INFLUENCE OF SPACING AND PHOSPHORUS ON GROWTH AND YIELD OF FRENCH BEAN

TAMANNA AKTER

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

JUNE, 2018

INFLUENCE OF SPACING AND PHOSPHORUS ON GROWTH AND YIELD OF FRENCH BEAN

BY

TAMANNA AKTER

REG. NO. : 12-05038

A Thesis
Submitted to the Department of Horticulture
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

HORTICULTURE

SEMESTER: JANUARY-JUNE, 2018

Approved by:

(Prof. Dr. Md. Ismail Hossain)	**(Prof. Dr. Mohammad Humayun Kabir)**
Department of Horticulture	Department of Horticulture
SAU, Dhaka	SAU, Dhaka
Supervisor	**Co-supervisor**

(Prof. Dr. Mohammad Humayun Kabir)
Chairman
Examination Committee

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

CERTIFICATE

*This is to certify that thesis entitled, "**INFLUENCE OF SPACING AND PHOSPHORUS ON GROWTH AND YIELD OF FRENCH BEAN (Phaseolus vulgaris)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **TAMANNA AKTER**, Registration No. **12-05038** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2018
Place: Dhaka, Bangladesh

(Prof. Dr. Md. Ismail Hossain)
Department of Horticulture
SAU,Dhaka
Supervisor

DEDICATED
TO
MY BELOVED MOTHER
AND FATHER

ACKNOWLEDGEMENTS

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

The author would like to express her heartfelt gratitude and most sincere appreciations to her Supervisor **Prof. Dr. Md. Islamil Hossain**, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for his valuable guidance, advice, immense help, encouragement and support throughout the study.

Likewise grateful appreciation is conveyed to Co-supervisor **Prof. Dr. Mohammad Humayun Kabir** Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for constant encouragement, cordial suggestions, constructive criticisms and valuable advice to compete the thesis.

The author would like to express her deepest respect and Soundless gratitude to all the respected teachers of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka and the entire staff member of the department of Horticulture (SAU).

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

The Author

INFLUENCE OF SPACING AND PHOSPHORUS ON GROWTH AND YIELD OF FRENCH BEAN

BY

TAMANNA AKTER

ABSTRACT

A field experiment was conducted at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2017 to February 2018.The experiment consisted of two factors. Factor A: three levels of plant spacing: S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm and S_3 = 30 cm × 20 cm and Factor B: four levels of phosphorus: P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1} and P_3 = 80 kg P ha^{-1} were used for the study. The experiment was laid out in randomized complete block design with 3 replications. Spacing and phosphorus levels showed significant variation on different growth, yield and yield contributing parameters. The highest fresh pod yield (16.21 t ha^{-1}) was found from the plant spacing, S_2 where the lowest (12.71 t ha^{-1}) was from S_3. For phosphorus, P_1 gave the highest fresh pod yield (16.41 t ha^{-1}) where P_0 gave the lowest (12.22 t ha^{-1}). For combined effect the highest fresh pod yield plot^{-1} (1333.00 g) and fresh pod yield (18.51 t ha^{-1}) were found from S_2P_1 where the lowest fresh pod yield plot^{-1} (826.00 g) and fresh pod yield (11.47 t ha^{-1}) were recorded from S_3P_0. Considering economic analysis, the highest benefit cost ratio (3.37) was also obtained from S_2P_1 where the lowest (2.16) from S_3P_0. Thus, the findings indicated that the spacing (30 cm × 15 cm) and phosphorus (40 kg ha^{-1}) could be used for yield maximization of french bean in Bangladesh.

CONTENTS

CONTENTS (Cont'd)

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CGR	=	Crop growth rate
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
FAO	=	Food and Agricultural Organization of United Nations
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	Milliliter
mg	=	Milligram
M.S.	=	Master of Science
SAU	=	Sher-e-Bangla Agricultural University
TDM	=	Total dry matter
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
K	=	Potassium
P	=	Phosphorus
Ca	=	Calcium
L	=	Litre
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

French bean *(Phaseolus vulgaris* L.), a native of Central and South America (Swiader*et al.*, 1992) has one of the longest histories of cultivated plants and is widely cultivated in the temperate and subtropical regions and in many parts of the tropics. It is also known as bush bean, kidney bean, snap bean, pinto bean, basic bean, haricot bean, pole bean, wax bean, string bean, green bean, raj bean and bonchi (Duke, 1983; Salunkhe*et al.*, 1987; Tindall, 1988). In our country it is also known as Farashi sheem (Rashid, 1993) and Jhar sheem. Bush bean plants are indeterminate, short, bushy and becoming popular for its tender pods and shelled beans.

French bean is nutritionally rich. Each 100 g of pods contain on an average 36 calories food energy, 89% moisture, 2.7 g protein, 0.2 g lipid, 7.9 g CHO, 43 mg Ca, 29 mg Mg, 28 mg P, 1.4 mg Fe, 0.8 mg Thiamin and 8.5 mg Niacin. On the other hand, dry bean contains 336 calories food energy with 12% moisture, 21.7 g proteins, 1.5 g lipid, 60.9 g CHO, 120 mg Ca, 8.2 mg Fe, 0.37 mg Thiamin and 2.4 mg Niacin (Sehoonhoren and Rovset, 1993). Protein from beans and seeds are easily transportable and absorbed in human body than animal protein. In Bangladesh, french bean grown in Sylhet, Chittagong hill tracts, Cox's Bazar and Comilla. But there is no statistics about the area and production of this crop.

It is an annual herbaceous plant and widely cultivated throughout the temperate, tropical and sub-tropical areas of the world (George, 1985). But it is more compatible as a winter (rabi) cropin the northern eastern plain of India. (AICPIP, 1987). According to the FAO statistics, french bean including other related species of the genus *Phaseolus* took possession of 32.08 million hectares of the world cropped area and the yield of pods was about 23,139,004 tons (FAO, 2013).

Production of french bean depends on many factors such as quality of seed, variety, fertilizer management, soil moisture, plant spacing, nutrient management and proper management practices. Among them, plant spacing is important aspect of crop production to maximize the yield. Optimum plant spacing ensures judicious use of natural resources, makes the intercultural operation easier, which help increase the number of leaves and branches. The farmers cultivate this crop according to their own conception due to absence of standard production technique. As a result they do not get satisfactory yield and ultimately become financially loser. In our country there are very few research works for focusing on the spacing and variety performance of bush bean production in Bangladesh. The maximum pod (1.88 kg m^{-2}) was recorded with the highest plant density (20 plants m^{-2}) (Moniruzzaman *et al.* 2009). These results are in agreement with the findings of Chakravorty *et al.* (2009) and Singh *et al.* (1996). Optimum plant spacing is essential for attaining desired yield because high plant density results in reduction of number of pods per plants and seeds per pod. So, optimum plant density is essential for maximizing the productivity of bush bean.

Phosphorus management is also an important factor for maximization of french bean yield. Among the fertilizers and manures, phosphorus is very important for french bean production. French bean responds well to application of phosphorus (Turuko and Mohammed, 2014; Ahlawat and Sharma, 1989). Phosphorus is very important in root development, translocation of photosynthate, formation and elongation of pod and in a number of physiological activities. Its application helps increase different growth and yield parameters (Verma and Singh, 2000). The seed yield accompanied by protein production showed significant response to phosphorus (Verma and Saxena, 1995). The yield of french bean may be increased through application of appropriate doses of phosphorus. The P deficiency is one of the most significant abiotic factors, limiting the crop productivity. It is reported that 40% of crop production in the world's arable land is limited by P availability resulted in 5 to 15% yield losses (Bargaz *et al*. 2012). Under limiting P conditions, legumes may lose the distinct advantage of an unlimited source of symbiotic N_2, decreases in N_2 fixation leading to decreases in plant growth and nodulation (Vadez *et al*. 1996). Dwarf growth and purpling of the leaves in bean production was found with P deficiency (Turk and Tawaha, 2002). P deficiency reduces plant growth and crop productions especially in arid and semi-arid areas with calcareous soils (Bargaz *et al*., 2016).

Moreover, phosphorus plays an important role in biological nitrogen fixation. For the symbiotic fixation of nitrogen to occur, the roots have to interact with compatible rhizobia in the soil and factors that affect root growth or the activity of the host plant would affect nodulation (Freire, 1984).

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

1. To determine the optimum spacing for maximizing the growth and yield of green pods of french bean,
2. To find out the suitable dose of phosphorus for maximizing the growth and yield of green pods of french bean, and
3. To find out the cost-effectiveness of phosphate fertilizer and spacing for the production of green pods of french bean.

CHAPTER II

REVIEW OF LITERATURE

Very few studies on the growth and yield of French bean have been carried out in our country as well as many other countries of the world. The research work had done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important informative works and research findings related to phosphorus and plant spacing on French bean so far been done at home and abroad have been reviewed in this chapter under the following headings.

2.1 Literature on spacing

Masa *et al*. (2017) conducted a field experiment assess the effects of inter and intra row spacing on yield and yield related traits of common bean varieties. The two common bean varieties [Hawassa dume (small seed sized) and Ibbado (large seed sized)], three inter (30 cm, 40 cm and 50 cm) and three intra (7 cm, 10 cm and 13 cm). The result showed significantly ($P<0.01$) higher days to 50% flowering (45.7), days to 90% physiological maturity (78.3) and hundred seed weight (44.07 g) for variety Ibbado, while significantly ($P<0.01$) highest number of total nodules (29.64), effective nodules (14.93), pod per plant (19.5), primary branches (2.6) and grain yield (2264 kg ha^{-1}) were recorded for variety Hawassa dume. As inter row increased from 30 cm to 50 cm; plant height, days to physiological maturity and grain yield decreased, while pods per plant and hundred seed weight increased. Also, as intra row increased from 7 cm to 13 cm; leaf area index, plant height, dry biomass and grain yield were decreased, whereas leaf area, pods per plant, seeds per pod and hundred seed weight were increased. Among the interaction combinations of variety Hawassa dume in 40 cm, 30 cm and 50 cm row spacing gave significant ($P<0.01$), highest leaf area (1099.9 cm^2), leaf area index (3.41) and seeds per pod (5.24), respectively, while highest dry biomass (4137 kg ha^{-1}) for variety Hawassa dume and (4533 kg ha^{-1}) for variety Ibbado in 30 cm. From the results of this study it can preliminary be concluded that the

30 cm inter-row and 7 cm intra-row spacing can be used for both varieties (Hawassa dume and Ibbado) to improve the productivity of the crop under study area.

Sahariar *et al*. (2015) investigated the effect of mulching and plant spacing on the growth and yield of French bean. The experiment consisted of three types of mulching namely (i) control (without mulch), (ii) water hyacinth and (iii) black ploythene much and three levels of spacing viz., (i) 30 cm × 25 cm (ii) 30 cm × 20 cm and (iii) 30 cm × 15 cm. 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). The maximum yield (6.22 t/ha) was obtained from 30 cm × 15 cm plant spacing and the lowest (4.58 t/ha) was obtained with 30 cm × 25 cm plant spacing. The combined effects of mulching and plant spacing were statistically significant. The combination of black polythene mulch with 30 cm × 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 × 25 cm treatment combination. Considering the above findings the black polythene mulch with 30 × 15 cm plant spacing may be recommend for French bean cultivation.

Elhag and Hussein (2014) conducted a field experiment with two sowing dates 7th November and 26th November, respectively and six plant populations obtained by three plant spacing (10, 15 and 20 cm 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 2 plants/hill and 20 cm 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 (3 plants/ hill at 10cm spacing) and the lowest at late sowing by the lowest plant population (2 plants/hill at 20 cm 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 15 cm or 2 plants/hill at the narrowest spacing 10 cm gave maximum pod yield per unit area and quality.

Getachew *et al.* (2014) carried out an experiment with five level of spacing (50 cm × 7 cm, 40 cm × 15 cm, 40 cm × 10 cm, 40 cm × 7 cm, 30 cm × 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 × 7 cm gave 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 × 7 cm which was on par with 40 cm × 15 cm and 40 cm ×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.). 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 significant in decrease in growth rate. Although intra-row spacing 20 cm produced the highest growth rate, cost benefit analysis could be ideal to justify its recommendation over intra-row spacing of 15 cm. Leaf number increased with time in all the four treatments with significant differences being observed as from the fourth week after sowing. The closest intra-row spacing of 10 cm and 15 cm produced statistically equal number of leaves until after six weeks when the latter recorded significantly higher number of leaves (10.2) than the former (8.7). The widest intra-row spacing of 30 cm produced the least number of leaves while the highest leaf number was observed at a spacing of 20 cm between plants.

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

Chakravorty *et al.* (2009) conducted a field experiment during Rabi season or 2005-06 and 2006-07 to study the effect of spacing on growth and yield of French bean viz. 10 cm × 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 pod 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 and 15 cm × 10 cm spacing was found to be optimum to achieve higher pod yield in French bean.

Samih (2008) conducted an experiment with six different planting densities (10 cm × 30 cm, 20 cm × 30 cm, 30 cm × 30 cm, 40 cm × 30 cm, 50 cm × 30 cm, 60 cm × 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 × 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 × 30 cm) was among the lowest yielding. The highest yields of French beans were obtained under the 20 cm × 30 cm (12.55 t/ha) and 30 cm × 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 × 30cm) which produced 6.98 t/ha.

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

Mozumder *et al.* (2003) was conveyed 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 × 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 field trial 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 250×10^3 plants/ha recorded markedly higher values of growth and yield attributes, except plant height which was the maximum with the highest plant density to 500×10^3 plants/ha.

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

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

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

Singh (2000) conducted an experiment to study the response of French bean cv. Arka Komal to plant spacing or 40 cm × 40 cm, 40 cm × 15 cm and 40 cm × 20 cm. The decreasing plant spacing from 40 cm × 20 cm to 40 cm × 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.

Akhter (1999) directed 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 × 10 cm (11.84 t/ha).

Blackshaw *et al.* (1999) conducted a field experiment 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. They observed that reduction in row- spacing increased yield in all years when grown at a density of 48 plants/m but only increased yield in 1 of 3 years when grown 24 plants/m. 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 × 25 cm) produced significantly the maximum green pod yield.

Chatterjee and Som (1991) conveyed a field experiment with plant spacing of 40 cm × 10 cm, 40 cm × 15 cm, or 40 cm × 20 cm. Reducing the inter row spacing of French bean *(Phaseolus vulgaris* L.) from 40 to 20 cm, yield was increased from 10.5 to 12.3 t/ha. Argerich and Calvar (1986) observed that closest spacing gave the higher pod yield.

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

Jadhao (1993) observed from an experiment conducted using 30 cm × 10 cm spacing (2,20,000 plants/ha) showed better performance than plant spacing of 30 cm x 15 cm and 30 cm × 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 × 10cm.

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

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

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.

