was significantly different from all other pruning treatments. Again, the pruning, P_0 (no pruning) produced the minimum number of seeds pod^{-1} (5.20) compared to others. This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

Different spacing treatment of french bean had significant effect on number of seeds pod^{-1} (Table 5 and Appendix XIII). Results signified that the maximum number of seeds pod^{-1} (7.21) was recorded from wider spacing of S_2 (30×15 cm) followed by the further wider spacing, S_3 (30×20 cm) where the minimum number of seeds pod^{-1} (5.17) was recorded from closer spacing, S_1 (30×10 cm). Probably wide spacing facilitated proper reproductive development of plant. Ahmed *et al*. (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and

Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Table 5. Effect of pruning and spacing on number of seeds pod^{-1}, individual pod weight and pod weight plant^{-1}

Treatments	Number of seeds pod^{-1}	Individual pod weight (g)	Pod weight plant^{-1} (g)
Pruning			
P_0	5.20 c	7.19 c	123.40 c
P_1	7.21 a	9.18 a	135.68 a
P_2	6.11 b	8.23 b	130.94 b
SE (±)	**0.046**	**0.055**	**0.377**
Spacing			
S_1	5.17 c	7.08 c	127.53 c
S_2	7.21 a	9.34 a	133.06 a
S_3	6.13 b	8.18 b	129.44 b
SE (±)	**0.046**	**0.055**	**0.377**

P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

Combined effect of pruning and spacing

Number of seeds pod^{-1} of french bean was varied by combined of pruning and spacing (Table 6 and Appendix XIV). Results exhibited that the highest number of seeds pod^{-1} (8.31) was achieved from the treatment combination of P_1S_2 followed. The minimum number of seeds pod^{-1} (4.19) was found from the treatment combination of P_0S_1 which was statistically differ with others combinations.

4.7 Individual pod weight (gm)

Effect of pruning

Significant variation was found for individual pod weight of french bean influenced by different prunings (Table 5 and Appendix XIV). Results indicated that the highest individual pod weight (9.18 g) was recorded from P_1 (one time pruning). Again, the lowest individual pod weight (7.08 g) was found from P_1 (no pruning) compared to others pruning. This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

Different spacing of french bean had significant effect on individual pod weight (Table 5 and Appendix XIV). It was observed that the highest individual pod weight (9.34 g) was recorded from wider spacing of S_1 (30×15 cm) where the lowest individual pod weight (7.08 g) was recorded from closer spacing, S_1 (30×10 cm). Probably wide spacing facilitated proper reproductive development of plant. Ahmed *et al.* (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Combined effect of pruning and spacing

Combined effect of pruning and spacing had influenced on individual pod weight of french bean (Table 6 and Appendix XIV). It was examined that the highest individual pod weight (8.07 g) was achieved from the treatment combination of P_1S_2. Again, the lowest individual pod weight (6.13 g) was found from the treatment combination of P_0S_1.

4.8 Pod weight plant^{-1}(gm)

Effect of pruning

Significant effect was observed in terms of pod weight plant^{-1} of french bean affected by different prunings (Table 5 and Appendix XV). Results showed that the highest value of pod weight plant^{-1} (135.68 g) was recorded from P_1 (pruning one time) which was statistically differ from others combination where the lowest value of pod weight plant^{-1} (123.40 g) was found from P_0 (no pruning). This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

The pod weight plant^{-1} was significantly varied due to different spacing of french bean (Table 5 and Appendix XV). Data represented that the highest value of pod weight plant^{-1} (133.06 g) was recorded from wider spacing of S_2 (30×15 cm) but further increasing of spacing P_2 (30×20 cm) did not increase the pod weight plant^{-1} where the lowest value of pod weight plant^{-1} (127.53 g) was recorded from closer spacing, S_1 (30×10 cm).

Combined effect of pruning and spacing

The pod weight plant^{-1} affect by combined effect of pruning and spacing was significant of french bean (Table 6 and Appendix XV). Results showed that the highest value of pod weight plant^{-1} (139.36 g) was achieved from the treatment combination of P_1S_2. But the lowest value of pod weight plant^{-1} (121.49 g) was found from the treatment combination of P_0S_1 which was statistically differ with other combinations.

Table 6. Combined effect of number of seeds pod^{-1}, individual pod weight and pod weight plant^{-1}

Treatments	Number of seeds pod^{-1}	Individual pod weight (g)	Pod weight plant^{-1} (g)
P_0S_1	4.19 e	6.13 e	121.49 e
P_0S_2	6.25 c	8.29 c	126.56 d
P_0S_3	5.17 d	7.14 d	122.17 e
P_1S_1	6.19 c	8.07 c	132.84 bc
P_1S_2	8.31 a	10.32 a	139.36 a
P_1S_3	7.13 b	9.17 b	134.83 b
P_2S_1	5.15 d	7.06 d	128.25 d
P_2S_2	7.07 b	9.40 b	133.25 bc
P_2S_3	6.10 c	8.22 c	131.32 c
SE (±)	**0.080**	**0.095**	**0.653**

P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

4.9 Pod weight plot^{-1}(kg)

Effect of pruning

There was a significant effect was observed in case of pod weight plant^{-1} of french bean distressed by different prunings (Table 7 and Appendix XVI). It was tested that the highest pod weight plant^{-1} (6.15 kg) was recorded from P_1 (one time pruning) which was statistically different from all other test prunings. The lowest pod weight plant^{-1} (4.51 kg) was obtained from the control treatment (P_0). This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al.* (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

Different spacing of french bean had significant influence on pod weight plant^{-1} (Table 7 and Appendix XVI). Results indicated that the highest pod weight plant^{-1} (6.24 kg) was recorded from spacing of S_2 (30×15 cm) where the lowest pod weight plant^{-1} (4.51 kg) was recorded from closer spacing, S_1 (30×10 cm). Probably wide spacing facilitated proper reproductive development of plant. Ahmed *et al*. (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Table 7. Effect of pruning and spacing on pod weight plot^{-1}, pod yield ha^{-1}

Treatments	Pod weight plot^{-1} (kg)	Pod yield (t ha^{-1})
Pruning		
P_0	4.51 c	9.21 c
P_1	6.16 a	13.86 a
P_2	5.25 b	10.27 b
SE (±)	**0.047**	**0.042**
Spacing		
S_1	4.51 c	9.83 c
S_2	6.24 a	12.27 a
S_3	5.16 b	11.23 b
SE (±)	**0.047**	**0.042**

P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

Combined effect of pruning and spacing

Different combined of pruning and spacing under the present study showed significant variation on pod weight plant^{-1} of french bean (Table 8 and Appendix XVI). It was observed that the highest pod weight plant^{-1} (5.13 kg) was achieved from the treatment combination of P_1S_2. On the other hand, the lowest pod weight plant^{-1} (4.18 kg) was found from the treatment combination of P_0S_1.

