GROWTH, SEED YIELD AND QUALITY OF BUSH BEAN (*Phaseolus vulgaris* L.) AS INFLUENCED BY VARIETY AND PHOSPHOROUS

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CERTIFICATE

This is to certify that the thesis entitled, ***"Application of Nitrogen and Phosphorus fertilizer for higher growth, seed yield and economic benefit of bush bean" (Phaseolus vulgaris L.)*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN SEED TECHNOLOGY*** *embodies the result of a piece of bona fide research work carried out by* ***MD.MONABBER HOSSASIN; Registration No. 11-04583,*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2018
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Dedicated to
My Beloved Par

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The Author

Growth, Seed yield and Quality of Bush bean (*Phaseolus vulgaris* L.) As Influenced by Variety and Phosphorous

ABSTRACT

The experiment was carried out at Horticultural Farm, Sher-e-Bangla Agricultural University, during the period from November 2016 to April 2017 to study the application of Phosphorus fertilizer interaction with Variety for higher growth, seed yield and seed quality of bush bean. The experiment consists of two factors. Factor A:Three BARI Bush Bean variety, BARI Bush Bean-1, BARI Bush Bean-2 and BARI Bush Bean-3. Factor B: four levels of phosphorus, P_0: 0 kg P_2O_5/ha, P_1: 80 kg P_2O_5/ha, P_2: 100 kg P_2O_5/ha and P_3:120 kg P_2O_5/ha were used for the present study. The experiment was laid out in RCBD with three replications. Results showed that highest seed yield of bush bean (3.46 t) was found from BARI Bush Bean-2 variety and lowest seed yield (2.12 t) was found from BARI Bush Bean-3 variety. For different levels of Phosphorus, highest seed yield of bush bean (3.44 t) was found from P_2 (100 kg P/ha) treatment and lowest seed yield (2.22 t) was found from P_0 (control) treatment. In case of combined effect, the highest seed yield of bush bean (3.99 t) was produced from V_2P_2 (BARI Bush Bean-2 and 100 kg P/ha) treatment combination and lowest seed yield (1.50 t) was found from V_3P_0 (control) treatment combination. The treatment combination of BARI Bush Bean-2 with 100 kg P_2O_5/ha appeared to be the best for cultivation of bush bean under Sher-e-Bangla Agricultural University Farm condition.

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LISTS OF ABBREVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
cm	=	Centimeter
^{0}C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
g	=	gram (s)
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^H	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	Percent

CHAPTER I

INTRODUCTION

Bush bean (*Phaseolus vulgaris*L.) or French bean is a herbaceous annual plant. Basically, it is a short durated high yielding legume crop and it can be utilized both as vegetable and pulse. It is widely cultivated in the temperate, tropical, subtropical regions of the world (George, 1985). While considering beans as a low status food ("meat of the poor") they provide the second most important source of protein after maize and the third most important source of calories after maize and cassava (Pachico, 1993). Being a vegetable crop, it is belonging to the family Leguminosae and subfamily Papiolionaceae (Swiader *et al.*,1992*)*. Various varieties of beans are popular for their seeds, green vegetables etc. It is also known as farashi seem, kidney bean, pinto bean, snap bean, green bean, navy bean, pole bean, raj bean, wax bean, string bean and bonchi (Duke, 1983*;* Salukhe *et al* 1987: Tindall, 1988). In our country, it is known as Farashi Seem (Rashid, 1993). Newly introduced as a winter vegetable crop in Bangladesh, it is cultivated in Shylet, Cox's Bazar, Chittagong Hill Tracts and some other parts of the country. According to the recent FAO statistics, bush bean including other related species of the genus *Phaseolus vulgaris* L. occupied 27.08 million hectares of the world's cropped area, (FAO, 2000) and China produces the largest quantity of green beans.

Bush bean are nutritionally rich in case of both pods and seeds. Dry bean seed contains 336 calories for energy with 12 % moisture, 21.7 g of protein, 1.5 g of lipid, 60 g CHO, 120 mg of Ca, 8.2 mg of Fe, 0.37 mg of Thiamin and 2.4 mg of Niacin. (Schoonhoren and Rovset,1993). Because of its exporting demand and increasing consumer preference, the growing of bush bean is gaining popularity in Bangladesh.