2.2 Literature on phosphorus

Rahman *et al*. (2018) directed an experiment to assess the effect of phosphorus levels on the growth, yield attributes and yield of French bean (*Phaseolus vulgaris* L.) varieties. The experiment was conducted maintaining randomized complete block design consisting three French bean varieties, viz. V_1 - BARI Jhar Sheem-1, V_2 - BARI Jhar Sheem-2 and V_3 – Nick and four levels of phosphorus viz. 0, 20, 40 and 60 kg phosphorus ha^{-1}, respectively replicated thrice. Varieties showed significant results on growth and yield attributes except number of branches $plant^{-1}$ but phosphorus exhibited significant results of all growth and yield attributes except number of seeds pod^{-1}. Varieties combined with phosphorus given significant results of all the parameters. Highest pod yield (22.70 t ha^{-1}) was obtained from BARI Jhar Sheem-2 while lowest (16.64 t ha^{-1}) from BARI Jhar Sheem-1. Highest dose of phosphorus @ 60 kg ha^{-1} gave highest pod yield (22.12 t ha^{-1}), whereas lowest (18.82 t ha^{-1}) was obtained in control. Apparently, the highest value of pod yield (24.40 t ha^{-1}) was found from the combination of BARI Jhar Sheem-2 with 60 kg ha^{-1} phosphorus and lowest (15.23 t ha^{-1}) from the combination of BARI Jhar Sheem-1 with control treatment.

Emam *et al*. (2018) dealed with a field experiment to study the effect of two green bean cultivars (Paulista and Samantha) and three rates of rock phosphate (fine and granules) as a natural resource of P mixed with sand substrate in comparison with calcium superphosphate with recommended level on growth and yield of green bean (*Phaseolus vulgaris* L.) under plastic house conditions. Regarding the green bean cultivars, Paulista gave higher plant height, number of leaves, canopy and root fresh and dry weight than Samantha cultivar. Paulista cultivar produced the highest values of total pod yield per plant during the two successive seasons. Increasing phosphorus level (fine or granule rock phosphate) up to 150% enhanced pod yield with both used cultivars. The highest vegetative growth and yield were obtained from 150% fine rock phosphate combined with Paulista cultivar. Tissue nutrient analysis show that increase phosphorus level by rock phosphate source led to increase nutrient percentage for NPK in green beans leaves in comparison with recommended phosphorus dose applied as calcium superphosphate. The economic consideration among phosphorus and different P sources revealed that fine rock phosphate with Paulista cultivar gave the highest net income per greenhouse.

Rafat and Sharif (2015) carried out an experiment to study the effects of phosphorus fertilizer on yield and yield components of green bean (Sunray genotype). The rate of phosphorus fertilizer was 0, 20, 50, 75 and 100 kg ha^{-1}. Analysis of variance indicated that phosphorus fertilizer had a significant effect on plant height, pod length, number of pods per plant, green pod yield, biological yield and harvest index. Correlation analysis indicated pod yield positively correlated with plant height, number of pods per plant and harvest index. The result of regression analysis indicated that there was a significant positive and quadratic relationship between P application and pod yield. Application of 50 kg P ha^{-1} lead to maximum values of plant height, pod length, number of pods per plant and pod yield. Phosphorus fertilizers increased also dry matter accumulation. Phosphorus supply beyond 50 kg P ha^{-1} generally resulted in decline of pod yield and yield components. Thus, application of 50 kg P ha^{-1} is recommended for better production of green bean at Guilan province, Iran.

Kakon *et al*. (2016) conducted field experiments during rabi (winter) seasons of 2010-11 and 2011-12 at BARI, Joydebpur, Gazipur to study the effects of nitrogen and phosphorus on growth, dry matter production and yield of French bean. A randomized complete block design was followed with 10 combinations of N (0,50, 100, 150 and 200) and P (0,22, 33, 44 and 55) kg ha^{-1} along with a blanket dose of control. All the treatments showed the maximum leaf area index (LAI) at 65 days after sowing (DAS). All the treatments showed the maximum total dry matter production, crop growth rate and net assimilation rate at harvest and at 55-65 DAS, respectively in both the years. LAI, dry matter production, CGR, NAR and seed yield significantly increased with the increase in nitrogen and phosphorus level upto 150 kg N and 44 P kg ha^{-1}, respectively. Similar trend was followed in maximum number of pods (9.45) and seed yield (1563.33 kg ha^{-1}). The treatment comprises with 150 kg N and 44 P Kg ha^{-1} gave the highest seed yield which was 51.40 and 54.30 % higher than control plots.

Turuko and Mohammed (2014) conducted a field experiment to investigate the responses of common bean to different levels of phosphorus fertilizer and its effect on growth, dry matter yield and yield component of the crop. Five phosphorus rates (0, 10, 20, 30 and 40kg ha^{-1}) were used as treatments. Red Wolaita common bean variety was used as planting material. Recommended rate of N (60 kg/ha) was applied to all treatments. The experiment was laid out in a randomized complete block design with three replications. The effect of phosphorus was significantly increased dry matter yield, yield components and growth parameters such as leaf area and number of branches per plant, whereas its effect was not significant on plant height. Based on result obtained, application of 20 P kgha^{-1}is recommended for better production of common bean at Arba Minch and similar areas which have the same soil.

Lad *et al*. (2014) conducted a 3- year field experiment during 2003-04, 2004-05 and 2005-06 with four levels of nitrogen (0, 50, 100 and 150 kg/ha)and four levels of phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) to study their impact on growth, yield attributes, yield and economics of French bean (*Phaseolus vulgaris* L.) grown under medium deep Vertisol soil in Marawada region. Higher dose of nitrogen (150 kg/ha) and phosphorus (75 kg/ha)resulted significantly highest grain & straw yield of French bean and show at par result with crop receiving 100 kg N & 50 kg P_2O_5 ha^{-1}which was found more profitable.

Shubhashree *et al*. (2011) carried out a field experiment to study the “Response of rajmash (*Phaseolus vulgaris* L.) to the levels of nitrogen, phosphorus and potassium with three levels of nitrogen (40, 80 and 120 N kg ha^{-1}), three levels of phosphorus (25, 50 and 75 P_2O_5 kg ha^{-1}), two levels of potassium (30 and 60 K_2O kg ha^{-1}) with an absolute control (0:0:0 N:P:K kg ha^{-1}). Significantly higher grain yield was recorded with 120:75:60 kg N:P_2O_5 :K_2O ha^{-1} fertilization (1375 kg ha^{-1}) which was on par with 80:75:60 N:P_2O_5 :K_2O kg ha^{-1}(1352 kg ha^{-1}) and 80:75:30 N:P2O5 :K2O kg ha^{-1} (1337 kg ha^{-1}). Significantly higher plant height, number of branches per plant, leaf area index, total dry matter production, number of pods per plant, seeds per pod, 100- seed weight and seed yield per plant was recorded with 80:75:30 N:P_2O_5 :K_2O kg ha^{-1}. Significantly higher net returns (21113 ha^{-1}) and benefit cost ratio (2.72) was also obtained with application of 80:75:30 N:P_2O_5:K_2O kg ha^{-1}.

Saxena *et al.* (2003) conducted a fertilizer trial in Kanpur, Uttar Pradesh, India during the rabi seasons of 2000-02 where French bean cv. PDR-14 was supplied with 0, 60 and 90 kg P/ha. Leaf area index, leaf area distribution and relative growth rate were increased with growth stages, and crop yield increased with increasing rates of N, P, and K.

Farkade and Pawar (2002) dealed with an experiment in the Rabi season in Nagpur, India to determine the effects of N:P fertilizer at 60:45, 90:75 and 120:75 kg/ha on *Phaseolus vulgaris* cv. PDR-14, HUR-137 and VL-63. They observed that the yield and growth characters increased with increasing N:P fertilizer level, and the highest yield (15.93 Q/ha) was in VL-63 at 120:75kg N:P per ha.

Singh and Verma (2002) directed with an experiment in Bihar, India with 5 nitrogen (0, 30, 60, 90 and 120 kg/ha) and 3 phosphorus levels (0, 30, 60 kg/ha) on the growth, yield attributes, yield and economics of French bean. The highest rates of nitrogen and phosphorus resulted the highest plant height, branches per plant, pods per plant and seeds per pod.

Varennes *et al.* (2002) conducted an experiment in India and they reported that the application of 50, 100, 150 kg P/ha and 0, 50, 100 kg N/ha significantly increased the plant height, leaf number, root number and pod yield. Phosphorus at 150 kg/ha gave the highest yield and nitrogen at 100 kg/ha gave the highest yield.

Tomar (2001) carried out an experiment in the Agriculture Research Station, Kota, India to study the response of French bean to irrigation scheduling and phosphorus levels (20, 40, 60 and 80 kg/ha) in veretisols. He observed that application of phosphorus influenced the seed yield significantly up to 60 kg/ha. Consumptive use of water and AET:EO increased with increasing levels of phosphorus.

Chavan *et al.* (2000)conducted in a field experiment in Maharashrata, India during the rabi season of 1990 french bean *(Phaseolus vulgaris)* cultivars contender Arka komol and Waghya sown on 31 December, 1989 were supplied with 3 rates of N (0, 25 and 50 kg/ha) and 3 rates of P (0, 25 and 75 kg/ha). A basal application of a half of N and full rate of P and K at sowing and a top dressing of a half rate of N after one month was applied. Seeds were evaluated for N, P and K contents of total dry matter and protein production. The highest P uptake (6.3 kg/ha) by seeds and straw was recorded in both Waghya and Arka komol. Waghya recorded the highest total dry matter (17.2 q/ha). The highest total P uptake (8.5 kg/ha) was recorded from the highest N rate (50 kg/ha). Total P uptake increased linearly with increase in P rates.

Singh (2000) reported that response of French bean cv. Arka komal to different rates of N (50, 75, 100 and 125 kg/ha) and P (25, 50 and 75 kg P_20_5/ha) was studied on a sandy loam soil in Bihar, India. The decreasing plant spacing from 40 cm × 20 cm to 40 cm × 10 cm improved the yield significantly without adversely affecting the pod quality. The application of N upto 75 or 100 kg N/ha significantly improved the pod size, vigour of plants and individual plant productivity. Significantly higher pod yield, net returns and rate of net profit were observed for 125 kg N/ha. Phosphorus application upto kg $P_2$05/ha positively affected the pod size, while plant size remained unaffected. The yield of pod and net returns were highest at 50 kg P t/ha. The net profit decreased at increasing P levels.

Tewari and Singh (2000) carried out an experiment at N. D. University of Agriculture and Technology, Kamarganj, India to determine the effect of N and P on growth and seed yield of French bean. The crop was treated with 0, 40, 80, 120 or 160 kg N/ha and 0, 20, 40 or 60 kg P_20_5/ha. They found that plant height, number of branches and length of pod increased with successive increase in the doses of N as well as P. Application of 120 kg N/ha produced significantly higher number of pods per plant, weight of seeds per plant, number of seeds per pod and seed yield, whereas 160 kg N/ha significantly reduced seed yield. The highest values on the above yield attributes were recorded with 60 kg P_2O_5/ha. The combination of 120 kg N + 60 kg P_20_5/ha along with 60 kg P_20_5/ha gave the highest seed yield, net profit and net return per rupee investment followed by 120 kg N + 40 kg P_20_5/ha.

Verma and Singh (2000) conducted an experiment to see the effects of phosphorus and potassium on the growth, yield and quality of French bean. They applied three levels of phosphorus (0, 75, 125 kg P_20_5/ha) and three levels of potassium (0, 50, 100 kg K_20/ha). They reported that both phosphorus and potassium significantly influenced plants height, leaves number and yield of french bean and got the highest yield from 125 P_2O_5/ha and 100 kg K_20/ha.

Alt*et al.* (1999) conducted an experiment to study the effect of different rates of P (0, 19, 34 and 58 kg/ha) fertilizers on the yield of selected vegetable crops. They found that *Phaseolus valgaris* showed strong response to P and K.

Arya *et al.* (1999) conducted an experiment in India to investigate the effect of N, P and K on French bean. They used different doses of NPK combinations. It was concluded that N promoted growth and suggested that 25 kg N/ha, 75 kg P_2O_5 /ha and 50 kg K_20/ha was the best combination.

Kanaujia *et al.* (1999) conducted an experiment of French bean treated with P at 0, 40, 80 or 120 kg P_2O_5/ha and K at 0, 30, 60 or 90 Kg K_20/ha. Highest plant height, number of branches per plant, pod length and girth, number of pods per plant, green pod yield among P rates were recorded for P at 80 kg/ha. These parameters were increased with the increasing K rates upto 60 kg K_20/ha.

Parmar *et al.* (1999) reported that French bean was treated with three levels of nitrogen (0, 15 or 30 kg/ha) and four levels of Phosphorus (0, 30, 60 or 90 kg P_2O_5/ha) in a field experiment conducted in Himachal Pradesh, India during summer season. Plant height, number of pods per plant and seeds per pod were increased with increasing rate of N and P.

Devender *et al.* (1998) carried out an experiment to study the effect of nitrogen and phosphorus on the yield of French bean, and stated that application of nitrogen upto 150 kg and 60 kg P_2O_5/ha significantly increased seed per pod and seed yield.

Gajendra and Singh (1998) conducted a field experiment at Lalchaoti with moisture regimes and fertility levels in soil on French bean. They reported that 120 kg N + 90 kg P_20_5 and 45 kg K_20 per hectare gave higher grain yield of French bean.

Sushant *et al.* (1998) conducted a field experiment in Uttar Pradesh to investigate the effects of irrigation, nitrogen and phosphorus on the seed yield of French bean, and stated that application of nitrogen upto 100 kg/ha and upto 60 kg P_2O_5/ha significantly increased the yield attributes, yield and water use efficiency.

Ahlawat (1996) conducted a field experiment in New Delhi, India to study the comparative performance of French bean varieties and their response to phosphorus fertilizer. They reported that application of phosphorus greatly improved the yield attributes (pods per plant and seeds per pod), seed yield and the N and P uptake. The response of applied P was linear upto 40 kg P/ha.

CHAPTER III

MATERIALS AND METHODS

In this chapter a short description of the location of the experimental plot, climatic condition of the area where the plot was situated, materials used for experimental treatments, design of the experiment, method of cultivation, method of data collection, statistical analysis have been presented.

3.1 Experimental site

The research work was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to study the effect of spacing and phosphorous on the yield contributing characters and yield of French bean during the period from November 2017 to February 2018. Experimental field was located at 90°22/ E longitude and 23°41/ N latitude and altitude of 8.2 m above the sea level. The experimental site is presented in Appendix I.

3.2 Climate

Experimental area belongs to subtropical climatic zone which is characterized by heavy rainfall, high temperature and relatively long day period during "Kharif-1" season (April-September) and scarce rainfall, low humidity, low temperature and short day period during "Rabi" season (October-March). This climate is also characterized by distinct season, *viz*. the monsoon extending from May to October, the winter or dry season from November to February and per-monsoon period or hot season from March to April (Edris *et al.*, 1979). The meteorological data in respect of temperature, rainfall, relative humidity, average sunshine and soil temperature for the entire experimental period have been shown in Appendix II.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract in Agroecological Zone (AEZ)-28 (UNDP, 1988). It was medium high land and the soil series was Tejgaon (FAO, 1988). The soil was having a texture of sandy loam with pH and CEC were 5.6 and 2.64 meq/100 g soil, respectively. The characteristics of the soil under the experimental plot were analyzed in the Soil Testing laboratory, SRDI, Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Appendix III.