4.10 Pod yield (tonha^{-1})

Effect of pruning

Different prunings of french bean gave statistically significant difference on pod yield of french bean (Table 7 and Appendix XVII). Results revealed that the highest pod yield (13.86 t ha^{-1}) was recorded from P_1 (one time pruning) which was statistically different from all other test prunings. With further increasing of pruning (P_2= two time pruning) the pod yield did not increased further. The lowest pod yield (9.21 t ha^{-1}) was found from P_0 (no pruning). This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

Significant variation was obtained on pod yield of french bean influenced by different spacing (Table 7 and Appendix XVII). It was examined that the highest pod yield ha^{-1} (12.27 t ha^{-1}) was recorded from wider spacing of S_2 (30×15 cm). But data demonstrated that with an increasing the spacing S_3 (30×20 cm) the pod yield did not increase. However, the lowest pod yield (9.83 t ha^{-1}) was found in control pruning treatment (P_0). Probably wide spacing facilitated proper reproductive development of plant. Ahmed *et al*. (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Combined effect of pruning and spacing

Pod yield ha^{-1} of french bean was significantly varied due to combined effect of pruning and spacing (Table 8 and Appendix XVII). Results indicated that the highest pod yield (15.22 t ha^{-1}) was achieved from the treatment combination of P_1S_2. On the contrary, the lowest pod yield (8.10 t ha^{-1}) was found from the treatment combination of P_0S_1 which was immediate lower than P_0S_3. The highest yield ha^{-1} from the treatment combination of P_1S_2 might be due to cause of higher number of pods $plant^{-1}$, number of individual pod weight, number of seeds pod^{-1} and pod weight $plant^{-1}$ from this treatment combination.

Table 8. Combined effect of pod weight plot^{-1}, pod yield and seed yield

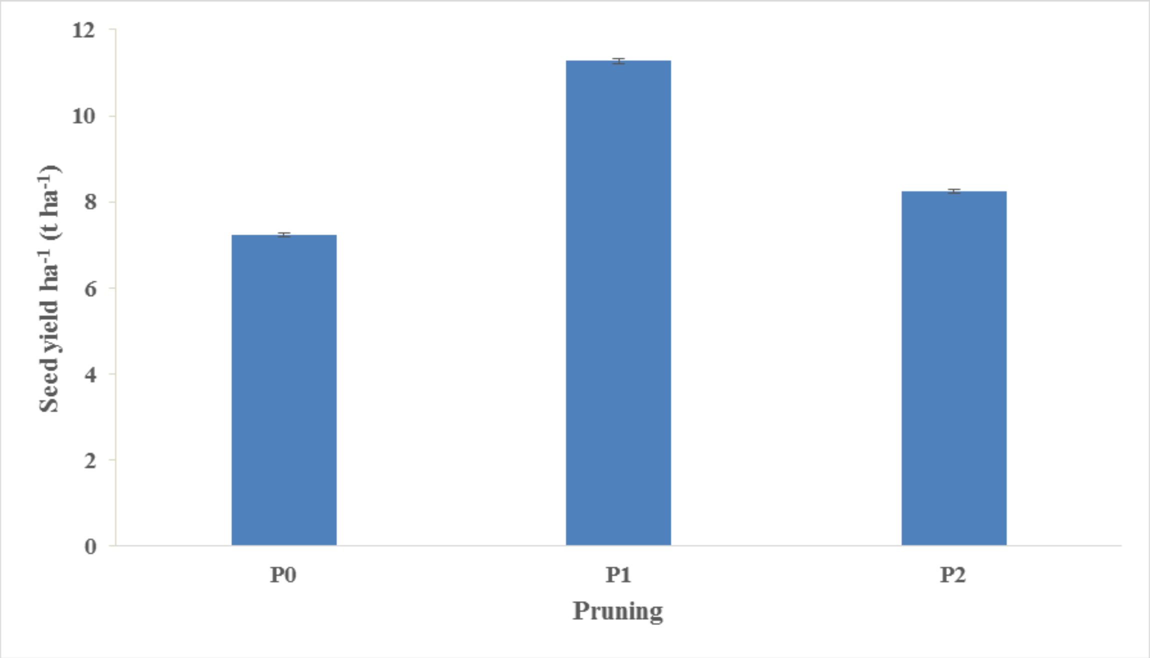
Treatments	pod weight plot^{-1} (kg)	Pod yield (t ha^{-1})	Seed yield (t ha^{-1})
P_0S_1	4.18 d	8.10 g	6.15 g
P_0S_2	5.22 c	10.29 e	8.32 e
P_0S_3	4.12 d	9.23 f	7.27 f
P_1S_1	5.13 c	12.21 c	10.23 c
P_1S_2	7.21 a	15.22 a	12.42 a
P_1S_3	6.14 b	14.15 b	11.18 b
P_2S_1	4.24 d	9.19 f	7.17 f
P_2S_2	6.31 b	11.31 d	9.19 d
P_2S_3	5.20 c	10.32 e	8.16 e
SE (±)	**0.081**	**0.073**	**0.084**

P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

4.11 Seed yield (tha^{-1})

Effect of pruning

Different prunings of french bean gave statistically significant difference on seed yield of french bean (Figure 5 and Appendix XVIII). Results revealed that the highest seed yield (11.27 t ha^{-1}) was recorded from P_1 (one time pruning) which was statistically different from all other test prunings. With further increasing of pruning (P_2= two time pruning) the seed yield did not increased further. The lowest seed yield (7.24 t ha^{-1}) was found from P_0 (no pruning). This might be due to that pruning helped in reproductive development of plant. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