One of the most important factors that influence on the productivity and profitability of bush bean is variety. For pod production, a few well adopted

local varieties such as (Sylhet local, Chittagong local) etc used to cultivate local farmers normally in limited areas of Bangladesh. Some works have been followed in Bangladesh Agricultural Research Institute (BARI) on the development of this crop. Only three varieties viz. BARI bush bean-1 (BARI Bush Bean-1), BARI bush bean-2 (BARI Bush Bean -2) and BARI bush bean-3 (BARI Bush Bean-3) have so far been released from BARI (BARI, 2017). Although few works have been conducted regarding performance and characterization of bush bean varieties, more attention should be paid on these aspects to improve yield mainly seed yield. All the varieties do not produce same quantity and quality of pod. So, it is a foremost task to identify specific variety which is more productive than others.

One of the most significant determinants of plant growth is phosphorus (Wang *et al.,* 1998). For the general health and vigor of all plants, it is an essential plant nutrient. Growth and development of crops depend mostly on the development of root system. Phosphorus highten the root development, which ameliorates the supply of other nutrients and water to the thriving parts of the plants, resulting in an increased photosynthetic area and thereby more dry matter aggregation. Robinson *et al.* (1981) reported the effect of phosphorus in stimulating root and plant growth. Phosphorus makes its contribution through quality seed formation (Buckmand and Brady, 1980). Phosphorus improves fertilization, quality of fruits, vegetable and grain crops and increases their resistance to diseases, drought and adverse environmental conditions. It is a major component of compounds whose functions relate to growth, root development, flowering, and ripening (Raboy, 2003).

Huge amount of research is essential for quantitative improvements of seed yield of bush bean with appropriate level of P_2O_5 . Optimum combination of variety with P_2O_5 may bring about considerable increase in the yield of bush bean seed due to their complementary effects. A systemic and detailed study is necessary to find out the requirements of phosphorous for maximizing the seed yield of bush bean varieties in Bangladesh.

Considering all these facts, the study was focused to achieve the following objectives;

1. To assess the varietal performance for maximum growth and seed yield of bush bean,
2. To study the optimum level of P_2O_5 for ensuring higher growth and seed yield and seed quality of bush bean,and
3. To find out the suitable combinations of variety and P_2O_5 for ensuring higher seed yield and seed quality of bush bean.

CHAPTER II

REVIEW OF LITERATURE

Bush bean (*Phaseolus vulgaris* L.) is a popular and important vegetable crop of the world. There is very few researches in formation about growth, seed yield and quality of bush bean as influenced by variety and phosphorous available at present in Bangladesh. So, there is a brief review of the available literatures has been furnished in this chapter.

2.1 Effect of variety on productivity of Bush Bean

Kakon *et al.* (2015) dealed with an experiment into agronomy research field of Bangladesh Agricultural Research Institute (BARI), Joydebpur under Gazipurdistricts of Bangladesh during the period from November 2009-10 and 2010-11.The experiment site was located Chhiata Series under Agro-Ecological Zone-28 (AEZ-28) and found that effect of flowering pattern and floral abscission on theyield and yield attributed characters of French bean varieties. There ninevarieties were treated- (1) BARI Jharsheem-l (2) BARI Jharsheem-2 (3) Sylhet local 1 (4) Sylhet local 2 (5) Sylhet local 3 (6) Sylhet local 4 (7) Syihet local 5(8) Sylhet local 6 and (9) Sylhet local 7. The duration of flowering was dependent on growing periods and varieties. All local varieties started flowering at 37-40 DAS and high yielding variety BARI Jharsheem-1 and BARI Jharsheem-2 were taken 5-6 days more than local variety. In both the years, the longest among the treatment the highest number of flower was recorded within 5 to 8 days in BARI Jharsheem-2. Although, the maximum flower opened within *5* to 8 days and following ceased within 15 to 20 days after first flowering. The total number of flowers per plant varied between 19.36 to 45.06 and 22.0 to 47.20 in two consecutive years while percentage of pod abscission varied between 70.53 to 82.26 and 73.46 to 80.75 in two consecutive years. The flowering pattern and percent abscission as well greater number of pod were found to be the influential character for the highest yield of French bean.