3.4 Planting materials

The variety of French bean used in the present experiment was BARI Jhar sheem-1. The seeds were collected from the Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Treatments of the experiment

Factor A: Spacing

1. S_1 = 30 cm × 10 cm
2. S_2 = 30 cm × 15 cm
3. S_3 = 30 cm × 20 cm

Factor B: Phosphorus (P)

1. P_0 = 0 kg P ha^{-1} (Control)
2. P_1 = 40 kg P ha^{-1}
3. P_2 = 60 kg P ha^{-1}
4. P_3 = 80 kg P ha^{-1}

There were 12 (3×4) treatment combinations given below:

S_1P_0, S_1P_1, S_1P_2, S_1P_3, S_2P_0, S_2P_1, S_2P_2, S_2P_3, S_3P_0, S_3P_1, S_3P_2, S_3P_3

3.6 Design and layout of the experiment

The two factor experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. There were 12 treatment combinations. In total 36 plots for 3 replications. Each block consisted of 12 unit plots. The size of each unit plot was (1.2 m × 0.6 m). The distance maintained between two replications and two plots were 1 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.7 Land preparation

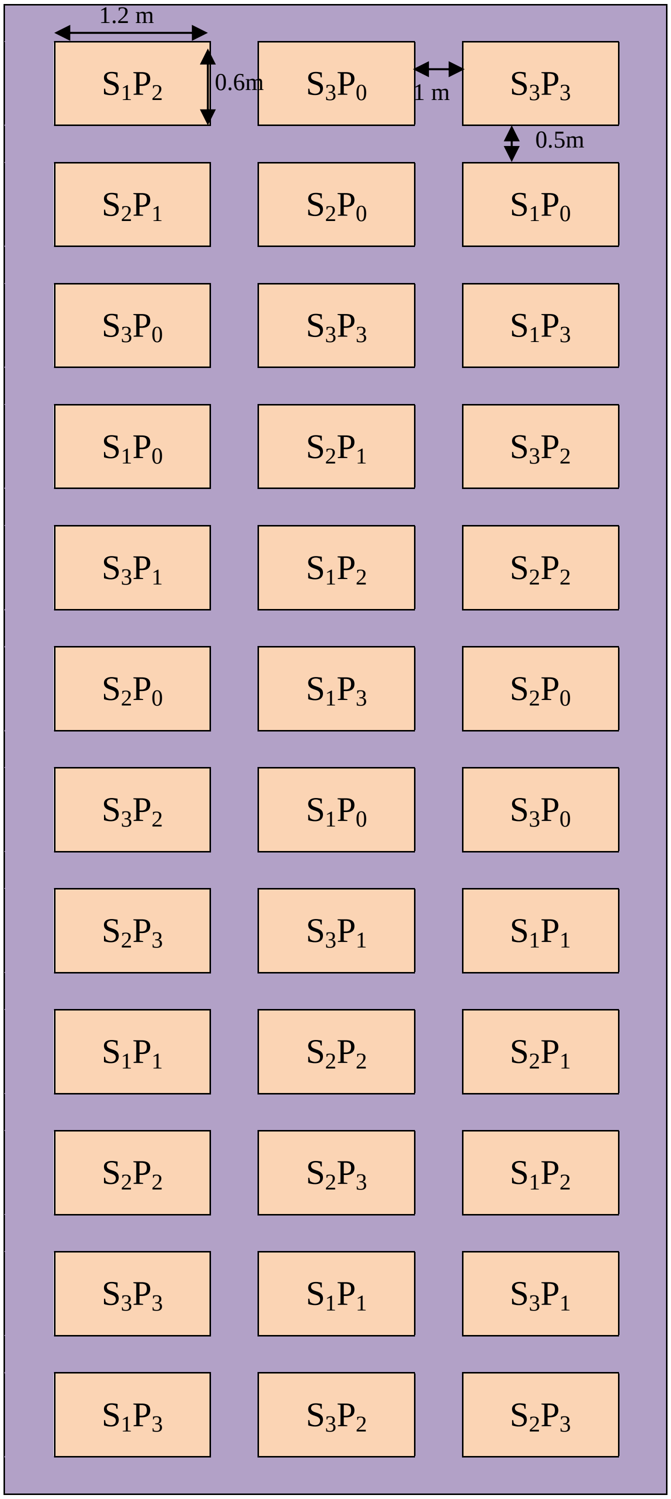
The experimental area was first ploughed by a power tiller and the soil was exposed to sun for 5 days. Then the land was thoroughly prepared by ploughing and cross ploughing. The weeds and stubbles were removed from the field. Then the land was divided into 36 unit plots keeping plot and block to block spacing. During land preparation, carbofuran @16 kg ha^{-1} was mixed with the soil uniformly for controlling soil borne insects.

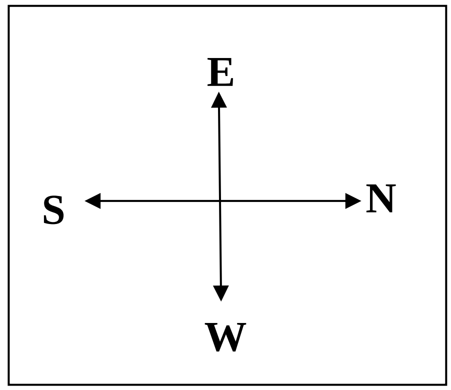
3.8 Manures and fertilizer

The following doses of manure and fertilizers were applied for French bean production under the present study

Manures and fertilizer	**Doses ha^{-1}**
Cowdung	5 ton
Urea	200 kg
TSP	As per treatment
MoP	150 kg

The entire amount of well-decomposed cowdung, triple super phosphate (TSP) and muriate of potash (MoP) were applied and mixed with the soil during final land preparation. The ⅓ amount of urea was applied during final land preparation and rest amount of urea applied in two installments at 15 and 30 days after sowing the seeds.





LEGEND

Plot size	: 1.2 m × 0.6 m
Plot length	: 1.2 m
Plot breadth	: 0.6 m
Plot to plot distance	: 1 m
Block to block distance	: 0.5 m

Fig. 1. Layout of the experimental plot

3.9 Sowing of seeds

Two seeds were sown per hill at a depth of 3.0 cm on 15th November, 2017 in the row. Plant to plant distance and row to row distance were maintained according to the treatment. The seeds were covered with pulverized soil just after sowing and gently pressed with hands. Surrounding of the experimental plots, French been seeds were also sown as border crop to reduce border effects.

3.10 Intercultural operation

3.10.1 Gap filling

During seed sowing, few seeds were sown in the border of the plots. Seedlings were transferred to fill up the gap where seeds failed to germinate. Seedlings about 15 cm height were transplanted from border rows with roots plunged 5 cm below the soil in hills in the evening and watering was done to protect the seedlings from wilting. All gaps were filled up within two weeks after germination of seeds.

3.10.2 Thinning

When the plants established, one healthy plant per hill was kept and remaining one was plucked.

3.10.3 Weeding and mulching

Weeding and mulching were done whenever it was necessary to keep the plots free from weeds and to pulverize the soil.

3.10.4 Plant protection

3.10.4.1 Insect pests

At the early stage of growth, some plants were attacked by insect's pests (mainly aphid) and Malathion 57 EC was sprayed twice at the rate of 2 ml/liter at an interval of 10 days.

3.10.4.2 Diseases

Seedlings were attacked by damping off and Dithane M-45 was sprayed twice at the rate of 2 ml $litre^{-1}$ at an interval of 7 days. Some plants were attacked by Bean Common Mosaic Virus (BCMV) which is an important disease of French bean. These plants were removed from the plots and destroyed and also Admire 20 SL sprayed twice at the rate of 1ml $liter^{-1}$ at 10 days interval.

3.11 Harvesting

Immature green pods were harvested at tender stage through hand picking and weighed to estimate the yield of fresh pod. At harvest, pods were nearby full size, with the seeds still small (about one quarter developed) with firm flesh (Swiader *et al.,* 1992) and the pods were soft and smooth.

3.12 Collection of data

Five representative plants were selected at random from each of unit plot to avoid border effect and tagged in the field. Data were recorded periodically from the sample plants at different days interval. The following data were recorded for the present study:

3.12.1 Growth parameters

1. Plant height (cm)
2. Number of leaves $plant^{-1}$
3. Number of branches $plant^{-1}$

3.12.2 Yield contributing parameters

1. Leaf area (cm^2)
2. Number of flowers $plant^{-1}$
3. Number of pods $plant^{-1}$
4. Pod length (cm)
5. Pod diameter (cm)

6. Percent (%) dry matter of pod

3.12.3 Yield parameters

1. Weight of single pod
2. Weight of pods plant^{-1} (g)
3. Fresh pod yield plot^{-1} (kg)
4. Fresh pod yield (t ha^{-1})

3.12.4 Economic analysis

1. Total cost of production
2. Gross return (Tk. ha^{-1})
3. Net return (Tk. ha^{-1})
4. BCR

3.13 Procedure of recording data

The following procedure was followed for recording of data

3.13.1 Plant height

Plant height was considered as the height from ground level to the tip of largest leaf of the plants. The plant height was recorded at 15, 30, and 45 days after sowing (DAS). Plant height of five randomly sampled plants were recorded and mean was calculated in centimeter (cm).

3.13.2 Number of leaves plant^{-1}

The number of leaves of five randomly selected plants was counted from each unit plot at 15 days interval from 15 to 45 DAS and means were calculated.

3.13.3 Leaf area

The leaf area was determined by area meter and express in cm^2.

3.13.4 Number of branches plant^{-1}

The number of branches of five randomly selected plants from each plot at different days after sowing was counted. Number of branches plant^{-1} was recorded at 15, 30, and 45 days after sowing (DAS).

3.13.5 Number of flowers plant^{-1}

From five randomly selected plants per unit plot, the number of flowers was counted and their mean values were recorded.

3.13.6 Number of pods plant^{-1}

Number of pods from five randomly selected plants from each plot was counted from 1st harvest to last harvest and their mean values were calculated.

3.13.7 Pod length

Five pods were randomly selected from green pods of each selected plant and length was measured using a centimeter scale and the mean value was calculated and expressed in centimeter (cm).

3.13.8 Pod diameter

Five pods were randomly selected from green pods of each selected plant and diameter was measured using a slide calipers and the mean value was calculated and expressed in centimeter (cm).

3.13.9 Percent (%) dry matter of pod

Fresh pods from five plants were collected randomly from each plot. 100 g sample from each plot were placed in oven maintained at 70^{0}C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The dry weight was recorded in gram (g) by using a beam balance.

3.13.10 Weight of single pod

Pods of each selected plants were weighed and their average was measured. Weight of single pod was expressed in gram (g).

3.13.11 Weight of pods plant^{-1}

Fresh pods of 5 sample plants were weighed and their average was taken in gram (g).

3.13.12 Fresh pod yield plot^{-1}

Total pod was collected from 1st harvest to last harvest from each plot and weighed. The total weight was considered as fresh pod yield plot^{-1} and expressed in kilogram (kg).

3.13.13 Fresh pod yield ha^{-1}

Per plot yield was converted to ton per hectare using plot area and was expressed in ton per hectare (t ha^{-1}).

3.14 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of spacing and phosphorus. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests rate were also calculated. The market price of French bean was considered for estimating the cost and return.

Analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

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

3.15 Statistical analysis

The recorded data on different parameters were statistically analyzed using MSTAT computer package programme. The analysis of variance for the characters under the present study were performed by ‘F’ variance test. The differences between the pairs of treatment means was compared using DMRT test (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

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

4.1 Growth parameters

4.1.1 Plant height

Different plant spacing had significant influence on plant height of french bean at different growth stages (Fig.2 and Appendix IV). It was found that the highest plant height (22.25, 25.09 and 38.45 cm at 15, 30 and 45 DAS, respectively) from the plant spacing, S_1 (30 cm × 10 cm), which was significantly different from other treatments. The lowest plant height (20.15, 22.39 and 35.38 cm at 15, 30 and 45 DAS, respectively) was obtained from the plant spacing, S_3 (30 cm × 20 cm).Similar result was also observed by Masa *et al.* (2017), Elhag and Hussein (2014) which supported the present study.

There was a significant variation on plant height influenced by different levels of phosphorus at different growth stages (Fig. 3 and Appendix IV). The highest plant height (22.60, 26.05 and 39.04 cm at 15, 30 and 45 DAS, respectively) was achieved from the treatment, P_3 (80 kg P ha^{-1}) followed by P_2 (60 kg P ha^{-1}). The lowest plant height (19.73, 21.02 and 34.47 cm at 15, 30 and 45 DAS, respectively) was observed from the control treatment, P_0 (0 kg P ha^{-1}). Similar result was also observed by Emam *et al.* (2018), Rafat and Sharif (2015) which supported the present study.