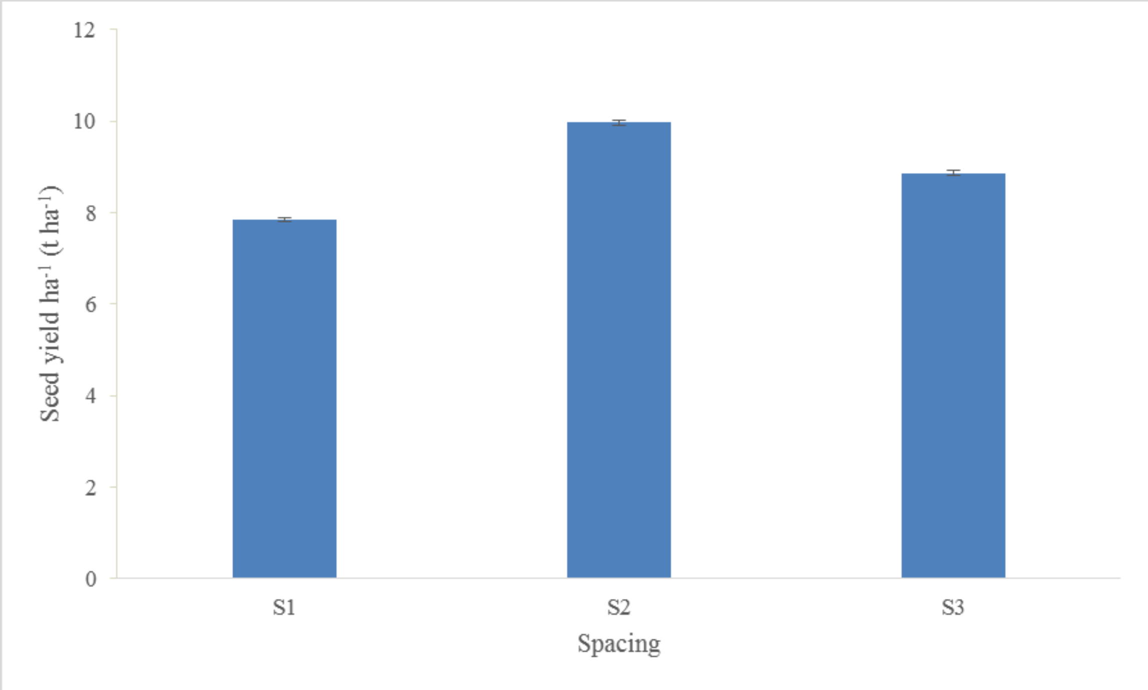


P_0= no pruning, P_1= one time pruning, P_2= two times pruning

Figure 5. Effect of pruning on seed yield of french bean

Effect of spacing

Significant variation was obtained on seed yield of french bean influenced by different spacing (Figure 6 and Appendix XVIII). It was examined that the highest seed yield ha^{-1} (9.97 t ha^{-1}) was recorded from wider spacing of S_2 (30×15 cm). But data demonstrated that with an increasing the spacing S_3 (30×20 cm) the seed yield did not increase further. However, the lowest seed yield (7.85 t ha^{-1}) was found in control pruning treatment (P_0). Probably wide spacing facilitated proper reproductive development of plant. Ahmed *et al.* (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.



S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

Figure 6. Effect of spacing on seed yield of french bean

Combined effect of pruning and spacing

The seed yield ha^{-1} of french bean was showed wide range of variations due to the combined effect of pruning and spacing (Table 8 and Appendix XVIII). Results indicated that the highest seed yield (12.42 t ha^{-1}) was achieved from the treatment combination of P_1S_2. On the contrary, the lowest pod yield (6.15 t ha^{-1}) was found from the treatment combination of P_0S_1 which was immediate lower than P_0S_3. The highest yield ha^{-1} from the treatment combination of P_1S_2 might be due to cause of higher number of pods $plant^{-1}$, number of individual pod weight, number of seeds pod^{-1} and pod weight $plant^{-1}$ from this treatment combination.

Seed quality parameters

4.12. Germination (%)

Effect of pruning

Germination percentage of french bean showed statistically significant variations among the pruning treatment (Table 9 and Appendix XIX). Result demonstrated that the highest value of germination percentage (92.24%) of french bean was recorded from the pruning treatment P_1 (one time pruning). The lowest value of the same trait (81.35%) was found from the treatment P_0 (control) compared to the others treatments. This might be due to that pruning helped in seed quality. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

Significant variations of the germination percentage of french bean was found for the different spacing treatment (Table 9 and Appendix XIX). Table represents that the maximum number of germinated seedling (88.95%) was found in the wider spacing S_2 (30×15 cm). But the minimum number of germinated seedling (83.90%) was observed in the closer spacing S_1 (30×10 cm). Probably wide spacing facilitated the seed quality. Ahmed *et al.* (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Table 9. Effect of pruning and spacing on germination, shoot length and root length

Treatments	Germination (%)	Shoot length (cm)	Root length (cm)
Pruning			
P_0	81.35 c	13.16 c	6.11 c
P_1	92.24 a	17.17 a	8.26 a
P_2	85.56 b	15.17 b	7.14 b
SE (±)	**0.076**	**0.021**	**0.059**
Spacing			
S_1	83.90 c	14.18 c	6.09 c
S_2	88.95 a	16.18 a	8.26 a
S_3	86.30 b	15.14 b	7.15 b
SE (±)	**0.076**	**0.021**	**0.059**

P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

Combined effect of pruning and spacing

The combined effect between pruning and spacing showed a wide range of variations among the treatment combinations (Table 10 and Appendix XIX). Data showed that the highest value of the germination percentage (95.31%) was recorded in the P_1S_2 while the lowest value (79.20%) of the same trait was found in the combination P_0S_1.

4.13. Shoot length (cm)

Effect of pruning

The shoot length of french bean showed statistically significant variations due the the pruning treatment (Table 9 and Appendix XX). Result indicated that the highest value of shoot length (17.17 cm) of french bean was recorded from the pruning treatment P_1 (one time pruning). The lowest value of the shoot length (13.16 cm) was found from the treatment P_0 (control) compared to the other pruning treatments. This might be due to that pruning helped in seed quality. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Effect of spacing

The significant variation of the shoot length of french bean was found for the different spacing treatment (Table 9 and Appendix XX). Data revealed that the highest shoot length (16.18 cm) was found in the wider spacing S_2 (30×15 cm). But the lowest shoot length (14.18 cm) was observed in the closer spacing S_1 (30×10 cm). Probably wide spacing facilitated the seed quality. Ahmed *et al*. (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Combined effect of pruning and spacing

The combined effect of pruning and spacing showed a wide range of variations among the treatment combinations (Table 10 and Appendix XX). Table showed that the highest value of the shoot length (18.16 cm) was recorded in the P_1S_2 while the lowest value (12.19 cm) of the shoot length was found in the combination P_0S_1.

4.14 Root length (cm)

Effect of pruning

The root length of french bean showed statistically significant variations among the pruning treatments (Table 9 and Appendix XXI). Result demonstrated that the highest value of root length (8.26 cm) of french bean was recorded from the pruning treatment P_1 (one time pruning). The lowest of the root length (6.11 cm) was found from the treatment P_0 (control) compared to the others treatments. This might be due to that pruning helped in seed quality. The present finding is agreed with the findings of Sabaruddin *et al*. (2013), Sebetha *et al*. (2010), Awodun *et al*. (2007), Ayoola and Agboola (2004) and Sulistyono (2000).