Noor *et al.* (2014) directed an experiment that eleven genotypes variety of bush bean including BARI bush bean-1 and BARI bush bean-2 which were screened to select a suitable one which could provide optimum yield of fresh pod. The maximum fresh pod yield (14.25 t/ha) was found for BARI bush bean-1 followed by BARI bush bean-2 (13.23 t/ha). BARI bush bean-1 required the minimum time of 88.33 days while BB-3 the maximum of110.00 days to attain 90% pods maturity. The highest number of diseased plants was observed in BB-5 (30.33%) and the lowest were in BARI bush bean-1 (7.33%) whereas BARI bush bean-2 was highest disease incident 16.67%. No significant difference ($P< 0.05$) in maximum protein content among the studied genotypes was observed, for example BB 15 (21.60%) and BARI bush bean-1 (21.57%). Maximum crude fiber (5.53%) was obtained from BARI bush bean-1 followed by BB 6 (5.50%), BB 20 (5.50%) and BB5 (5.47%) which all were statistically similar. Among all the genotypes, BARI bush bean-1 showed highest pod yield and superior quality of French bean that was recorded in BARI bush bean-1 (64.13 g and 14.25 t/ha) followed by BARI bush bean-2 (59.53 g and 13.23 t/ha) ($P< 0.05$) which are more suitable for human consumption. BARI bush bean-1 took minimum time for 90% flowering (34.67days), 90% pod setting (37.33 days), and 90% maturity of pods (88.33 days).Moreover, the maximum crude protein (21.57%) and crude fiber (5.53%) were obtained from BARI bush bean-1. Therefore, BARI bush bean-1 was selected as best for its quality and yields (fresh pod) among eleven genotypes of French bean.

Moniruzzaman *et al*. (2007) conveyed an experiment on French bean having three varieties (BARI Jhar sheem-1, BARI Jhar sheem-2 and Local) and six sowing dates at 10 days interval from November 01 to December 20) was conducted at the Agricultural Research Station, Raikhali, Rangamati Hill District during the Rabi seasons of 2004-05 and 2005-06 to find out the suitable variety and optimum sowing date for getting higher pod yield. Varieties showed significant variation in plant height, number of branches per plant and dry weight per plant. Variety BARI Jhar sheem-2 produced

significantly smallest plant in both the years, whereas the plant height was highest in local variety though at par with BARI Jhar sheem-1 during 2005-06. However, branches/plant and dry weight/plant was significantly lowest in local variety compared to BARI Jhar sheem-2 and BARI Jhar sheem-1 during both the years. Bari Jhar sheem-1 significantly produced maximum number of branches/plant closely followed by BARI Jhar seem-2 and highest dry weight/plant in both the years.

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

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

flowering. The number of pods per plant was the highest in BB 15 (22.64) followed by BB 3 (17.87) whereas BARI bush bean (7.97).

Significant differences were confirmed by Dahiya *et al.* (2000) for 16 traits in 48 genotypes of French bean. Days to first flowering, days to 50% flowering, days to pod initiation, plant height, primary branches per plant and secondary branches per plant were characterized by high genetic advance combined of these characters and indicating the possibility of improving these traits through simple selection. The investigation revealed that among the genotypes, HUR-146 genotype was the highest yielder.

Varieties had significant effect on the yield attributes (pod length, pod width, pods/plant and weight of 10 pods) and yield of French bean. The variety BARI Jhar sheem-2 significantly produced longer pods having lowest diameter during both the years. November 10 sowing was statistically at par with November 20 sowing gave the highest pod yield of French bean. Two variety are produced maximum pod yield 16.57 t/ha and 16.5 t/ha respectively.

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

A field experiment was conveyed by Joshi *et al.* (1987), reported that the varieties required 45-46 days to attain 50% flowering, which was in

consonance with the majority of varieties under investigation. Days to 90% pod setting was significantly varied (P< 0.05) in different genotypes. The genotypes BB 3 (58.67) and BB 15 (57.33) required maximum days; whereas BARI bush bean-1 (37.33) required minimum days for 90% pod setting. Minimum days for 90% maturation of pods (88.33 days) were recorded in BARI bush bean-1 and maximum in BB 3 (110 days) (P< 0.05).

Salam *et al*. (1997) guided from their study with 13 cultivars of French bean that all the parameters like plant height, days to 50% flowering, seeds/pod, 100-seed weight, yield/plant (g) showed wide variability except pod length. Phenotypic and genotypic variances were maximum (26.55 and 15.42) in 100-seed weight and minimum (0.47 and 0.41) in pod length. They also observed that the Phenotypic Coefficients of Variation (PCV) had higher estimate than corresponding Genotypic Coefficients of Variation (GCV). Yield/plant and days to 50% flowering showed the highest and lowest PCV, respectively. The little difference between PCV and GCV were obtained for days to 50% flowering and pod length.

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

Singh *et al.* (1993) dealed with an experiment on nine yield related characters in seven French bean genotypes grown during "Rabi" 1989-90 and 1990-91 at Keonjhar, India. The best performing genotypes were "Se 12" and "Pusha Parvati" for number of pods/plant (22.7 and 18.8, respectively). Arka Komal (Se 19) was the earliest genotypes (42.7 days to 50% flowering) gave the highest pod yield (19080 kg/ha), and was recommended as the genotype most suitable for growing in the north-central plateau of Orissa

Twenty-one genotypes of French bean including the check cultivar "Contender", were evaluated in a randomized block design at Solan during 1994 for plant height, days to 50% flowering, days to first picking, number of pods per cluster, number of pods per plant, pod length, girth, shape and color, yield per plant, harvest index, number of seeds per pod and 100-seed weight, Korla *et al*. (1997) analyzed that all the characters showed significant differences.