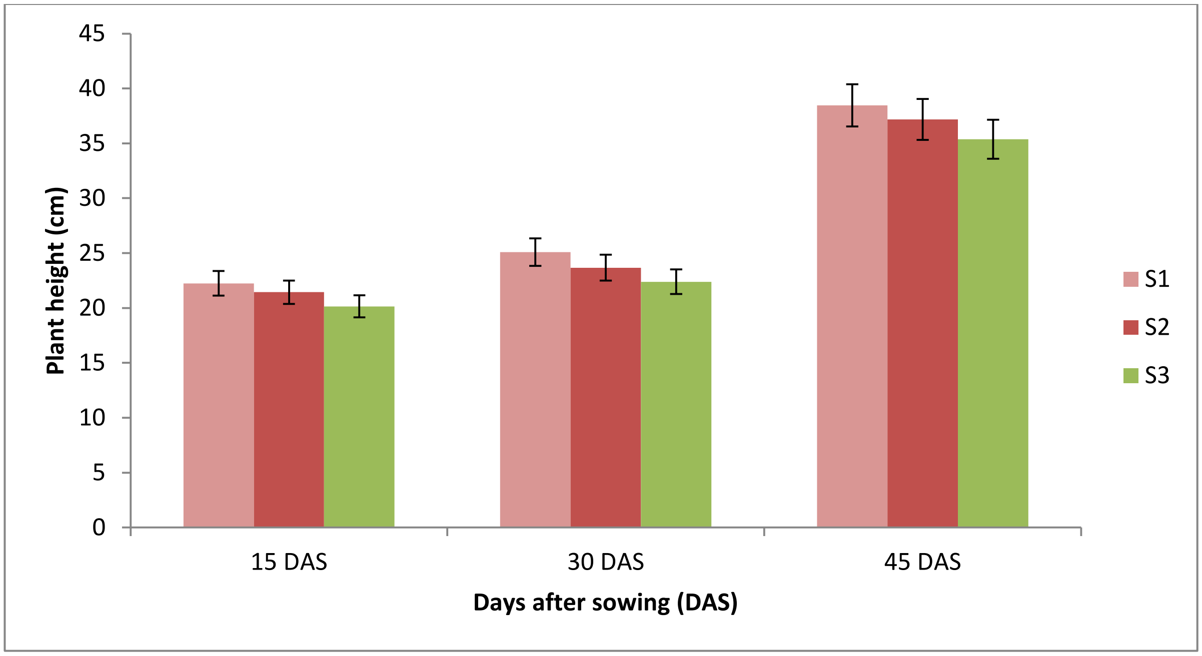


Fig. 2. Effect of spacing on plant height of french bean

Here, S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm

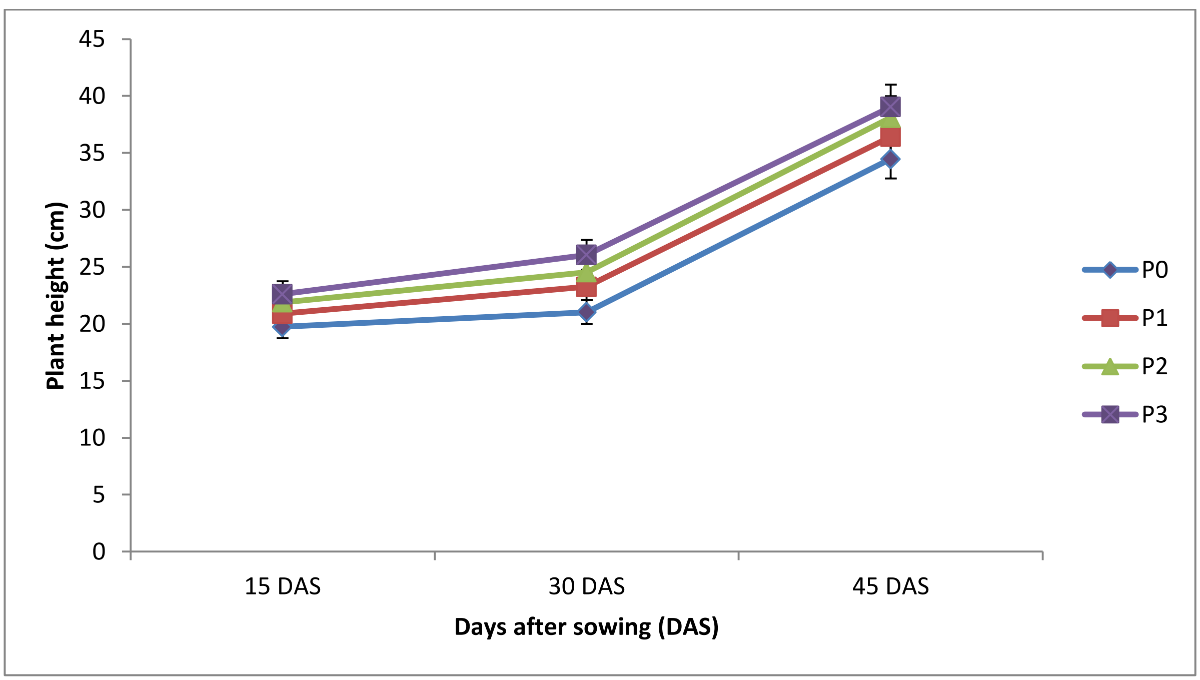


Fig. 3. Effect phosphorus on plant height of french bean

Here, P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

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

Treatment	Plant height (cm)		
	15 DAS	**30 DAS**	**45 DAS**
S_1P_0	20.13 e	21.87 f	36.20 e
S_1P_1	21.93 b	25.07 bc	37.80 cd
S_1P_2	23.27 a	25.80 b	39.47 ab
S_1P_3	23.67 a	27.60 a	40.33 a
S_2P_0	19.67 ef	20.87 g	33.87 f
S_2P_1	20.67 cd	22.80 d	36.73 de
S_2P_2	22.07 b	25.13 bc	38.40 bc
S_2P_3	23.33 a	25.87 b	39.73 ab
S_3P_0	19.40 f	20.33 g	33.33 f
S_3P_1	20.07 de	21.87 ef	34.73 f
S_3P_2	20.33 cd	22.67 de	36.40 de
S_3P_3	20.80 c	24.67 c	37.07 c-e
$LSD_{0.05}$	0.591	0.783	1.347
CV(%)	8.58	9.64	9.93

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

Here,

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

P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Plant height at different growth stages was significantly influenced by combined effect of plant spacing and phosphorus levels (Table 1 and Appendix V). Results revealed that the highest plant height (23.67, 27.60 and 40.33 cm at 15, 30 and 45 DAS, respectively) was found from the treatment combination of S_1P_3 which was statistically identical with the treatment combination of S_1P_2 and S_2P_3 at 15 DAS and statistically similar at 45 DAS. The lowest plant height (19.40, 20.33 and 33.33 cm at 15, 30 and 45 DAS, respectively) was found from the treatment combination of S_3P_0 which was statistically identical with the treatment combination of S_2P_0 and S_3P_1 at 45 DAS.

4.1.2 Number of leaves plant^{-1}

Significant variation was observed on number of leaves plant^{-1} at different growth stages influenced by different plant spacing (Fig. 4 and Appendix V). The highest number of leaves plant^{-1} (8.15, 12.17 and 20.80 at 15, 30 and 45 DAS, respectively) was found from the plant spacing, S_3 (30 cm × 20 cm) which was statistically identical with S_2 (30 cm × 15 cm) at all growth stages. The lowest number of leaves plant^{-1} (7.02, 10.75 and 18.67 at 15, 30 and 45 DAS, respectively) was obtained from the plant spacing, S_1 (30 cm × 10 cm). The result obtained from the present study was similar with the findings of Emam *et al.* (2018) and Masa *et al.* (2017).

Number of leaves plant^{-1} was significantly varied due to different levels of phosphorus at different growth stages (Fig. 5 and Appendix V). The highest number of leaves plant^{-1} (8.11, 12.11 and 20.73 at 15, 30 and 45 DAS, respectively) was achieved from the treatment, P_1 (40 kg P ha^{-1}) followed by P_2 (60 kg P ha^{-1}) and P_3 (80 kg P ha^{-1}) where the lowest number of leaves plant^{-1} (6.91, 10.62 and 18.33 at 15, 30 and 45 DAS, respectively) was observed from the control treatment, P_0 (0 kg P ha^{-1}). The result obtained from the present study was similar with the findings of Varennes *et al.* (2002) and Verma and Singh (2000).

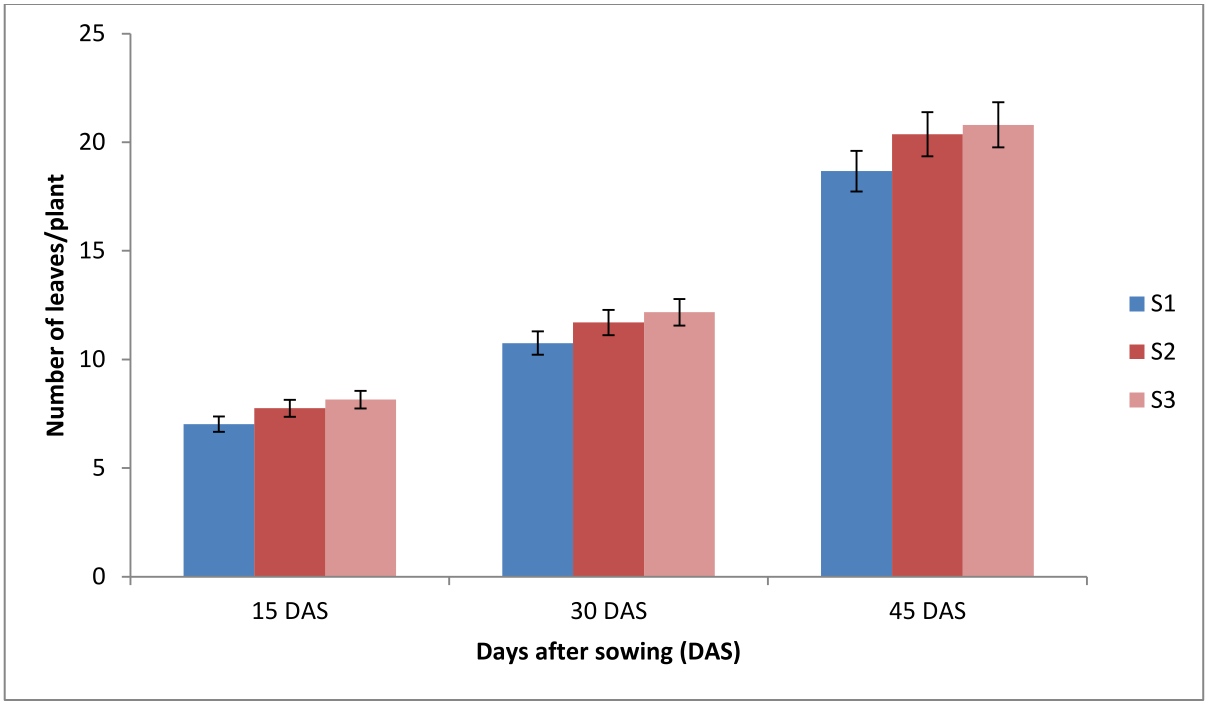


Fig. 4. Effect of spacing on number of leaves plant^{-1} of french bean

Here, S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm

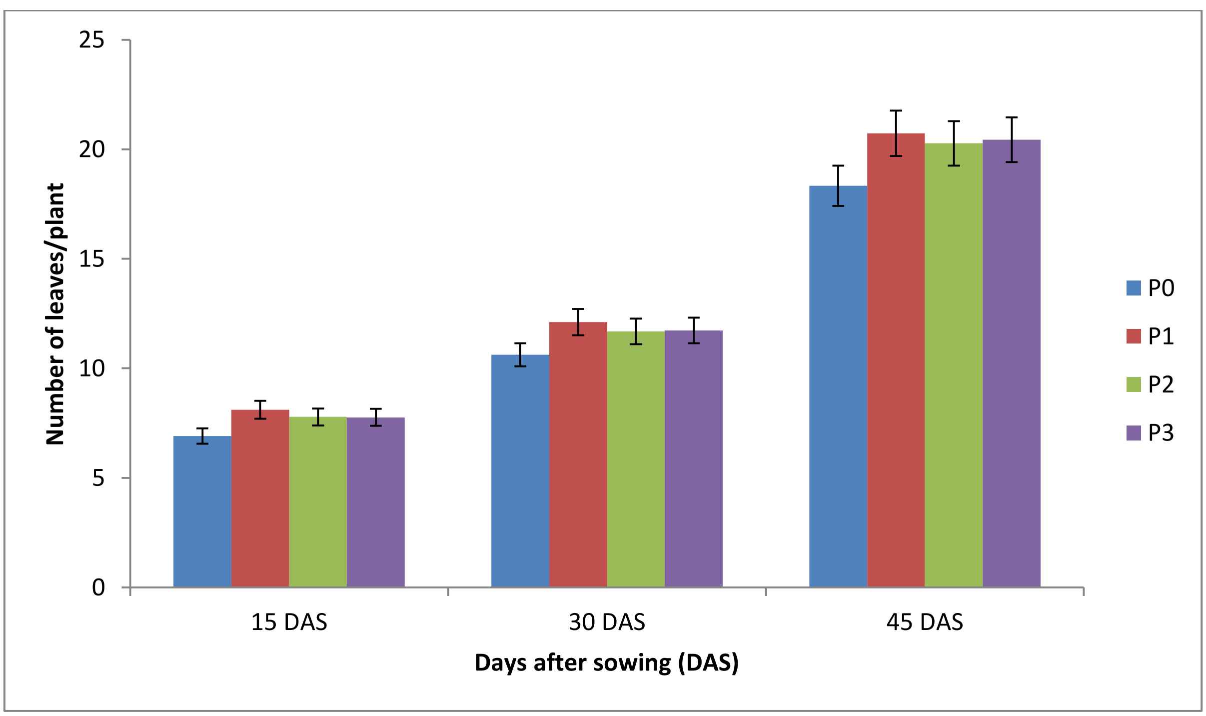


Fig. 5. Effect of phosphorus on number of leaves plant^{-1} of french bean

Here, P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Table 2. Combined effect of spacing and phosphorus on number of leaves plant^{-1} of french bean

Treatment	Number of leaves plant^{-1}		
	15 DAS	30 DAS	45 DAS
S_1P_0	6.20 d	9.67 f	18.00 e
S_1P_1	7.00 c	10.33 e	18.07 e
S_1P_2	7.40 c	11.40 cd	19.20 d
S_1P_3	7.47 bc	11.60 cd	19.40 d
S_2P_0	7.13 c	10.87 de	18.47 e
S_2P_1	8.67 a	12.60 b	22.00 a
S_2P_2	7.53 bc	11.60 cd	20.27 c
S_2P_3	7.67 bc	11.73 c	20.73 bc
S_3P_0	7.40 c	11.33 cd	18.53 e
S_3P_1	8.67 a	13.40 a	22.13 a
S_3P_2	8.40 a	12.07 bc	21.33 b
S_3P_3	8.13 ab	11.87 c	21.20 b
$LSD_{0.05}$	0.653	0.664	0.644
CV(%)	8.03	8.77	9.31

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

Here,

S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm
P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Significant variation was observed on number of leaves plant^{-1} at different growth stages influenced by combined effect of plant spacing and phosphorus levels (Table 2 and Appendix VI). The highest number of leaves plant^{-1} (8.67, 13.40 and 22.13 at 15, 30 and 45 DAS, respectively) was found from the treatment combination of S_3P_1 which was statistically identical with S_2P_1 at 15 and 45 DAS. The lowest number of leaves plant^{-1} (6.20, 9.67 and 18.00 at 15, 30 and 45 DAS, respectively) was found from the treatment combination of S_1P_0 which was statistically identical with S_1P_1, S_2P_0 and S_3P_0.

4.1.3 Number of branches plant^{-1}

Number of branches plant^{-1} was significantly varied due to different plant spacing at different growth stages (Fig. 6 and Appendix VI). The highest number of branches plant^{-1} (0.72, 2.35 and 2.96 at 15, 30 and 45 DAS, respectively) was found from the plant spacing, S_3 (30 cm × 20 cm) followed by S_2 (30 cm × 15 cm). The lowest number of branches plant^{-1} (0.43, 2.01 and 2.57 at 15, 30 and 45 DAS, respectively) was obtained from the plant spacing, S_1 (30 cm × 10 cm). Similar result was also observed by Masa *et al.* (2017) and Mureithi *et al* (2012) which supported the present study.

Significant variation was observed on number of branches plant^{-1} influenced by different levels of phosphorus at different growth stages (Fig. 7 and Appendix VI). The highest number of branches plant^{-1} (0.69, 2.36 and 2.98 at 15, 30 and 45 DAS, respectively) was achieved from the treatment, P_1 (40 kg P ha^{-1}) followed by P_2 (60 kg P ha^{-1}). The lowest number of branches plant^{-1} (0.40, 1.94 and 2.56 at 15, 30 and 45 DAS, respectively) was observed from the control treatment, P_0 (0 kg P ha^{-1}).