Table 10. Combined effect of on germination, shoot length and root length

Treatments	Germination (%)	Shoot length (cm)	Root length (cm)
P_0S_1	79.20 h	12.19 g	5.07 e
P_0S_2	83.37 f	14.19 e	7.19 c
P_0S_3	81.48 g	13.11 f	6.07 d
P_1S_1	89.19 c	16.18 c	7.08 c
P_1S_2	95.31 a	18.16 a	9.51 a
P_1S_3	92.23 b	17.19 b	8.19 b
P_2S_1	83.30 f	14.19 e	6.12 d
P_2S_2	88.18 d	16.19 c	8.10 b
P_2S_3	85.19 e	15.13 d	7.19 c
SE (±)	**0.132**	**0.036**	**0.102**

P_0= no pruning, P_1= one time pruning, P_2= two times pruning; S_1= 30×10 cm spacing, S_2=30×15 cm spacing and S_3= 30×20 cm spacing

Effect of spacing

Significant variations of the root length of french bean was found for the different spacing treatment (Table 9 and Appendix XXI). Table represents that the highest value of the toot length (8.26 cm) was found in the wider spacing of S_2 (30×15 cm). But the lowest value of root length (6.09 cm) was observed in the closer spacing S_1 (30×10 cm). Probably wide spacing facilitated the seed quality. Ahmed *et al*. (2016), Sahariar *et al.* (2015), Tuarira and Moses (2014) and Getachew *et al.* (2014) reported the similar finding for the spacing experiment of french bean.

Combined effect of pruning and spacing

The combined effect between pruning and spacing showed a significant variation among the treatment combinations (Table 10 and Appendix XXI). Data showed that the highest value of the root length (9.51 cm) was recorded in the P_1S_2 while the lowest value (5.07 cm) of the root length was found in the combination P_0S_1.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the central Farm, Sher-e-Bangla Agricultural University to find out the quality seed production of french bean influence as pruning and spacing. Results suggested that vegetative growth, reproductive development and seed quality were highest for one time stem pruning and wider spacing (S_2).

The tallest plants (38.63, 51.42 and 60.22 cm at 30, 45 DAS and at harvest respectively) were found from P_1 which was significantly different from other treatments where the smallest plants (32.01 cm, 41.43 cm and 47.60 cm at 30, 45 DAS and at harvest respectively) were found from P_2. It was found that wider spacing (30×15 cm) gave higher plant growth. The tallest plants (37.69, 49.92 and 57.18 cm at 30, 45 DAS and at harvest respectively) were found from S_2 while the shortest plants (32.70, 42.65 and 50.67 cm at 30, 45 DAS and at harvest respectively) were found from S_1. Results indicated that the tallest plants (45.25, 57.91 and 63.47 cm at 30, 45 DAS and at harvest respectively) were found from the treatment combination of P_1S_2. The treatment combination of P_0S_1 produced shortest plant (29.80, 38.58 and 44.74 cm at 30, 45 DAS and at harvest respectively) compared to others combinations.

The maximum numbers of branches plant^{-1} (6.27, 10.16, 10.16 at 30, 45 DAS and at harvest, respectively) was recorded from P_1 (one time pruning). The minimum numbers of branches plant^{-1} (4.77, 8.77 and 8.77 at 30, 45 DAS and at harvest, respectively) were recorded from the control treatment (no pruning). Results revealed that the maximum numbers of branches plant^{-1} (6.51, 10.53 and 10.53 at 30, 45 DAS and at harvest, respectively) were recorded from wider spacing S_2 (30×15 cm). While the minimum numbers of branches plant^{-1} (4.13, 8.08 and 8.08 at 30, 45 DAS and at harvest, respectively) were recorded from the closer spacing S_1 (30×10 cm). Results also revealed that the treatment combination of P_1S_2 exhibited the maximum numbers of branches plant^{-1} (7.36, 11.37 and 11.37 at 30, 45 DAS and at harvest, respectively). The minimum numbers of branches plant^{-1} (3.10, 7.16 and 7.16 at 30, 45 DAS and at harvest, respectively) were found from the treatment combination of P_0S_1.

It was found that the maximum numbers of pods plant^{-1} (27.27) were recorded from P_1 (one time pruning) followed by P_2 (two time pruning) where the minimum number of pods plant^{-1} (23.58) was found from P_0 (no pruning). Results also revealed that the maximum values of number of pods plant^{-1} (26.98) was recorded from the spacing of S_2 (30×15 cm) and the minimum value of the number of pods plant^{-1} (23.58) was recorded from spacing, S_1 (30×10 cm) followed by the spacing of S_3 (30×20 cm). Results demonstrated that the treatment combination of P_1S_2 exhibited the maximum number of pods plant^{-1} (29.36). The minimum value of number of pods plant^{-1} (22.16) was found from the treatment combination of P_0S_1.

It was found that the highest value of pod length (14.18 cm) was recorded from P_1 (pruning one time) which was statistically different from all other pruning treatments where the lowest pod length (12.19 cm) was found from P_0 (control) which was also statistically different from all other pruning treatments. Results revealed that the highest pod length (14.17 cm) was recorded from the wider spacing of S_1 (30×15 cm) which was statistically different from the rest. The lowest pod length (12.16 cm) was recorded from closer spacing S_1 (30×10 cm) followed by the spacing of S_3 (30×20 cm). Results showed that the treatment combination of P_1S_2 exhibited the highest pod length (15.18 cm) which was statistically different from other combinations. The lowest pod length (11.19 cm) was found from the treatment combination of P_0S_1 which was statistically differ from rest of the combinations.

It was found that the highest pod diameter (1.58 cm) was recorded from P_1 (pruning one time) followed by the pruning P_2 (two times pruning). Again, the lowest pod diameter (1.30 cm) was recorded from P_0 (No pruning). Results revealed that the highest pod diameter (1.59 cm) was recorded from spacing of S_1 (30×15 cm) Again, the lowest pod diameter (1.26 cm) was recorded from closer spacing, S_1 (30×10 cm). Results demonstrated that the treatment combination of P_1S_2 exhibited the highest value pod diameter (1.94 cm) while the lowest value of pod diameter (1.22 cm) of French bean was recorded from the combination of P_0S_1.