Dimova and Svetleva (1993) guided that in French bean, estimates of heritability were high for pod number, pod length and seed weight/plant. Pod number/plant had the greatest effect on seed weight/plant, both directly and indirectly.

Shah *et al.* (1986) directed that genetic advance was high for plant height and yield per plant but low for the other six yields attributes in dwarf French bean. They found that the yield was positively correlated with number of primary branches, pod length and number of pods per plant.

Six green bean varieties were evaluated in a replicated small plot trial at the Gladstone Road Agricultural Centre during 2012. Results from this study indicated that there were significant differences among the six varieties with respect to the total number of pods per plant, weight of pods per plant and pod length (Richardson, 2012).

Muthal *et al.* (2012) conveyed an experiment involving twelve varieties were laid out at the Research Block of Vegetable Section in Sector No.1, University of Horticultural Sciences, Bagalkot (Karnataka, India) during Rabi season of 2012. Among the varieties studied, Arka Anoop was better with respect to growth parameters like plant height and number of primary branches along with number of nodules on roots and dry matter content in pods as well as yield attributing characters like number of pods per clusters, number of pods per plant and weight of ten pods which is determined by pod length and number of seeds per pod reflecting in higher pod yield per plant and per hectare (24.58 t/ha).

The studies of Anjanappa *et al*. (2000) on the evaluation of four French bean cultivars (Local, Burfi Stringless, Arka Komal and Selection-11) revealed that Arka Komal recorded significantly more number of primary branches plant^{-1} (5.24) whereas, Local recorded significantly less number of primary branches plant^{-1} (4 07).

Four green bean varieties (*Phaseolus vulgaris* L.) were evaluated in a replicated small plot trial at the Gladstone Road Agricultural Centre, Bahamas, during 2012. There were significant differences among the three surviving varieties with respect to the total number of pods per plant, weight of pods per plant and pod length (Richardson, 2012).

Among the three varieties of French bean (HUR-87, PDR-14 and VL-63) evaluated by Dhanjal *et al*. (2001) at Baraut (Uttar Pradesh, India), HUR-87 produced taller plants (26.45 cm) than PDR-14 (24.82 cm) and VL-63 (21.70 cm).

2.2 Effects of phosphorus on the growth and yield of French bean:

A field experiment was conducted by Shamima (2005) at the research field of Sher-e-Bangla Agricultural University, Dhaka in Modhupur Tract (AEZ 28), during rabi season from December 2004 to February 2005 to study the effect

of nitrogen and phosphorus on the growth and yield of bush bean (*Phaseolu svulgaris* L.) cv. BARI bush bean-I. The highest green pod yield (15.35 t ha_{-1}) and seed yield (2.58 ha^{-1}) were obtained from P_{75}.

Rima (2016) conducted an experiment at Horticultural Farm, Sher-e-Bangla Agricultural University, during the period from November 2015 to March 2016 to study the application of Nitrogen and Phosphorus fertilizer for higher growth, seed yield and economic benefit of BARI bush bean-I. The highest seed yield of bush bean (2.90 t) was found from P_2 (100 kg P/ha) treatment and lowest seed yield (2.50 t) was found from P_0 (control) treatment.

Singh and Singh (2000) was carried out a field experiment b in Uttar Pradesh, India. French bean (*Phaseolus vulgaris*) were given 0, 60 of 120 kg P/ha. They had found that yield and yield component were generally highest with 60 kg P.

P_20_5 at the rates of 0, 30 and 60 kg ha^{-1} and K_2O at the rates of 0, 20 and 40 kg ha^{-1} was applied by Sexena *et al* (1996) .They observed that seed yield was highest with 60 kg P_20_5.They also reported that seed yield was positively correlated with leaf area, dry matter plant', relative moisture content in leaves, number of branches, number of pods, seed yield plant'. 1000 seed weight and harvest index application of 60 kg P_20_5 gave the highest seed yield (0.95 t /ha).

Roy and Parthasarathy (1999) was conducted a field experiment to investigate the phosphorus requirement of French bean varieties. They used 0-120 kg P/ ha and observed that pod yield was highest (07.69 t/ ha) with 120 kg P/ ha.