Significant influence was noted on number of branches plant^{-1} at different growth stages affected by combined effect of plant spacing and phosphorus levels (Table 3 and Appendix VI). The highest number of branches plant^{-1} (0.93, 2.60 and 3.27 at 15,

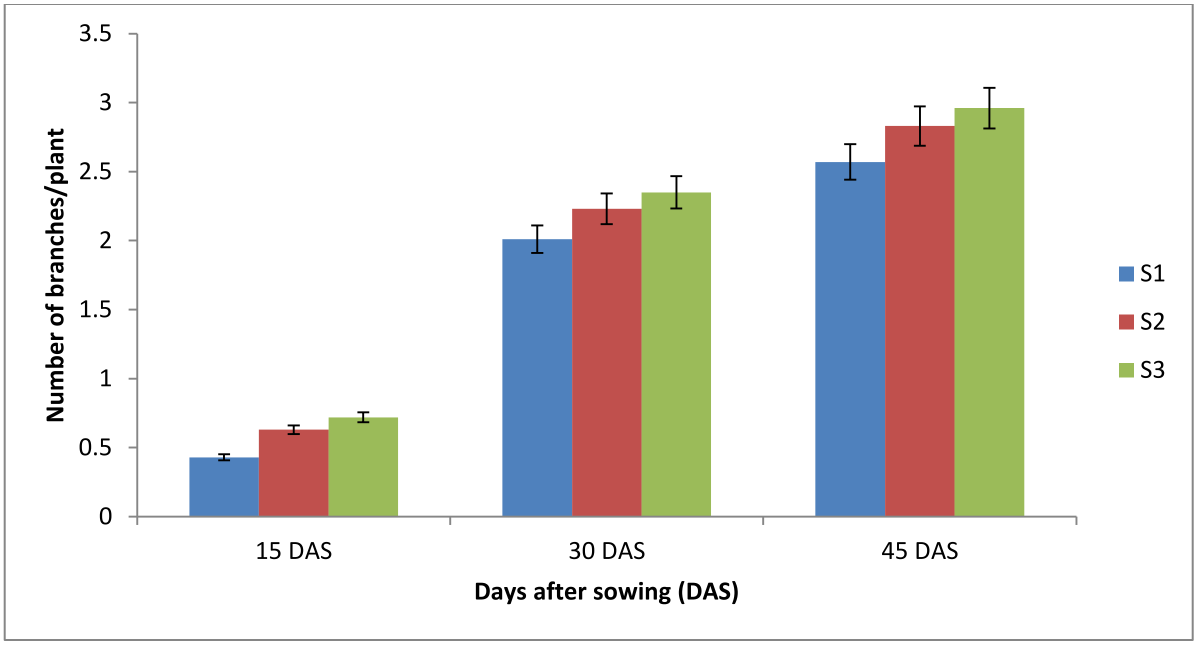


Fig. 6. Effect of spacing on number of branches plant^{-1}of french bean

Here, S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm

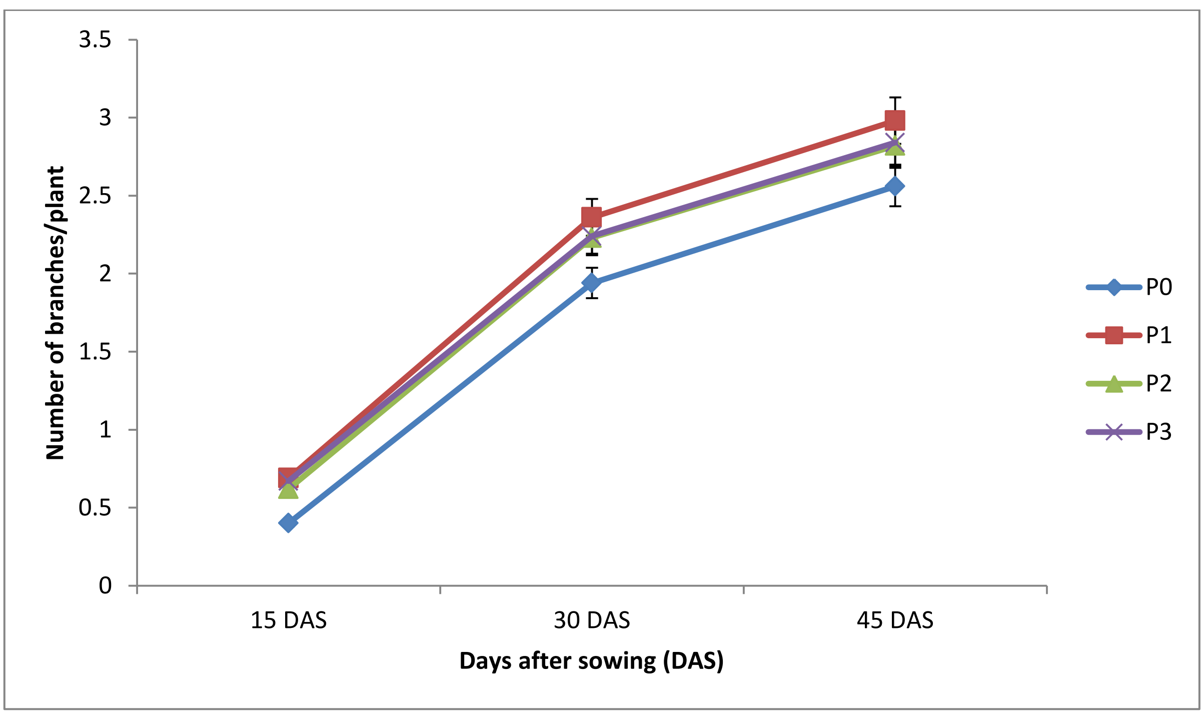


Fig. 7. Effect of phosphorus on number of branches plant^{-1}of french bean

Here, P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Table 3. Combined effect of spacing and phosphorus on number of branches plant^{-1} of french bean

Treatment	Number of branches plant^{-1}		
	15 DAS	**30 DAS**	**45 DAS**
S_1P_0	0.30 f	1.90 g	2.40 f
S_1P_1	0.33 f	1.93 g	2.47 f
S_1P_2	0.47 e	2.07 e-g	2.67 ef
S_1P_3	0.60 d	2.13 d-f	2.73 de
S_2P_0	0.40 ef	1.93 g	2.60 ef
S_2P_1	0.80 b	2.53 a	3.20 ab
S_2P_2	0.67 cd	2.20 c-e	2.73 e
S_2P_3	0.67 cd	2.27 cd	2.80de
S_3P_0	0.47 e	2.00 fg	2.67 ef
S_3P_1	0.93 a	2.60 a	3.27 a
S_3P_2	0.73 bc	2.47 ab	3.07 bc
S_3P_3	0.73 bc	2.33 bc	2.93 cd
$LSD_{0.05}$	0.076	0.178	0.186
CV(%)	4.71	7.55	5.96

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

Here,

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

P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

30 and 45 DAS, respectively) was found from the treatment combination of S_3P_1 which was statistically similar with the treatment combination of S_2P_1 at 45 DAS. The lowest number of branches plant^{-1} (0.30, 1.90 and 2.40 at 115, 30 and 45 DAS, respectively) was found from the control treatment combination of S_1P_0 which was statistically identical with the treatment combination of S_1P_1 and statistically similar with the treatment combination of S_1P_2, S_2P_0 and $S_3P_{0.}$ Rahman *et al.* (2018) and Turuko and Mohammed (2014) also found similar result with the present study.

4.2 Yield contributing parameters

4.2.1 Leaf area

Significant influence was noted on leaf area affected by different plant spacing at 45 DAS (Table 4 and Appendix VII). The highest leaf area (46.80) was found from the plant spacing, S_2 (30 cm × 15 cm) which was statistically identical with S_3 (30 cm × 20 cm). The lowest leaf area (44.79) was obtained from the plant spacing, S_3 (30 cm × 20 cm). Similar result was also observed by Masa *et al.* (2017) and Mureithi *et al* (2012).

Significant variation was remarked on leaf area as influenced by different levels of phosphorus at 45 DAS (Table 4 and Appendix VII). The highest leaf area (49.99) was achieved from the treatment, P_3 (80 kg P ha^{-1}) followed by P_2 (60 kg P ha^{-1}). The lowest leaf area (42.33) was observed from the control treatment, P_0 (0 kg P ha^{-1}) followed by P_1 (40 kg P ha^{-1}). Similar result was also observed by Kakon *et al.* (2016) and Turuko and Mohammed (2014).

Leaf area was found significant with the combined effect of plant spacing and phosphorus levels at 45 DAS (Table 5 and Appendix VII). The highest leaf area (51.13) was found from the treatment combination of S_2P_3 which was statistically similar with the treatment combination of S_3P_3. The lowest leaf area (40.66) was found from the treatment combination of S_1P_0 which was statistically identical with the treatment combination of S_2P_0.

Table 4. Effect of spacing and phosphorus on yield contributing parameters of leaf area, number of flowers plant^{-1}, number of pods plant^{-1} of french bean

Treatment	Yield contributing parameters		
	Leaf area (cm^2)	Number of flowers plant^{-1}	Number of pods plant^{-1}
Effect of plant spacing			
S_1	44.79 b	21.64 c	17.58 b
S_2	46.80 a	23.18 b	19.03 b
S_3	46.34 a	23.69 a	19.60 a
$LSD_{0.05}$	0.686	0.218	0.286
CV(%)	9.62	9.21	8.32
Effect of phosphorus			
P_0	42.33 d	19.80 c	15.96 d
P_1	45.21 c	24.96 a	20.71 a
P_2	46.37 b	23.54 b	19.56 b
P_3	49.99 a	23.05 b	18.73 c
$LSD_{0.05}$	0.744	0.726	0.516
CV(%)	9.62	9.21	8.32

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

Here,

S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm
P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

4.2.2 Number of flowers plant^{-1}

Significant variation on number of flowers plant^{-1} was noted influenced by different plant spacing (Table 4 and Appendix VII). The highest number of flowers plant^{-1}(23.69) was found from the plant spacing, S_3 (30 cm × 20 cm) followed by S_2 (30 cm × 15 cm). The lowest number of flowers plant^{-1}(21.64) was obtained from the plant spacing, S_1 (30 cm × 10 cm).

Number of flowers plant^{-1} of french bean affect by different levels of phosphorus was significant (Table 4 and Appendix VII). The highest number of flowers plant^{-1} (24.96) was achieved from the treatment, P_1 (40 kg P ha^{-1}) followed by P_2 (60 kg P ha-1) and P_3 (80 kg P ha^{-1}). The lowest number of flowers plant^{-1} (19.80) was observed from the control treatment, P_0 (0 kg P ha^{-1}).

The recorded data on number of flowers plant^{-1}was significant due to combined effect of plant spacing and phosphorus levels (Table 5 and Appendix VII). The highest number of flowers plant^{-1} (25.90) was found from the treatment combination of S_3P_1 which was statistically identical with the treatment combination of S_2P_1. The lowest number of flowers plant^{-1} (19.10) was found from the control treatment combination of S_1P_0which was significantly different from followed by S_2P_0 and S_3P_0.

4.2.3 Number of pods plant^{-1}

Considerable influence was observed on number of pods plant^{-1} affected by different plant spacing (Table 4 and Appendix VII). The highest number of pods plant^{-1} (19.60) was found from the plant spacing, S_3 (30 cm × 20 cm) followed by S_2 (30 cm × 15 cm). The lowest number of pods plant^{-1} (17.58) was obtained from the plant spacing, S_1 (30 cm × 10 cm). The result obtained from the present study was similar with the findings of Masa *et al*. (2017) and Elhag and Hussein (2014).

Table 5. Combined effect of spacing and phosphorus on yield contributing parameters of leaf area, number of flowers plant^{-1}, number of pods plant^{-1} of french bean

Treatment	Yield contributing parameters		
	Leaf area (cm^2)	Number of flowers plant^{-1}	Number of pods plant^{-1}
S_1P_0	40.66 f	19.10 g	15.00 g
S_1P_1	44.40 e	23.27 cd	19.33 cd
S_1P_2	44.79 de	21.70 e	18.00 e
S_1P_3	49.29 b	22.47 de	18.00 e
S_2P_0	42.28 f	19.90 f	16.00 fg
S_2P_1	45.88 de	25.70 a	21.33 a
S_2P_2	47.90 bc	24.33 b	20.00 bc
S_2P_3	51.13 a	22.80 d	18.80 de
S_3P_0	44.06 e	20.40 f	16.87 f
S_3P_1	45.34 de	25.90 a	21.47 a
S_3P_2	46.42 cd	24.60 b	20.67 ab
S_3P_3	49.55 ab	23.87 bc	19.40 cd
$LSD_{0.05}$	1.720	0.876	1.056
CV(%)	9.62	9.21	8.32

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

Here,

S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm
P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Number of pods plant^{-1} was significantly varied due to the different levels of phosphorus (Table 4 and Appendix VII). The highest number of pods plant^{-1} (20.71) was achieved from the treatment, P_1 (40 kg P ha^{-1}) followed by P_2 (60 kg P ha^{-1}). The lowest number of pods plant^{-1} (15.96) was observed from the control treatment, P_0 (0 kg P ha^{-1}) followed by P_3 (80 kg P ha^{-1}). Rafat and Sharif (2015) also found similar result with the present study.

Significant variation was observed on number of pods plant^{-1} influenced by combined effect of plant spacing and phosphorus levels (Table 5 and Appendix VII). The highest number of pods plant^{-1} (21.47) was found from the treatment combination of S_3P_1 which was statistically identical with the treatment combination of S_2P_1. The lowest number of pods plant^{-1} (15.00) was found from the control treatment combination of S_1P_0which was significantly different from all other treatment combinations.

4.2.4 Pod length

Variation on pod length was noted influenced by different plant spacing (Table 6 and Appendix VIII). The highest pod length (13.94 cm) was found from the plant spacing, S_3 (30 cm × 20 cm) which was statistically identical with S_2 (30 cm × 15 cm). The lowest pod length (13.60 cm) was obtained from the plant spacing, S_1 (30 cm × 10 cm). The result obtained from the present study was similar with the findings of Masa *et al.* (2017) and Elhag and Hussein (2014).

Pod length was found significant with the application of different levels of phosphorus (Table 6 and Appendix VIII). The highest pod length (14.14 cm) was achieved from the treatment, P_1 (40 kg P ha^{-1}) where the lowest pod length (13.48 cm) was observed from the control treatment, P_0 (0 kg P ha^{-1}). Rafat and Sharif (2015) found similar result which supported the present study.

Significant variation was remarked on pod length as influenced by combined effect of plant spacing and phosphorus levels (Table 7 and Appendix VIII). The highest pod

Table 6. Effect of spacing and phosphorus on yield contributing parameters of pod length, pod diameter, percent (%) dry matter of pod of french bean

Treatment	Yield contributing parameters		
	Pod length (cm)	**Pod diameter (cm)**	**Percent (%) dry matter of pod**
Effect of plant spacing			
S_1	13.60 b	1.04	6.33 b
S_2	13.88 a	1.05	6.84 a
S_3	13.94 a	1.06	6.99 a
$LSD_{0.05}$	0.188	0.092	0.293
CV(%)	3.81	3.03	7.74
Effect of phosphorus			
P_0	13.48 c	1.03	6.02 c
P_1	14.14 a	1.07	7.34 a
P_2	13.83 b	1.06	6.84 b
P_3	13.77 b	1.05	6.67 b
$LSD_{0.05}$	0.168	0.054	0.352
CV(%)	3.81	3.03	7.74

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

Here,

S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm
P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

length (14.30 cm) was found from the treatment combination of S_3P_1 which was statistically identical with the treatment combination of S_2P_1. The lowest pod length (13.43 cm) was found from the control treatment combination of S_1P_0 which was statistically identical with the treatment combination of S_1P_2, S_3P_3, S_2P_0 and S_0P_0.