Results revealed that the maximum number seeds pod^{-1} (7.21) was recorded from P_1 (one time pruning) which was significantly different from all other pruning treatments. Again, the pruning, P_0 (no pruning) produced the minimum number of seeds pod^{-1} (5.20) compared to others. Results signified that the maximum number of seeds pod^{-1} (7.21) was recorded from wider spacing of S_2 (30×15 cm) followed by the further wider spacing, S_3 (30×20 cm) where the minimum number of seeds pod^{-1} (5.17) was recorded from closer spacing, S_1 (30×10 cm). Results exhibited that the highest number of seeds pod^{-1} (8.31) was achieved from the treatment combination of P_1S_2 followed. The minimum number of seeds pod^{-1} (4.19) was found from the treatment combination of P_0S_1 which was statistically differ with others combinations.

Results indicated that the highest individual pod weight (9.18 g) was recorded from P_1 (one time pruning). Again, the lowest individual pod weight (7.08 g) was found from P_1 (no pruning) compared to others pruning. It was observed that the highest individual pod weight (9.34 g) was recorded from wider spacing of S_1 (30×15 cm) where the lowest individual pod weight (7.08 g) was recorded from closer spacing, S_1 (30×10 cm). It was examined that the highest individual pod weight (8.07 g) was achieved from the treatment combination of P_1S_2. Again, the lowest individual pod weight (6.13 g) was found from the treatment combination of P_0S_1.

Results showed that the highest value of pod weight plant^{-1} (135.68 g) was recorded from P_1 (pruning one time) which was statistically differ from others combination where the lowest value of pod weight plant^{-1} (123.40 g) was found from P_0 (no pruning). Data represented that the highest value of pod weight plant^{-1} (133.06 g) was recorded from wider spacing of S_2 (30×15 cm) but further increasing of spacing P_2 (30×20 cm) did not increase the pod weight plant^{-1} where the lowest value of pod weight plant^{-1} (127.53 g) was recorded from closer spacing, S_1 (30×10 cm). Results showed that the highest value of pod weight plant^{-1} (139.36 g) was achieved from the treatment combination of P_1S_2. But the lowest value of pod weight plant^{-1} (121.49 g) was found from the treatment combination of P_0S_1 which was statistically differ with other combinations.

It was tested that the highest pod weight plant^{-1} (6.15 kg) was recorded from P_1 (one time pruning) which was statistically different from all other test prunings. The lowest pod weight plant^{-1} (4.51 kg) was obtained from the control treatment (P_0). Results indicated that the highest pod weight plant^{-1} (6.24 kg) was recorded from spacing of S_2 (30×15 cm) where the lowest pod weight plant^{-1} (4.51 kg) was recorded from closer spacing, S_1 (30×10 cm). It was observed that the highest pod weight plant^{-1} (5.13 kg) was achieved from the treatment combination of P_1S_2. On the other hand, the lowest pod weight plant^{-1} (4.18 kg) was found from the treatment combination of P_0S_1.

Results revealed that the highest pod yield (13.86 t ha^{-1}) was recorded from P_1 (one time pruning) which was statistically different from all other test prunings. With further increasing of pruning (P_2= two time pruning) the pod yield did not increased further. The lowest pod yield (9.21 t ha^{-1}) was found from P_0 (no pruning). It was examined that the highest pod yield ha^{-1} (12.27 t ha^{-1}) was recorded from wider spacing of S_2 (30×15 cm). But data demonstrated that with an increasing the spacing S_3 (30×20 cm) the pod yield did not increase. However, the lowest pod yield (9.83 t ha^{-1}) was found in control pruning treatment (P_0). Results indicated that the highest pod yield (15.22 t ha^{-1}) was achieved from the treatment combination of P_1S_2. On the contrary, the lowest pod yield (8.10 t ha^{-1}) was found from the treatment combination of P_0S_1 which was immediate lower than P_0S_3. The highest yield ha^{-1} from the treatment combination of P_1S_2 might be due to cause of higher number of pods plant^{-1}, number of individual pod weight, number of seeds pod^{-1} and pod weight plant^{-1} from this treatment combination.

Results revealed that the highest seed yield (11.27 t ha^{-1}) was recorded from P_1 (one time pruning) which was statistically different from all other test prunings. With further increasing of pruning (P_2= two time pruning) the seed yield did not increased further. The lowest seed yield (7.24 t ha^{-1}) was found from P_0 (no pruning). It was examined that the highest seed yield ha^{-1} (9.97 t ha^{-1}) was recorded from wider spacing of S_2 (30×15 cm). But data demonstrated that with an increasing the spacing S_3 (30×20 cm) the seed yield did not increase further. However, the lowest seed yield (7.85 t ha^{-1}) was found in control pruning treatment (P_0). Results indicated that the highest seed yield (12.42 t ha^{-1}) was achieved from the treatment combination of P_1S_2. On the contrary, the lowest pod yield (6.15 t ha^{-1}) was found from the treatment combination of P_0S_1 which was immediate lower than P_0S_3. The highest yield ha^{-1} from the treatment combination of P_1S_2 might be due to cause of higher number of pods $plant^{-1}$, number of individual pod weight, number of seeds pod^{-1} and pod weight $plant^{-1}$ from this treatment combination.

Result demonstrated that the highest value of germination percentage (92.24%) of french bean was recorded from the pruning treatment P_1 (one time pruning). The lowest value of the same trait (81.35%) was found from the treatment P_0 (control) compared to the others treatments. Table represents that the maximum number of germinated seedling (88.95%) was found in the wider spacing S_2 (30×15 cm). But the minimum number of germinated seedling (83.90%) was observed in the closer spacing S_1 (30×10 cm). Data showed that the highest value of the germination percentage (95.31%) was recorded in the P_1S_2 while the lowest value (79.20%) of the same trait was found in the combination P_0S_1.

Result indicated that the highest value of shoot length (17.17 cm) of french bean was recorded from the pruning treatment P_1 (one time pruning). The lowest value of the shoot length (13.16 cm) was found from the treatment P_0 (control) compared to the other pruning treatments. Data revealed that the highest shoot length (16.18 cm) was found in the wider spacing S_2 (30×15 cm). But the lowest shoot length (14.18 cm) was observed in the closer spacing S_1

(30×10 cm).). Table showed that the highest value of the shoot length (18.16 cm) was recorded in the P_1S_2 while the lowest value (12.19 cm) of the shoot length was found in the combination P_0S_1.

Result demonstrated that the highest value of root length (8.26 cm) of french bean was recorded from the pruning treatment P_1 (one time pruning). The lowest of the root length (6.11 cm) was found from the treatment P_0 (control) compared to the others treatments. Table represents that the highest value of the toot length (8.26 cm) was found in the wider spacing of S_2 (30×15 cm). But the lowest value of root length (6.09 cm) was observed in the closer spacing S_1 (30×10 cm). Data showed that the highest value of the root length (9.51 cm) was recorded in the P_1S_2 while the lowest value (5.07 cm) of the root length was found in the combination P_0S_1.