4.2.5 Pod diameter

Pod diameter was not significantly influenced by different plant spacing (Table 6 and Appendix VIII). However, the highest pod diameter (1.06 cm) was found from the plant spacing, S_3 (30 cm × 20 cm) and the lowest pod diameter (1.04 cm) was obtained from the plant spacing, S_1 (30 cm × 10 cm)

Non-significant influence was noted on pod diameter affected by different levels of phosphorus (Table 6 and Appendix VIII). However, the highest pod diameter (1.07 cm) was achieved from the treatment, P_1 (40 kg P ha^{-1}) and the lowest pod diameter (1.03 cm) was observed from the control treatment, P_0 (0 kg P ha^{-1}). Rafat and Sharif (2015) also found similar result with the present study.

Remarkable variation was observed on pod diameter influenced by combined effect of plant spacing and phosphorus levels (Table 7 and Appendix VIII). However, the highest pod diameter (1.09 cm) was found from the treatment combination of S_3P_1 and the lowest pod diameter (1.02 cm) was found from the control treatment combination of S_1P_0.

4.2.6 Percent (%) dry matter of pod

Percent (%) dry matter of pod was significantly varied due to different plant spacing (Table 6 and Appendix VIII). The highest percent (%) dry matter of pod (6.99%) was found from the plant spacing, S_3 (30 cm × 20 cm) which was statistically identical with S_2 (30 cm × 15 cm). The lowest percent (%) dry matter of pod (6.33%) was obtained from the plant spacing, S_1 (30 cm × 10 cm).

Table 7. Combined effect of spacing and phosphorus on yield contributing parameters of pod length, pod diameter, percent (%) dry matter of pod of french bean

Treatment	Yield contributing parameters		
	Pod length (cm)	Pod diameter (cm)	Percent (%) dry matter of pod
S_1P_0	13.43 d	1.02	5.80 g
S_1P_1	13.90 bc	1.06	6.80 cd
S_1P_2	13.52 d	1.04	6.30ef
S_1P_3	13.55 d	1.04	6.40 e
S_2P_0	13.51 d	1.03	6.10 f
S_2P_1	14.22 a	1.07	7.50 a
S_2P_2	13.94 bc	1.06	7.03bc
S_2P_3	13.83 c	1.05	6.73 d
S_3P_0	13.51 d	1.04	6.16ef
S_3P_1	14.30 a	1.09	7.73 a
S_3P_2	14.02 b	1.06	7.20 b
S_3P_3	13.93 bc	1.06	6.86 cd
$LSD_{0.05}$	0.142	0.178	0.239
CV(%)	3.81	3.03	7.74

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

Here,

S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm
P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Significant variation was observed on percent (%) dry matter of pod influenced by different levels of phosphorus (Table 6 and Appendix VIII). The highest percent (%) dry matter of pod (7.34%) was achieved from the treatment, P_1 (40 kg P ha^{-1}) where the lowest percent (%) dry matter of pod (6.02%) was observed from the control treatment, P_0 (0 kg P ha^{-1}). The treatment, P_2 (60 kg P ha^{-1}) and P_3 (80 kg P ha^{-1}) showed intermediate result compared to highest treatments.

There was a significant variation on percent (%) dry matter of pod influenced by combined effect of plant spacing and phosphorus levels at different growth stages (Table 7 and Appendix VIII). The highest percent (%) dry matter of pod (7.73%) was found from the treatment combination of S_3P_1which was statistically identical with the treatment combination of S_2P_1. The lowest percent (%) dry matter of pod (5.80%) was found from the control treatment combination of S_1P_0 which was significantly different from all other treatment combinations followed by S_1P_3.

4.3 Yield parameters

4.3.1 Weight of single pod

Non-significant variation on weight of single pod was noted influenced by different plant spacing (Table 8 and Appendix IX). However, the highest weight of single pod (6.38 g) was found from the plant spacing, S_3 (30 cm × 20 cm) and the lowest weight of single pod (6.16 g) was obtained from the plant spacing, S_1 (30 cm × 10 cm). Similar result was also observed by Sahariar *et al.* (2015).

Weight of single pod was found significant with the application of different levels of phosphorus (Table 8 and Appendix IX). The highest weight of single pod (6.46 g) was achieved from the treatment, P_1 (40 kg P ha^{-1}) which was statistically identical with P_2 (60 kg P ha^{-1}) and P_3 (80 kg P ha^{-1}). The lowest weight of single pod (6.02 g) was observed from the control treatment, P_0 (0 kg P ha^{-1}). The result obtained from the present study was similar with the findings of Rafat and Sharif (2015).

Significant variation was remarked on weight of single pod as influenced by combined effect of plant spacing and phosphorus levels (Table 9 and Appendix IX). The highest weight of single pod (6.63 g) was found from the treatment combination of S_3P_1 which was significantly different from all other treatment combinations followed by S_2P_1 and S_3P_2. The lowest weight of single pod (5.91 g) was found from the control treatment combination of S_1P_0 which was also significantly different from all other treatment combinations.

4.3.2 Weight of pods plant^{-1}

Weight of pods plant^{-1} varied significantly due to different plant spacing (Table 8 and Appendix IX). The highest weight of pods plant^{-1} (72.02 g) was found from the plant spacing, S_3 (30 cm × 20 cm) which was significantly different from others. The lowest weight of pods plant^{-1} (55.39 g) was obtained from the plant spacing, S_1 (30 cm × 10 cm).Masa *et al.* (2017), Sahariar *et al.* (2015) and Mozumder *et al.* (2003) also found similar result with the present study.

Significant influence was noted on weight of pods plant^{-1} affected by different levels of phosphorus (Table 8 and Appendix IX). The highest weight of pods plant^{-1} (77.06 g) was achieved from the treatment, P_1 (40 kg P ha^{-1}) which was significantly different from other treatments followed by P_2 (60 kg P ha^{-1}). The lowest weight of pods plant^{-1} (47.60 g) was observed from the control treatment, P_0 (0 kg P ha^{-1}). Similar result was also observed by Rahman *et al.* (2018) and Rafat and Sharif (2015).

Remarkable variation was observed on weight of pods plant^{-1} influenced by combined effect of plant spacing and phosphorus levels (Table 9 and Appendix IX). The highest weight of pods plant^{-1} (83.31 g) was found from the treatment combination of S_3P_1 which was statistically similar with the treatment combination of S_2P_1. The lowest weight of pods plant^{-1} (38.71 g) was found from the control treatment combination of S_1P_0 followed by the treatment combination of S_2P_0 and S_3P_0.

4.3.3 Fresh pod yield plot^{-1}

Fresh pod yield plot^{-1} was significantly varied due to different plant spacing (Table 8 and Appendix IX). The highest fresh pod yield plot^{-1} (1167.08 g) was found from the plant spacing, S_2 (30 cm × 15 cm) which was significantly different from followed by S_1 (30 cm × 10 cm). The lowest fresh pod yield plot^{-1} (915.33 g) was obtained from the plant spacing, S_3 (30 cm × 20 cm).

Significant variation was observed on fresh pod yield plot^{-1} at influenced by different levels of phosphorus (Table 8 and Appendix IX). The highest fresh pod yield plot^{-1} (1181.67 g) was achieved from the treatment, P_1 (40 kg P ha^{-1}) which was significantly different from treatments where the lowest fresh pod yield plot^{-1} (880.10 g) was observed from the control treatment, P_0 (0 kg P ha^{-1})

There was a significant variation on fresh pod yield plot^{-1} influenced by combined effect of plant spacing and phosphorus levels (Table 9 and Appendix IX). The highest fresh pod yield plot^{-1} (1333.00 g) was found from the treatment combination of S_2P_1 which was significantly different from all other treatment combinations followed by the treatment combination of S_2P_2. The lowest fresh pod yield plot^{-1} (826.00g) was found from the control treatment combination of S_3P_0 followed by the treatment combination of S_1P_0.

4.3.4 Fresh pod yield ha^{-1}

Significant influence was noted on fresh pod yield affected by different plant spacing (Table 8 and Appendix IX). The highest fresh pod yield (16.21 t ha^{-1}) was found from the plant spacing, S_2 (30 cm × 15 cm) which was significantly different from other treatments, followed by S_1 (30 cm × 10 cm). The lowest fresh pod yield (12.71 t ha^{-1}) was obtained from the plant spacing, S_3 (30 cm × 20 cm). Masa *et al.* (2017) and Sahariar *et al*. (2015) also found similar result with the present study.

Table 8. Effect of spacing and phosphorus on yield parameters of french bean

Treatment	Yield parameters			
	Weight of single pod (g)	**Weight of pods plant^{-1} (g)**	**Fresh pod yield plot^{-1} (g)**	**Fresh pod yield (t ha^{-1})**
Effect of plant spacing				
S_1	6.16	55.39 c	1139.50 b	15.83 b
S_2	6.29	68.08 b	1167.08 a	16.21 a
S_3	6.38	72.02 a	915.33 c	12.71 c
$LSD_{0.05}$	0.108	2.053	5.375	0.236
CV(%)	5.21	7.63	9.64	8.38
Effect of phosphorus				
P_0	6.02 b	47.60 d	880.10 d	12.22 c
P_1	6.46 a	77.06 a	1181.67 a	16.41 a
P_2	6.37 a	69.22 b	1166.00 b	16.19 a
P_3	6.26 a	66.77 c	1068.10 c	14.83 b
$LSD_{0.05}$	0.107	2.103	3.661	0.441
CV(%)	5.21	7.63	9.64	8.38

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

Here,

S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm
P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Table 9. Combined effect of spacing and phosphorus on yield parameters of french bean

Treatment	Yield parameters			
	Weight of single pod (g)	Weight of pods plant^{-1} (g)	Fresh pod yield plot^{-1} (g)	Fresh pod yield (t ha^{-1})
S_1P_0	5.91 g	38.71 g	887.00 i	12.32 f
S_1P_1	6.26 d	68.84 d	1264.00 c	17.56 b
S_1P_2	6.23 de	55.03 ef	1233.00 d	17.13 b
S_1P_3	6.24 d	58.98 e	1174.00 e	16.30 c
S_2P_0	6.03 f	51.40 f	927.30 h	12.88 ef
S_2P_1	6.49 b	79.02 ab	1333.00 a	18.51 a
S_2P_2	6.40 bc	73.94 c	1321.00 b	18.34 a
S_2P_3	6.25 d	67.94 d	1087.00 f	15.09 d
S_3P_0	6.13 ef	52.69 f	826.00 j	11.47 g
S_3P_1	6.63 a	83.31 a	948.00 g	13.17 e
S_3P_2	6.48 b	78.69 b	944.00 g	13.11 ef
S_3P_3	6.30 cd	73.38 c	943.30 g	13.10 ef
$LSD_{0.05}$	0.107	4.325	6.291	0.759
CV(%)	5.21	7.63	9.64	8.38

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

Here,

S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm
P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Remarkable variation was observed on fresh pod yield influenced by different levels of phosphorus (Table 8 and Appendix IX). The highest fresh pod yield (16.41 t ha^{-1}) was achieved from the treatment, P_1 (40 kg P ha^{-1}) which was statistically identical with the treatment combination of P_2 (60 kg P ha^{-1}). The lowest fresh pod yield (12.22 t ha^{-1}) was observed from the control treatment, P_0 (0 kg P ha^{-1}). The result obtained from the present study was similar with the findings of Rafat and Sharif (2015), Rahman *et al.* (2018).

Fresh pod yield was significantly varied due to combined effect of plant spacing and phosphorus levels (Table 9 and Appendix IX). The highest fresh pod yield (18.51 t ha^{-1}) was found from the treatment combination of S_2P_1, which was statistically identical with the treatment combination of S_2P_2. The lowest fresh pod yield (11.47 t ha^{-1}) was found from the control treatment combination of S_3P_0 which was significantly different from all other treatment combinations followed by S_1P_0.

4.4 Economic analysis

All the material and non-material input cost like land preparation, french bean seed cost organic manure, fertilizers, irrigation and manpower required for all the operation, interest on fixed capital of land (Leased land by ban loan basis) etc. and miscellaneous cost were considered for calculating the total cost of production from planting seed to harvesting of french bean were recorded for unit plot and converted into cost per hectare (Table 10 and Appendix X). Price of french bean fruit was considered at market rate. The economic analysis is presented under the following headlines:

4.4.1 Gross income

The combination of different spacing and phosphorus levels showed varied gross return (Table 10). Gross income was calculated on the basis of sale of green pod. The highest gross return (Tk 277650) obtained from S_2P_1 (30 cm × 15 cm spacing with 40kg P ha^{-1}) treatment combination and lowest gross return (Tk 172050) obtained from the treatment combination of S_3P_0 (30 cm × 20 cm spacing with 0 kg P ha^{-1}).

Table 10. Economic analysis of french bean production as influenced by plant spacing and phosphorus

Treatments	Economic analysis				
	Pod yield (t ha^{-1})	Total cost of production	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
S_1P_0	12.32	81163	184800	103637	2.28
S_1P_1	17.56	83537	263400	179863	3.15
S_1P_2	17.13	84724	256950	172226	3.03
S_1P_3	16.30	85911	244500	158589	2.85
S_2P_0	12.88	80071	193200	113129	2.41
S_2P_1	18.51	82445	277650	195205	3.37
S_2P_2	18.34	83632	275100	191468	3.29
S_2P_3	15.09	84819	226350	141531	2.67
S_3P_0	11.47	79634	172050	92416	2.16
S_3P_1	13.17	82008	197550	115542	2.41
S_3P_2	13.11	83195	196650	113455	2.36
S_3P_3	13.10	84382	196500	112118	2.33

Here,

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

P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

4.4.2 Net return

Treatment combinations of different spacing and phosphorus levels showed net returns variation (Table 10). The highest net return (Tk 195205) obtained from the treatment combination of S_2P_1 (30 cm × 15 cm spacing with 40 kg P ha^{-1}) and lowest net return (Tk 92416) obtained from the treatment combination of S_3P_0 (30 cm × 20 cm spacing with 0 kg P ha^{-1}).

4.4.3 Benefit cost ratio (BCR)

Among different treatment combinations of spacing and phosphorus levels, variation on BCR was observed among the treatment combinations (Table 10). The highest Benefit cost ratio (BCR); 3.37 was obtained from the treatment combination of S_2P_1 (30 cm × 15 cm spacing with 40 kg P ha^{-1}) and lowest BCR (2.16) was obtained from S_3P_0 (30 cm × 20 cm spacing with 0 kg P ha^{-1}) treatment combination. From economic point of view, it was noticeable from the above results, the treatment combination of S_2P_1 (30 cm × 15 cm spacing with 40 kg P ha^{-1}) was more profitable than rest of the treatment combinations.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Horticultural farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during the period from November 2017 to February 2018 to study the influence of spacing and phosphorus on growth and yield of french bean (*Phaseolus vulgaris*). In the experiment, the treatments consist of two factors *viz*. Factor A- three levels of plant spacing; S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm and S_3 = 30 cm × 20 cm and Factor B- four levels of P application; P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}and P_3 = 80 kg P ha^{-1}. The experiment was laid out in randomized complete block (RCBD) design having twelve treatment combinations with 3 replications. Data were collected on the different growth, yield and yield con parameters and economic analysis was done regarding BCR.

Different plant spacing showed significant variation on different growth and yield parameters of french bean. The highest plant height (22.25, 25.09 and 38.45 cm at 15, 30 and 45 DAS, respectively) was found from the plant spacing, S_1 (30 cm × 10 cm) where the lowest plant height (20.15, 22.39 and 35.38 cm at 15, 30 and 45 DAS, respectively) was obtained from the plant spacing, S_3 (30 cm × 20 cm). Similarly, the highest number of leaves plant^{-1} (8.15, 12.17 and 20.80 at 15, 30 and 45 DAS, respectively) and number of branches plant^{-1} (0.72, 2.35 and 2.96 at 15, 30 and 45 DAS, respectively) were also found from the plant spacing, S_3 (30 cm × 20 cm) but the highest leaf area index(46.80) was found from the plant spacing, S_2 (30 cm × 15 cm). Again, the highest number of flowers plant^{-1} (23.69), number of pods plant^{-1} (19.60), pod length (13.94 cm), pod diameter (1.06 cm), percent (%) dry matter of pod (6.99%), weight of single pod (6.38 g) and weight of pods plant^{-1} (72.02 g) were found from the plant spacing, S_3 (30 cm × 20 cm) but the highest fresh pod yield plot^{-1} (1167.08 g) and fresh pod yield (16.21 t ha^{-1}) was found from the plant spacing, S_2 (30 cm × 15 cm). The lowest number of leaves plant^{-1} (7.02, 10.75 and 18.67 at 15, 30 and 45 DAS, respectively) and number of branches plant^{-1} (0.43, 2.01 and 2.57 at 15, 30 and 45 DAS, respectively) was obtained from the plant spacing, S_1 (30 cm × 10 cm) but the lowest leaf area index (44.79) was obtained from the plant spacing, S_3 (30 cm × 20 cm). Again, the lowest number of flowers plant^{-1}(21.64), number of pods plant^{-1} (17.58), pod length (13.60 cm), pod diameter (1.04 cm), percent (%) dry matter of pod (6.33%), weight of single pod (6.16 g) and weight of pods plant^{-1} (55.39 g) was obtained from the plant spacing, S_1 (30 cm × 10 cm) but the lowest fresh pod yield plot^{-1} (915.33 g) and fresh pod yield (12.71 t ha^{-1}) were obtained from the plant spacing, S_3 (30 cm × 20 cm).

Different levels of phosphorus application showed significant variation on different growth and yield parameters of french bean. The highest plant height (22.60, 26.05 and 39.04 cm at 15, 30 and 45 DAS, respectively) and leaf area index at 35 DAS (49.99) were achieved from the treatment, P_3 (80 kg P ha^{-1}) but the highest number of leaves plant^{-1} (8.11, 12.11 and 20.73 at 15, 30 and 45 DAS, respectively) and number of branches plant^{-1} (0.69, 2.36 and 2.98at 15, 30 and 45 DAS, respectively) were achieved from the treatment, P_1 (40 kg P ha^{-1}). Again, the highest number of flowers plant^{-1} (24.96), number of pods plant^{-1} (20.71), pod length (14.14 cm), pod diameter (1.07 cm), percent (%) dry matter of pod (7.34%), weight of single pod (6.46 g), weight of pods plant^{-1} (77.06 g), fresh pod yield plot^{-1} (1181.67 g) and fresh pod yield (16.41 t ha^{-1}) were also achieved from the treatment, P_1 (40 kg P ha^{-1}).Similarly, the lowest plant height (19.73, 21.02 and 34.47 cm at 15, 30 and 45 DAS, respectively), number of leaves plant^{-1} (6.91, 10.62 and 18.33 at 15, 30 and 45 DAS, respectively), leaf area index at 35 DAS (42.33) and number of branches plant^{-1} (0.40, 1.94 and 2.56 at 15, 30 and 45 DAS, respectively) was observed from the control treatment, P_0 (0 kg P ha^{-1}). Again, the lowest number of flowers plant^{-1} (19.80), number of pods plant^{-1} (15.96), pod length (13.48 cm), pod diameter (1.03 cm), percent (%) dry matter of pod (6.02%), weight of single pod (6.02 g), weight of pods plant^{-1} (47.60 g), fresh pod yield plot^{-1} (880.10 g) and lowest fresh pod yield (12.22 t ha^{-1}) were also observed from the control treatment, P_0 (0 kg P ha^{-1}).

In case of combined effect of plant spacing and phosphorus, most of the studied parameters were significantly influenced. The highest plant height (23.67, 27.60 and 40.33 cm at 15, 30 and 45 DAS, respectively) was found from the treatment combination of S_1P_3 but the highest number of leaves plant^{-1} (8.67, 13.40 and 22.13 at 15, 30 and 45 DAS, respectively) and number of branches plant^{-1} (0.93, 2.60 and 3.27 at 15, 30 and 45 DAS, respectively) were found from the treatment combination of S_3P_1 where the highest leaf area index at 35 DAS (51.13) was found from the treatment combination of S_2P_3. Again, the highest number of flowers plant^{-1} (25.90), number of pods plant^{-1} (21.47), pod length (14.30 cm), pod diameter (1.09 cm), percent (%) dry matter of pod (7.73%), weight of single pod (6.63 g) and weight of pods plant^{-1} (83.31 g) were found from the treatment combination of S_3P_1 but the highest fresh pod yield plot^{-1} (1333.00 g) and fresh pod yield (18.51 t ha^{-1}) were found from the treatment combination of S_2P_1.Similarly, the lowest plant height (19.40, 20.33 and 33.33 cm at 15, 30 and 45 DAS, respectively) was found from the control treatment combination of S_3P_0 where the number of leaves plant^{-1} (6.20, 9.67 and 18.00 at 15, 30 and 45 DAS, respectively), leaf area index at 35 DAS(40.66), number of branches plant^{-1} (0.30, 1.90 and 2.40 at 15, 30 and 45 DAS, respectively), number of flowers plant^{-1} (19.10), number of pods plant^{-1} (15.00), pod length (13.43 cm), pod diameter (1.02 cm), percent (%) dry matter of pod (5.80%), weight of single pod (5.91 g) and weight of pods plant^{-1} (38.71 g) was found from the control treatment combination of S_1P_0 but the lowest fresh pod yield plot^{-1} (826.00 g) and lowest fresh pod yield (11.47 t ha^{-1}) was found from the control treatment combination of S_3P_0.

Considering economic analysis, the highest Benefit cost ratio (BCR); 3.37 was obtained from the treatment combination of S_2P_1 (30 cm × 15 cm spacing with 40 kg P ha^{-1}) with highest gross return (Tk 277650) and highest net return (Tk 195205). The lowest BCR (2.16) was obtained from S_3P_0 (30 cm × 20 cm spacing with 0 kg P ha^{-1})

treatment combination with lowest gross return (Tk 172050) and lowest net return (Tk 92416) obtained from the treatment combination of S_3P_0 (30 cm × 20 cm spacing with 0 kg P ha^{-1}).

Conclusion

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

1. The higher pod yield was produced from S_2 (30 cm × 15 cm).
2. The P treatment, P_1 (40 kg P ha^{-1}) performed better than P_2 (60 kg P ha^{-1}) and P_3 (80 kg P ha^{-1}) in respect of growth, yield and yield contributing parameters.
3. From the literature review, it was evident that P deficiency showed dwarf plant, lower number of leaf, branches and pod and decreased yield of french bean. Under the present study, control treatment (without P application i.e. P deficiency) also showed lower levels of growth and yield of french bean.
4. Treatment combination of S_2P_1 (30 cm × 15 cm spacing with 40 kg P ha^{-1}) showed best performance regarding yield and yield contributing parameters and Benefit Cost Ratio (BCR).
5. The treatment combination of S_2P_2 (30 cm × 15 cm spacing with 60 kg P ha^{-1}) was statistically identical with S_2P_1 (30 cm × 15 cm spacing with 40 kg P ha^{-1}) in respect of pod yield but S_2P_1 was considered as best because BCR from S_2P_1 was higher than S_2P_2.
6. From the findings of the experiment, it may be suggested that S_2P_1 (30 cm × 15 cm spacing with 40 kg P ha^{-1}) treatment combination is suitable for higher pod yield of french bean.

REFERENCES

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

Ahlawat, I. P. S. and Sharma, R. P. 1989. Response of French bean genotype to soil moisture regimes and phosphate fertilization. *Indian J. Agron*., **34** (1): 70-74.

AICPIP. 1987. Consolidated report on Rabi pulse. Directorate of Pulses Research, Kanpur, India. pp. 62-67.

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

Alam, M. S., Iqbal, M. T., Amin, M. S. and Gaffer, M. A. 1989. Krishitattik Foshaler Utpadon O Unnayan. (In Bengali). T. M. Jubair Bin Iqbal, ManikPotal. Meghai, Sirajgonj. pp. 231-239.

Alt, D., Ladebusch, H., Melzer, O., Bums, I. G., Bending G. D. and Mulholland, B. 1999. Long term trial with increasing amounts of phosphorus, potassium and magnesium applied to vegetable crops. *Acta Hort.*, **506**: 29-36.

Anomymnous. 1995. Annual Report for 1993-1994. BARI. Joydebpur, Gazipur, Bangladesh. p. 25.

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

Arya, P. S., Sagar, V. and Singh, S. R. 1999. Effect of N, P and K on seed yield of French bean *(Phaseolus vulgaris* L.) var, Contender. *Hort Science,* **6**: 137-139.

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.

Bargaz, A., Faghire, M., Abdi, N., Farissi, M., Sifi, B., Drevon, J. J., Ikbal, M. C. and Ghoulam, C. 2012. Low soil phosphorus availability increases acid phosphatases activities and affects P partitioning in nodules, seeds and rhizosphere of *Phaseolus vulgaris*: *Agriculture*, **2**: 139-153.

Bargaz, A., Nassar, R. M. A., Rady, M. M., Gaballah, M. S., Thompson, S. M., Brestic, M. and Abdelhamid, M. T. 2016. Improved salinity tolerance by phosphorus fertilizer in two *Phaseolus vulgaris* recombinant inbred lines contrasting in their P-efficiency. *J. Agron. Crop Sci*., **202**(6): 497-507.

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.

Chakravorty, S., Ghosh, C., and Mandal, J., 2009. Effect of spacing on growth and yield of French Bean (*Phaseolus vulgaris* L.) in red and lateritic belt of West Bengal. *Environ. Eco*., **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.

Chavan, M. G., Remteke, J. R., Patil, B. P., Chavan, S. A. and. Shaikh, M. S. I. 2000. Studies on uptake of NPK and quality of French bean cultivars. *J. Maharastra Agril. Univ*., **25**(1): 95-96.

Devender, K. P., Sharma, T. R., Saini, J. P. and Sharma, V. 1998. Response of French bean to nitrogen and phosphorus in cold desert area of Himachal Pradesh. *Indian J. Agron*., **44**(4): 787-790.

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

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

Duke, J. A. 1983. Hand book of legumes of world economic importance (Second Ed.), *Plenum Press*, New York. p. 341.

Edris, K. M., Islam, A. T. M. T., Chowdhury, M. S. and Haque, A. K. M. M. 1979. Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People's Republic of Bangladesh. p. 118.

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

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

Emam, M. S. A., Noha, G., Abd El-Rahman and Abdrabbo, M. A. A. 2018. Evaluation of natural and chemical phosphorus fertilizers on Plant growth and yield of some green beans cultivars. *Annals Agric. Sci*., *Moshtohor*. **56**(2) (2018): 349 – 358.

FAO. 1988. Production Year Book. Food and Agricultural Organizations of the United Nations, Rome, Italy. **42**: 190-193.

FAO. 2013. Production Year Book. Food and Agricultural Organization of the United Nations, Rome, Italy. **54**: 108.

Farkade, B. K. and W. S. Pawar. 2002. Crowd, performance and yield of French bean varieties as influenced by different fertilizer level. *J. Soils Crops*, **12**(1): 142-144.

Freire, J. R. 1984. Important limiting factors in soil for the rhizobium-legume symbiosis. In: Alexander M (ed), BNF: Ecology, *Tech.Physiol.*, *Plenum Press*, New York. pp. 51-74.

Gajendra, S. and Singh, T. P. 1998. Effect of moisture regimes and fertility levels on growth, yield and water of French bean. *Indian J. Agron*., **44**(2): 389-391.

George, H. S., Singh, J. P., Tiwari, R. N., Sharma, R. K. and Swarup, V. 1985. Pusa-Parvati a profitable variety of French bean. *Indian Hort*., **16**(4): 19-20.

Getachew, E., Ali. M., Tesfaye, A. and Nebiyu, A. 2014. Growth and yield response of green beans **(***Phaseolus vulgaris* L.) in relation to time of sowing and plant spacing in the humid tropics of Jimma, southwest Ethiopia. *Int. J. Soil. Crop. Sci.*, **2**(5): 61-67.

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedure for agricultural research (2nd edn.). *Int. Rice Res. Inst. A Willey Int. Sci*., p. 64.

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

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

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

Kakon, S. S., Bhuiya, M. S. U., Hossain, S. M. A., Naher, Q. and Bhuiyan, M. D. H. 2016. Effect of nitrogen and phosphorus on growth and seed yield of French bean. *Bangladesh J. Agril. Res.*, **41**(4): 759-772.

Kanaujia, S. P., Narayan, R., Narayan, S., Narayan, R. and Narayan, S. 1999. Effect of phosphorus and potassium on growth, yield and quality of French bean *(Phaseolus vulgaris* L.) cv. Contender. *Veg. Sci.*, **26** (1): 91-92.

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. *Curr. Res.*, **24**: 209 – 211.

Lad, N. G., Patange M. J. and Dhage, S. J. 2014. Effect of nitrogen and phosphorous levels on growth, yield attributing characters, yield and economics of French bean (*Phaseolus vulgaris* L.). *Int. J. Curr. Microbiol. App. Sci.*, **3**(12): 822-827.

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

Masa, M., Tana, T. and Ahmed, A. 2017. Effect of plant spacing on yield and yield related traits of common Bean (*Phaseolus vulgaris* L.) varieties at Areka, Southern Ethiopia *J. Plant Biol. Soil Health*., **4**(2): 13.

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

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

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

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**: 96-100.

Parmar, D. K., Sharma, T. R., Saini, J. P. and Sharma, V. 1999. Response of French bean to nitrogen and phosphorus in cold desert area of Himachal Pradesh. *Indian J. Agron*., **44**(4): 487-790.

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

Rafat, M. and Sharif, P. 2015. The effect of phosphorus on yield and yield components of green bean. *J. Soil Nature*., **8**(1): 9-13.