Conclusion:

It might be concluded that one time pruning (P_1) planted with wider spacing (S_2) would be beneficial for the farmers throughout the entire period of the study.

Recommendation:

In this experiment performance of only two prunings were observed with three levels of spacing. So, the response of other pruning levels beyond the studied treatment with different spacing of planting should be studied in order to make a clear recommendation on the subject.

REFERENCES

Ahmed, N., Razaq, M. and Alam, H. (2016). Response of French Bean Cultivars to Plant Spacing Under Agroclimatic Condition of Baffa. *J. Northeast Agric. Univ. (English Edition)* **23**(1): 16-19.

Akhter, M. D. (1999). Effect of plant spacing on growth, yield and quality of French bean in Rabi season. *J. Agric Sci,* **35**(6): 362-369.

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

Awodun, M. A., Odogiyan, A. and Ojeniyi, S. O. (2007). Effect of gliricidia pruning on soil and plant nutrient status and yield of cowpea. *Intl J. of Agric. Res*, (*2*):402-405.

Ayoola, O. T. and Agboola, A. A. (2004). Influence of cassava planting patterns and pruning methods on crop yield in a cassava-based cropping system. *African Crop Sci. J.* **12**(2): 115-122.

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.

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.

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 Joydip, M. (2009). Effect of spacing on growth and yield of French bean (Phaseolus vulgaris L.) in red and lateritic belt of West Bengal. *Environ. Ecol.* **27**(2): 493-495.

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

Daniells, J. W. and Wilson, G. L. (1987). Effects of plant spacing on uniformity of pod maturity in French beans. *Scientia Horticulturae*, **32**(1-2): 1-8.

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].

Duguma, B., Kang, B. T. and Okali, D. U. U. (1988). Effect of pruning intensities of three woody leguminous species grown in alley cropping with maize and cowpea on an alfisol. *Agrofor. Sys.* **6**(1-3): 19-35.

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.

Ekwu, L. G. and Utobo, E. B. (2010). Effect of Staking and Pruning on the Growth and Yield of Cucumber (*Cucumis sativus* L.). *Intl. J. Agric. Rural Dev.* **13**(2):01-08.

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.

Enyi, B. A. C. (1975). Effects of defoliation on growth and yield in groundnut (*Arachis hypogea*), cowpeas (*Vigna unguiculata*), soyabean (*Glycine max*) and green gram (*Vigna aurens*). *Ann. Appl. Biol.* **79**(1): 55-66.

Field, R. J. and Nkumbula, S. (1986). Green Beans (Phaseolus vulgaris cv. Gallatin 50): effects of plant population density on yield and quality. *New Zealand J. Expt. Agric.* **14**(4): 435-442.

Fukai, S., Searle, C., Baiquni, H., Choenthong, S. and Kywe, M. (1990). Growth and grain-yield of contrasting barley cultivars under different plant densities. *Field Crops Res.* **23**(3-4): 239-254.

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. *Intl. J. Soil. Crop. Sci.* **2**(5): 061-067

Getachew, E., Mohammed, A. and Tesfaye, A. (2015). Impact of sowing date and plant spacing on yield, quality and disease incidence of Snap bean (*Phaseolus vulgaris* L.) varieties at Jimma Southwestern, Ethiopia. *Global Adv. Research J. Edu. Res. Rev.* **4**(5): 081-089.

Goulden, D. S. (1976). Effects of plant population and row spacing on yield and components of yield of navy beans (Phaseolus vulgaris L.). *New Zealand J. Expt. Agric.* **4**(2): 177-180.

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].

Humphries, E. G. (1994). Pickling cucumber vine pruning treatments and their implications for mechanical harvesting. **37** (1): *Tans- ASlA*. pp :71-75.

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.

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.

Jan, A., Taj, F. H., Khan, I. A. and Khan, N. (2002). Effect of sowing dates on yield and yield components of mashbean varieties. *Asian J. Plant Sci.* **1**: 622-624

Jarrick, J. (1986). Training and pruning. *Hort. Sci.* p: 400.

Karinge, P. G. (1991). *Effect of alley cropping with Calliandra calothyrsus (Meissm) on sequentially grown maize and cowpeas* (Doctoral dissertation).

Khoshkam, S. (2016). The effect of pruning and planting density on yield of greenhouses cucumber in Jiroft. *IJSEAS **2***: 212-227.

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 Res.* **24**: 209 – 211.

Kueneman, E. A., Sandsted, R. F., Wallace, D. H., Bravo, A. and Wien, H. C. (1979). Effect of Plant Arrangements and Densities on Yields of Dry Beans. *Agron. J.* **71**(3): 419-424.

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.

Lima, A. D. 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].

Maboko, M. M., Du Plooy, C. P. and Chiloane, S. (2011). Effect of plant population, fruit and stem pruning on yield and quality of hydroponically grown tomato. *Afr. J. Agric. Res.* **6**(22): 5144-5148.

Mangual, C. 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].

Mardhiana, M., Pradana, A. P., Adiwena, M., Kartina, K., Santoso, D., Wijaya, R. and Maliki, A. (2017). Effects of pruning on growth and yield of cucumber (*Cucumis sativus*) Mercy variety in the acid soil of North Kalimantan, Indonesia. *Cell Biol. Dev.* **1**(1): 13-17.

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. Agric. 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 bushbean (*Phaseolus vulgaris* L.) in the eastern hilly area of Bangladesh. *Leg. Res. Intl. J.* **26**(4): 242-247.

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. Appl. Sci.* **12**(1): 96-100.

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. Karnataka *J. Agric. Sci.* **20**: 684-685.

Rahman, M. H., Khaliq, Q. A., Hamid, A., Miajh, M. N. I. and Haque, M.M. (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, M. M. (1993). SabjiBiggan (in Bengali). 1st Edition. Bangla Academy, Bangladesh. pp. 387-390.

Rashid, M. M. (1999). SabjiBiggan (in Bengali). 2nd Edition. Rashid publishing House. Dhaka. pp. 396-399.

Sabaruddin, L., Kilowasid, L. M. H. and Syaf, H. (2013). Effect of “Komba-Komba" Pruning Compost and Planting Time of Mungbean in Intercropping with Maize on Yield and Soil Fauna. *Agrivita*, **35**(1): 13.

Sahariar, M. S., Karim, M. R., Nahar, M. A., Rahman, M. and Islam, M. U. (2015). Influence of mulching and plant spacing on growth and yield of french bean (*Phaseolus vulgaris* L.). *Progress. Agric.,* **26**(2): 129-135.

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.