Rahman, M. S., Kabir, M. A., Halder, B. C., Haque, M. E. and Rahman, M. A. 2018. Response of french bean (*Phaseolus vulgaris* L.) varieties to phosphorus levels in the active Tista Flood Plain. *Int. J. Agron. Agri. Res*., **12**(1): 20-25.

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

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.). *Prog. Agric*., **26**: 129-135.

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

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. Agri. Biol. Sci.,* **3**(4): 666-668.

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

Saxena, K. K., Aruh, S. and Singh, R. B. 2003. Response of French bean to nutrients application (NPK) in relation to physiological traits and their consequent effect on yield. *Farm Sci. J*., **12**(2): 150-152.

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

Shubhashree, K .S., Alagundagi, S. C., Hiremath, S. M., Chittapur, B. M., Hebsur, N. S. and Patil, B. C. 2011. Effect of nitrogen, phosphorus and potassium levels on growth, yield and economics of rajmash (*Phaseolus vulgaris*). *Karnataka J. Agric. Sci*., **24**(3) : (283 - 285).

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

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

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

Singh, N. B. and Verma, K. K. 2002. Nitrogen and phosphorus nutrition of French bean grown in eastern Uttar Pradsh under late sown condition. *Indian J. Agron*., **47**(1): 89-93.

Sushant, R. S., Dixit, S. P. and Singh. G. K. 1998. Effect of irrigation, nitrogen and phosphorus on seed yield and water use of Rajmash *(Phaseolus vulgaris). Indian J. Agron*., **44** (2): 382-388.

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

Tewari, J. K. and Singh, S. S. 2000. Effect of nitrogen and phosphorus on growth and seed yield of French bean *(Phaseolus vulgaris* L.). *Veg. Sci*., **27**(2): 172-175.

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

Tomar, S. S. 2001. Response of French bean to irrigation schedule and phosphorus level in vertisols. *Indian J. Agron*., **46** (3): 496-499.

Turk, M. A. and Tawaha, A. M. 2002. Impact of seeding rate, seeding date, rate and method of phosphorus application in faba bean (*Vicia faba* L. minor) in the absence of moisture stress. *Biotech Agron. Soc. Environ*., **6**: 171–178.

Turuko, M. and Mohammed, A. 2014. Effect of different phosphorus fertilizer rates on growth, dry matter yield and yield components of common bean (*Phaseolus vulgaris* L.). *World J. Agric. Res*., **2**(3): 88-92.

Vadez, V., Rodier, F., Payre, H., Drevon, J. J. 1996. Nodule conductance to O_2 and nitrogenase-linked respiration in bean genotypes varying in the tolerance of N_2 fixation to P deficiency. *Plant Physiol. Biochem*., **34**: 871-878.

Varennes, K. J., Yildrim, E. and Guvenc, I. 2002. Effect of nitrogen and potassium on the growth and yield of kidney bean. *European J. Agron*., **22**(1) : 11-18.

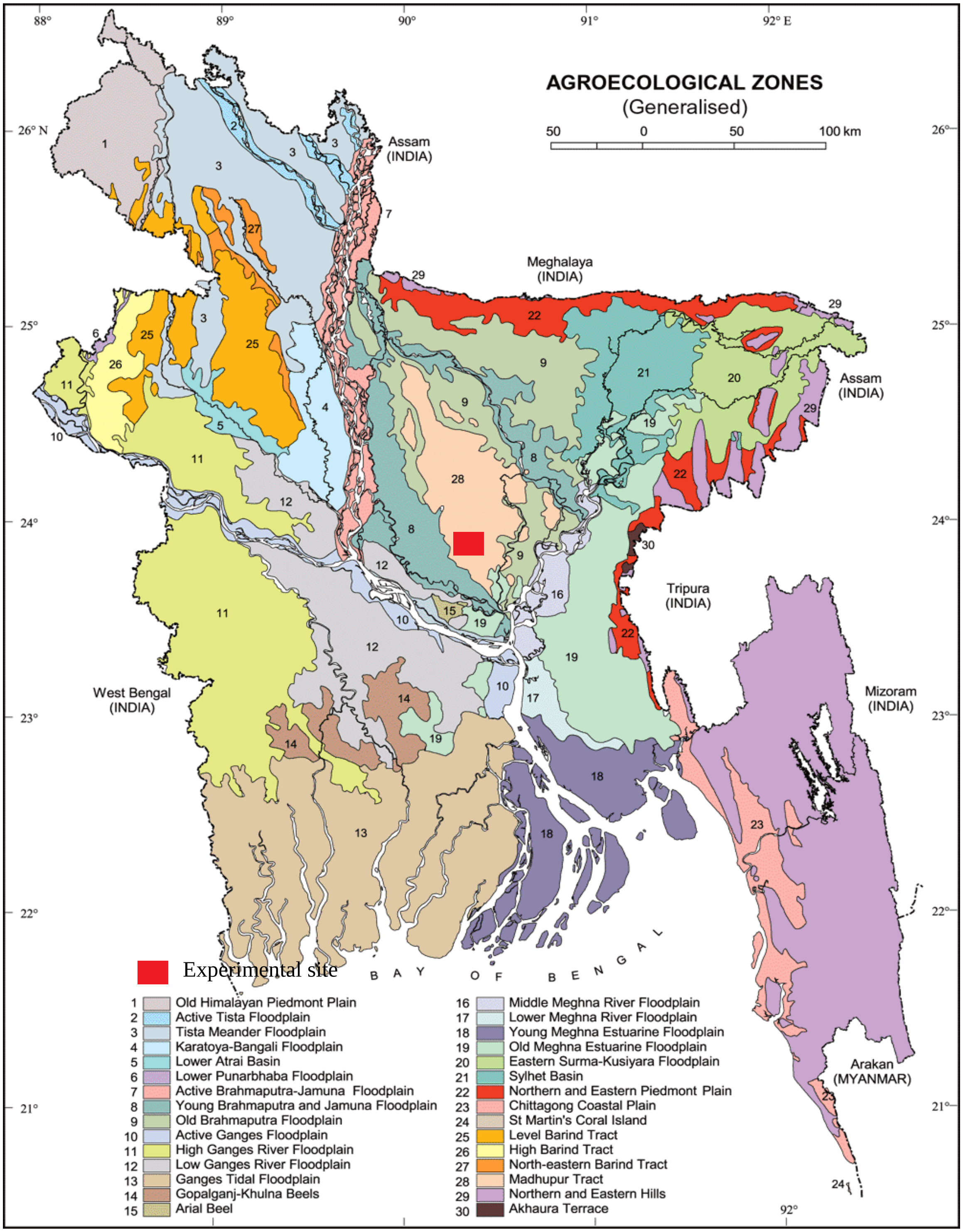
Verma, A. and Singh, N. 2000. Effects of phosphorus and potassium on the growth and yield of French bean. *Indian J. Agril. Sci*., **66** (6): 338- 342.

Verma, V. S. and Saxena, K. K. 1995. Response of French bean *(Phaseolus vulgaris* L.) to graded dose not nitrogen, phosphorus and potassium in silty loam soil of Central Uttar Pradesh. *Indian J. Agron*., **40** (1): 67- 71.

UNDP. 1988. Land Resource Apprisal of Bangladesh for Agricultural Development Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome, Italy. p. 577.

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2017 to February 2018

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2017	November	28.60	8.52	18.56	56.75	14.40
2017	December	25.50	6.70	16.10	54.80	0.0
2018	January	23.80	11.70	17.75	46.20	0.0
2018	February	22.75	14.26	18.51	37.90	0.0

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

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Analysis of variance of data on plant height of french bean

Source	Degrees of freedom	Mean square of plant height (cm)		
		15 DAS	30 DAS	45 DAS
Replication	2	6.191	14.084	44.559
Spacing (A)	2	16.481*	45.671*	53.290*
Phosphorus (B)	3	6.787*	10.907*	17.525*
A×B	6	3.779**	7.889*	8.846 *
Error	22	6.122	9.614	12.444

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Analysis of variance of data on number of leaves plant^{-1} of french bean

Source	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		15 DAS	30 DAS	45 DAS
Replication	2	1.774	7.708	30.621
Spacing (A)	2	3.204*	9.648*	6.534*
Phosphorus (B)	3	0.259*	0.638*	0.867*
A×B	6	1.716*	1.711**	10.179*
Error	22	1.149	1.024	8.145

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Analysis of variance of data on number of branches plant^{-1} of french bean

Source	Degrees of freedom	Mean square of number of branches plant^{-1}		
		15 DAS	30 DAS	45 DAS
Replication	2	1.081	4.963	6.203
Spacing (A)	2	0.111**	0.543**	0.280*
Phosphorus (B)	3	0.247*	0.124*	0.154*
A×B	6	0.046*	0.077*	0.216**
Error	22	0.182	0.316	0.200

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Analysis of variance of data on leaf area, no. of flowers plant^{-1}, no. of pods plant^{-1} of french bean

Source	Degrees of freedom	Mean square of yield contributing parameters		
		Leaf area(cm^2)	No. of flowers plant^{-1}	No. of pods plant^{-1}
Replication	2	9.034	7.517	70.484
Spacing (A)	2	0.283*	20.519*	20.321*
Phosphorus (B)	3	29.358*	29.823*	23.480*
A×B	6	37.220*	5.315**	4.662*
Error	22	81.334	12.068	12.689

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Analysis of variance of data of pod length, pod diameter, % dry matter of pod of french bean

Source	Degrees of freedom	Mean square of yield contributing parameters		
		Pod length (cm)	Pod diameter (cm)	% dry matter of pod
Replication	2	4.518	0.000^{NS}	2.014
Spacing (A)	2	0.908*	0.003^{NS}	2.384*
Phosphorus (B)	3	0.229**	0.001^{NS}	0.317**
A×B	6	0.070**	0.000^{NS}	0.951*
Error	22	0.276	0.001	1.420

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Analysis of variance of data on weight of single pod, weight of pods plant^{-1}, fresh pod yield plot^{-1}, fresh pod yield of french bean

Source	Degrees of freedom	Mean square of yield parameters			
		Weight of single pod (g)	Weight of pods plant^{-1} (g)	Fresh pod yield plot^{-1} (g)	Fresh pod yield (t ha^{-1})
Replication	2	3.144	81.926	7.194	44.559
Spacing (A)	2	0.267^{NS}	2272.919*	6315.444*	53.290*
Phosphorus (B)	3	0.144*	252.265*	957.139*	17.525*
A×B	6	0.063**	144.169*	47.000*	8.846*
Error	22	0.204	268.525	31.801	12.444

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X: Cost of production of French bean (BARI Jhar sheem-1) per hectare

A. Input cost (Tk. ha^{-1})

Treatments	Cultivation with Labor	Seed cost	Pesticides	Irrigation	Cowdung	Fertilizer			Seed sowing cost	Subtotal (A)
						Urea	TSP	MP		
S_1P_0	14000	2800	3000	2500	5000	480	0	450	8000	36230
S_1P_1	14000	2800	3000	2500	5000	480	2174	450	8000	38404
S_1P_2	14000	2800	3000	2500	5000	480	3261	450	8000	39491
S_1P_3	14000	2800	3000	2500	5000	480	4348	450	8000	40578
S_2P_0	14000	1800	3000	2500	5000	480	0	450	8000	35230
S_2P_1	14000	1800	3000	2500	5000	480	2174	450	8000	37404
S_2P_2	14000	1800	3000	2500	5000	480	3261	450	8000	38491
S_2P_3	14000	1800	3000	2500	5000	480	4348	450	8000	39578
S_3P_0	14000	1400	3000	2500	5000	480	0	450	8000	34830
S_3P_1	14000	1400	3000	2500	5000	480	2174	450	8000	37004
S_3P_2	14000	1400	3000	2500	5000	480	3261	450	8000	38091
S_3P_3	14000	1400	3000	2500	5000	480	4348	450	8000	39178

Here,
S_1 = 30 cm × 10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm

P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

B. Overhead cost (Tk. ha^{-1}), total cost of production (Tk. ha^{-1}), gross return (Tk. ha^{-1}), net return (Tk. ha^{-1}) and BCR

Treatments	Overhead cost (Tk. ha^{-1})				Subtotal (A)	Total cost of production (A+B)	Yield ha^{-1} (ton)	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
	Cost of leased land for 6 months (8% of value of land Tk. 10,00,000/-	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 month (8% of cost $year^{-1}$)	Subtotal (B)						
S_1P_0	40000	1811.5	3122	44933.16	36230	81163	12.32	184800	103637	2.28
S_1P_1	40000	1920.2	3213	45133.17	38404	83537	17.56	263400	179863	3.15
S_1P_2	40000	1974.55	3259	45233.17	39491	84724	17.13	256950	172226	3.03
S_1P_3	40000	2028.9	3304	45333.18	40578	85911	16.30	244500	158589	2.85
S_2P_0	40000	1761.5	3080	44841.16	35230	80071	12.88	193200	113129	2.41
S_2P_1	40000	1870.2	3171	45041.17	37404	82445	18.51	277650	195205	3.37
S_2P_2	40000	1924.55	3217	45141.17	38491	83632	18.34	275100	191468	3.29
S_2P_3	40000	1978.9	3262	45241.18	39578	84819	15.09	226350	141531	2.67
S_3P_0	40000	1741.5	3063	44804.36	34830	79634	11.47	172050	92416	2.16
S_3P_1	40000	1850.2	3154	45004.37	37004	82008	13.17	197550	115542	2.41
S_3P_2	40000	1904.55	3200	45104.37	38091	83195	13.11	196650	113455	2.36
S_3P_3	40000	1958.9	3245	45204.38	39178	84382	13.10	196500	112118	2.33

*Here, Cost of green French bean (selling) = Tk. 15.00

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

P_0 = 0 kg P ha^{-1} (Control), P_1 = 40 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}, P_3 = 80 kg P ha^{-1}

Plate 1: Prepared field for sowing seeds

Plate 2: Flowers of French bean

Plate 3: Pods of French bean

Plate 4: Staking of Plants

Plate 5: Harvesting of pods

Plate 6: Data collection of pods

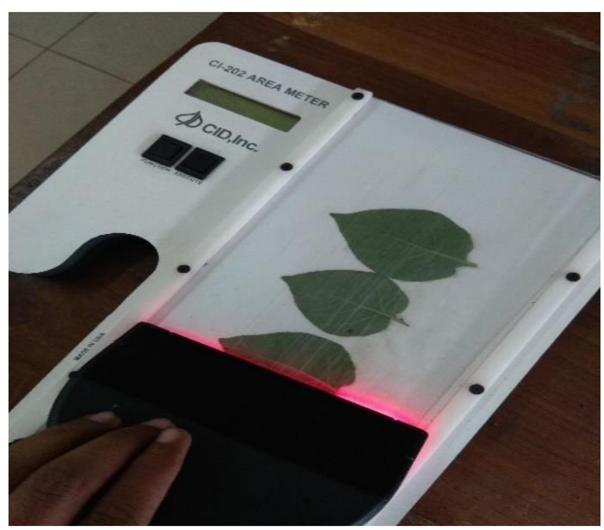


Plate 7: Data collection of leaf area