Sebetha, E. T., Ayodele, V. I., Kutu, F. R. and Mariga, I. K. (2010). Yields and protein content of two cowpea varieties grown under different production practices in Limpopo province, South Africa. *African J. Biotechnol.* **9**(5):12-20.

Shanmugavelu, K. G. (1989). Production Technology of Vegetable crops. Oxford and IBH publishing Company Private Limited. New Delhi. pp. 446- 461.

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

Sulistyono, B. (2000). Effect of pruning and Ethephon application on the performance of kidney beans. *Edisi khusus Balitkabi (Indonesia)*.

Swiader, J. M., Ware, G. W. and McCollum, J. P. (1992). Production Vegetables Crops.4th Edition. Interstate Publishers. Incorporation Danville Illions, United States of America. pp. 223-249

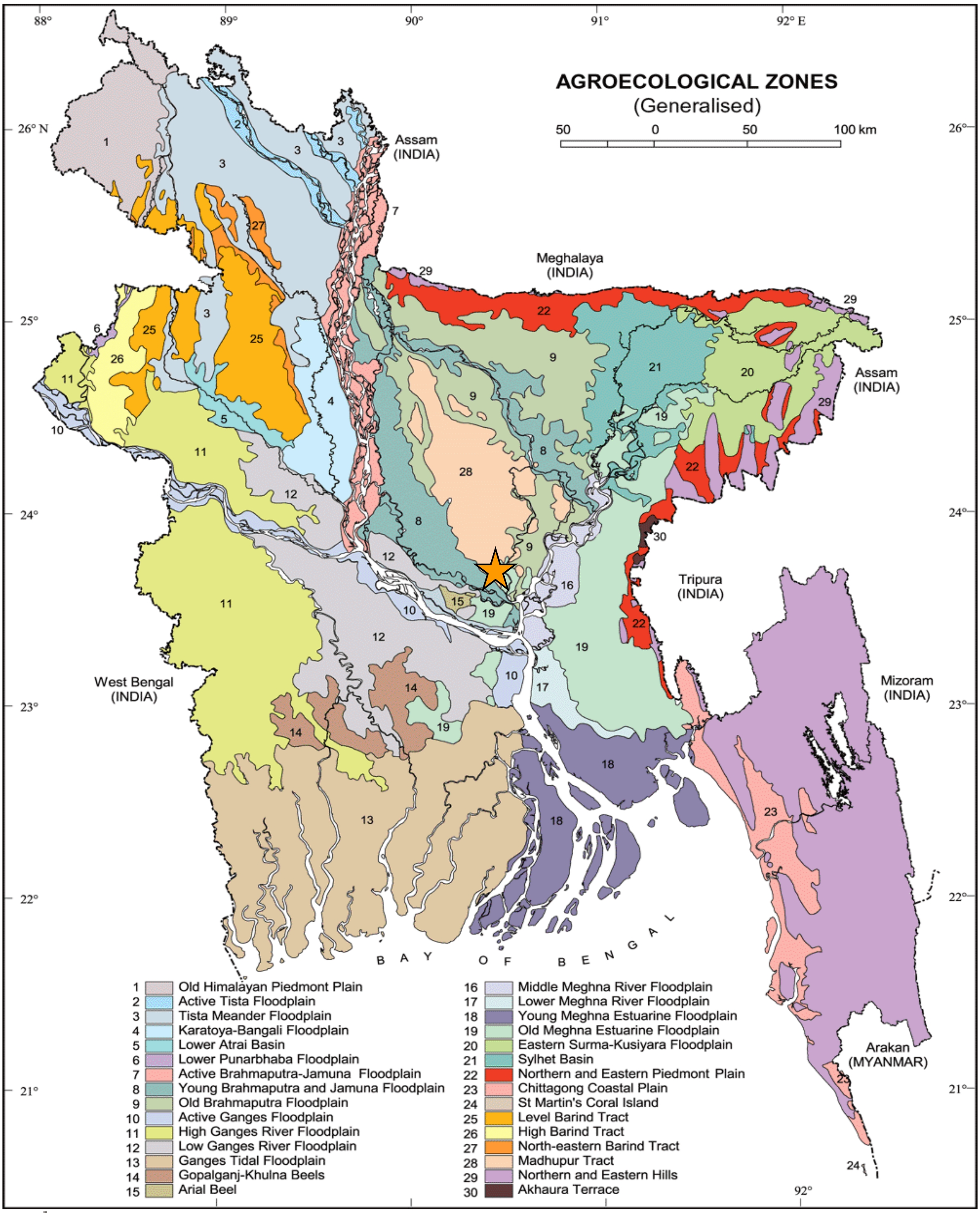
Tuarira, M. and Moses, M. (2014). Effects of plant density and planting arrangement in green bean seed production. *J. Glob. Innov. Agric. Soc. Sci.* **2**(4): 152-157.

Utobo, E. B., Ekwu, L. G., Ogah, E. O. and Nwokwu, G. N. (2010). Growth and yield of cucumber varieties as influenced by pruning at Abakaliki Agricultural Area Southeastern Nigeria. Cont. *J. Agron.* **4**: 23-27.

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].

APPENDIX

Appendix I. Map showing the experimental sites under study



☆ The experimental site under study

Appendix II. Monthly recorded the average air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from December 2016 to May 2017.

Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
December, 2016	26.4	14.1	69	12.8	5.5
January, 2017	25.4	12.7	68	7.7	5.6
February, 2017	28.1	15.5	68	28.9	5.5
March, 2017	32.5	20.4	64	65.8	5.2
April, 2017	38.9	23.6	70	76.4	5.7
May, 2017	40.5	24.5	75	80.6	5.8

Source: Sher-e-Bangla Agricultural University Weather Station

Appendix III. Physical and chemical soil properties of experimental plot

Characteristics	**Value**
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Factorial ANOVA for plant height at 30 DAS

Source	DF	SS	MS	F value	P value
Replication	2	0.271	0.1356		
Pruning	2	197.380	98.6898	91.13	0.0000
Spacing	2	112.367	56.1834	51.88	0.0000
Pruning*Spacing	4	26.218	6.5545	6.05	0.0037
Error	16	17.327	1.0829		
Total	26	353.562			

Appendix V. Factorial ANOVA for plant height at 45 DAS

Source	DF	SS	MS	F value	P value
Replication	2	6.543	3.272		
Pruning	2	458.393	229.196	185.16	0.0000
Spacing	2	241.713	120.856	97.63	0.0000
Pruning*Spacing	4	48.799	12.200	9.86	0.0003
Error	16	19.806	1.238		
Total	26	775.253			

Appendix VI. Factorial ANOVA for plant height at harvest

Source	DF	SS	MS	F value	P value
Replication	2	11.945	5.972		
Pruning	2	715.942	357.971	286.50	0.0000
Spacing	2	190.797	95.398	76.35	0.0000
Pruning*Spacing	4	1.482	0.371	0.30	0.8759
Error	16	19.991	1.249		
Total	26	940.158			

Appendix VII. Factorial ANOVA for number of branches plant^{-1} at 30 DAS

Source	DF	SS	MS	F value	P value
Replication	2	0.3524	0.1762		
Pruning	2	13.8276	6.9138	579.66	0.0000
Spacing	2	25.7700	12.8850	1080.29	0.0000
Pruning*Spacing	4	3.0345	0.7586	63.60	0.0000
Error	16	0.1908	0.0119		
Total	26	43.1753			

Appendix VIII. Factorial ANOVA for number of branches plant^{-1} at 45 DAS

Source	DF	SS	MS	F value	P value
Replication	2	0.2888	0.1444		
Pruning	2	9.4956	4.7478	126.19	0.0000
Spacing	2	27.0038	13.5019	358.87	0.0000
Pruning*Spacing	4	0.8998	0.2250	5.98	0.0039
Error	16	0.6020	0.0376		
Total	26	38.2900			

Appendix IX. Factorial ANOVA for number of branches plant^{-1} at harvest

Source	DF	SS	MS	F value	P value
Replication	2	0.2888	0.1444		
Pruning	2	9.4956	4.7478	126.19	0.0000
Spacing	2	27.0038	13.5019	358.87	0.0000
Pruning*Spacing	4	0.8998	0.2250	5.98	0.0039
Error	16	0.6020	0.0376		
Total	26	38.2900			

Appendix X. Factorial ANOVA for number of pods plant^{-1}

Source	DF	SS	MS	F value	P value
Replication	2	0.945	0.4725		
Pruning	2	62.683	31.3413	1323.07	0.0000
Spacing	2	52.024	26.0119	1098.09	0.0000
Pruning*Spacing	4	1.722	0.4304	18.17	0.0000
Error	16	0.379	0.0237		
Total	26	117.752			

Appendix XI. Factorial ANOVA for individual pod length

Source	DF	SS	MS	F value	P value
Replication	2	0.3430	0.17149		
Pruning	2	17.9157	8.95785	1356.20	0.0000
Spacing	2	18.1675	9.08374	1375.26	0.0000
Pruning*Spacing	4	0.0227	0.00568	0.86	0.5090
Error	16	0.1057	0.00661		
Total	26	36.5545			

Appendix XII. Factorial ANOVA for individual pod diameter

Source	DF	SS	MS	F value	P value
Replication	2	0.00074	0.00037		
Pruning	2	0.38183	0.19091	148.82	0.0000
Spacing	2	0.41870	0.20935	163.19	0.0000
Pruning*Spacing	4	0.25788	0.06447	50.25	0.0000
Error	16	0.02053	0.00128		
Total	26	1.07967			

Appendix XIII. Factorial ANOVA for number of seeds pod^{-1}

Source	DF	SS	MS	F value	P value
Replication	2	0.4258	0.21290		
Pruning	2	18.1388	9.06938	929.05	0.0000
Spacing	2	18.6450	9.32249	954.97	0.0000
Pruning*Spacing	4	0.0426	0.01065	1.09	0.3941
Error	16	0.1562	0.00976		
Total	26	37.4084			

Appendix XIV. Factorial ANOVA for individual pod weight

Source	DF	SS	MS	F value	P value
Replication	2	0.5652	0.2826		
Pruning	2	17.9910	8.9955	652.39	0.0000
Spacing	2	22.8564	11.4282	828.83	0.0000
Pruning*Spacing	4	0.0263	0.0066	0.48	0.7528
Error	16	0.2206	0.0138		
Total	26	41.6594			

Appendix XV. Factorial ANOVA for pod weight plant^{-1}

Source	DF	SS	MS	F value	P value
Replication	2	16.743	8.371		
Pruning	2	689.598	344.799	538.56	0.0000
Spacing	2	141.901	70.951	110.82	0.0000
Pruning*Spacing	4	8.614	2.153	3.36	0.0353
Error	16	10.244	0.640		
Total	26	867.099			

Appendix XVI. Factorial ANOVA for pod weight plot^{-1}

Source	DF	SS	MS	F value	P value
Replication	2	0.5906	0.29530		
Pruning	2	12.3459	6.17293	612.95	0.0000
Spacing	2	13.7590	6.87951	683.11	0.0000
Pruning*Spacing	4	1.4448	0.36121	35.87	0.0000
Error	16	0.1611	0.01007		
Total	26	28.3015			

Appendix XVII. Factorial ANOVA for pod yield ha^{-1}

Source	DF	SS	MS	F value	P value
Replication	2	0.707	0.3533		
Pruning	2	106.962	53.4810	6581.52	0.0000
Spacing	2	26.962	13.4812	1659.04	0.0000
Pruning*Spacing	4	0.955	0.2388	29.39	0.0000
Error	16	0.130	0.0081		
Total	26	135.716			

Appendix XVIII. Factorial ANOVA for seed yield ha^{-1}

Source	DF	SS	MS	F value	P value
Replication	2	0.764	0.3819		
Pruning	2	80.180	40.0902	3765.98	0.0000
Spacing	2	20.384	10.1922	957.43	0.0000
Pruning*Spacing	4	0.058	0.0146	1.37	0.2888
Error	16	0.170	0.0106		
Total	26	101.557			

Appendix XIX. Factorial ANOVA for germination (%)

Source	DF	SS	MS	F value	P value
Replication	2	1.054	0.527		
Pruning	2	542.982	271.491	10275.83	0.0000
Spacing	2	115.060	57.530	2177.50	0.0000
Pruning*Spacing	4	3.542	0.886	33.52	0.0000
Error	16	0.423	0.026		
Total	26	663.062			

Appendix XX. Factorial ANOVA for shoot length

Source	DF	SS	MS	F value	P value
Replication	2	0.4138	0.2069		
Pruning	2	72.5209	36.2605	18235.77	0.0000
Spacing	2	17.8494	8.9247	4488.33	0.0000
Pruning*Spacing	4	0.0104	0.0026	1.30	0.3105
Error	16	0.0318	0.0020		
Total	26	90.8263			

Appendix XXI. Factorial ANOVA for root length

Source	DF	SS	MS	F value	P value
Replication	2	0.4014	0.2007		
Pruning	2	20.8583	10.4291	656.49	0.0000
Spacing	2	21.2818	10.6409	669.82	0.0000
Pruning*Spacing	4	0.2017	0.0504	3.17	0.0424
Error	16	0.2542	0.0159		
Total	26	42.9973