On contrary, Tomar *et al* (1991) obtained the highest seed yield with the application of 30 kg P_20_5. ha^{-1} and rates beyond that did not give further significant increase in yield. However, applied P increased the nodule number $plant^{-1}$ from 26 to 51, seed and pod number $plant^{-1}$ and 1000 seed weight.

In New Delhi, Ahlawat (1996) conducted a field experiment, India to study the comparative performance of French bean varieties and their response to phosphorus fertilizer, lie reported that application of phosphorus greatly

improved the yield attributes (pods plant^{-1}and seeds pod-^{1}), seed yield and the N and P uptake. The response of applied p was linear up to 40 kg P ha^{-1}.

A field experiment was conducted by Arya and Kalra (1988) where they stated that application of phosphorus had no effect on vegetative growth of the plants, but phosphorus had pronounced effect of reproductive growth and number of pods plant^{-1}, weight of pods plant^{-1}, weight of grain plant^{-1}, number of grain plant^{-1} grain yield plant^{-1} and harvest index. They also reported that phosphorus induced early in flowering and maturity.

Prabhakar *et al*. (1987) carried out an experiment where he reported that green pod yield of French bean increased with phosphorus fertilization up to 75 kg ha^{-1}.

At the same time, addition of phosphorus and zinc up to certain level increased the yield of green grain (Patial and Somawanshi. 1982).

Phosphorus and sulfur interacted on growth of a variety of legume when they were grown in soils deficient in both nutrients (Robinson and Jones, 1972).

In case of Haryana, India Brar (1987) conducted an experiment and found increasing number and size of nodules with the application of phosphorus in moong bean.

Dash and Dash (1987) conducted a field experiment to observe the response ofbush bean to different levels of Phosphorus (0.50 and 100 kg P_20_5/ha) and different spacing in sandy loam soil in Vanarash, Uttar Pradesh, India during 1986-87. They found that most of the growth and yield characters of French bean had been influenced by phosphorus. They reported that 100 kg P_20_5/ha gave the highest yield 15 ton/ha.

Subhan (1989) carried out an field experiment in Indonesia to investigate the effect of plant distance and phosphate fertilizer on growth and yield of *Phaseolus vulgaris* L. He observed that yields were highest at 250 kg P_2O_5/ha.

An experiment was conveyed by Devender *et al.* (1998), 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.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Central Research Farm of Sher-e-Bangla Agricultural University, Dhaka from November 2015 to April 2016 to study the growth, seed yield and quality of bush bean as influenced by variety and phosphorous. This chapter includes materials and methods those were used in conducting the experiment and presented below under the following headings:

3.1 Experimental site

The study was conducted at central research farm in the Sher-e-Bangla Agricultural University farm, Dhaka, under Modhupur Tract, AEZ-28. The experimental site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level (Appendix -I).

3.2 Climate and weather

The geographical location was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Idris *et al*., 1979.) The meteorological data of air temperature, RH (relative humidity) and rainfall during the period of the experiment were collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix -II.

3.3 Soil

The soil belongs to "The Modhupur Tract", AEZ – 28 (FAO, 1988). The soil was silt loam in texture having P^H 6.12. It was deep red brown terrace soil and belongs to "Noadda" cultivated series. The altitude of the location was 8 m above the sea level as per the Bangladesh Metrological Department, Agargaon,

Dhaka-1207. The amount of organic carbon, total N, available P and K were 1.25%, 0.09%, 18.49 ppm and 0.09 mg/l00g soil, respectively. The physical and chemical characteristics of the soil have been presented in Appendix-I.

3.4 Planting materials

There are three bush bean varieties used named "BARI Bush Bean -1", BARI Bush Bean -2", BARI Bush Bean -3", The seeds were collected from Horticultural Research Center (HRC) of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

BARI Bush Bean-1:. It's a dwarf and bushy type plant, flower and seed is white in color and fresh pod yield is 12-13 tons/ha. It was approved in 1996.

BARI Bush Bean-2: Generally, its seeds are consumed as vegetable not the pod and the seed yield is 4.5-5 tons/ha. It was approved in 2010.

BARI Bush Bean-3: It has a good vegetative growth, seed is larger in size and seed yield is 4-5 tons/ha. It was approved in 2015.

3.5 Treatments of the experiment

The experiment was consisted of the following two factors:

Factor A: Varieties

V_1 = BARI Bush Bean-1

V_2 = BARI Bush Bean-2

V_3= BARI Bush Bean-3

Factor B: Four levels of Phosphorous

P_0= 0 Kg P_2O_5/ha

P_1= 80 Kg P_2O_5/ha

P_2= 100 Kg P_2O_5/ha

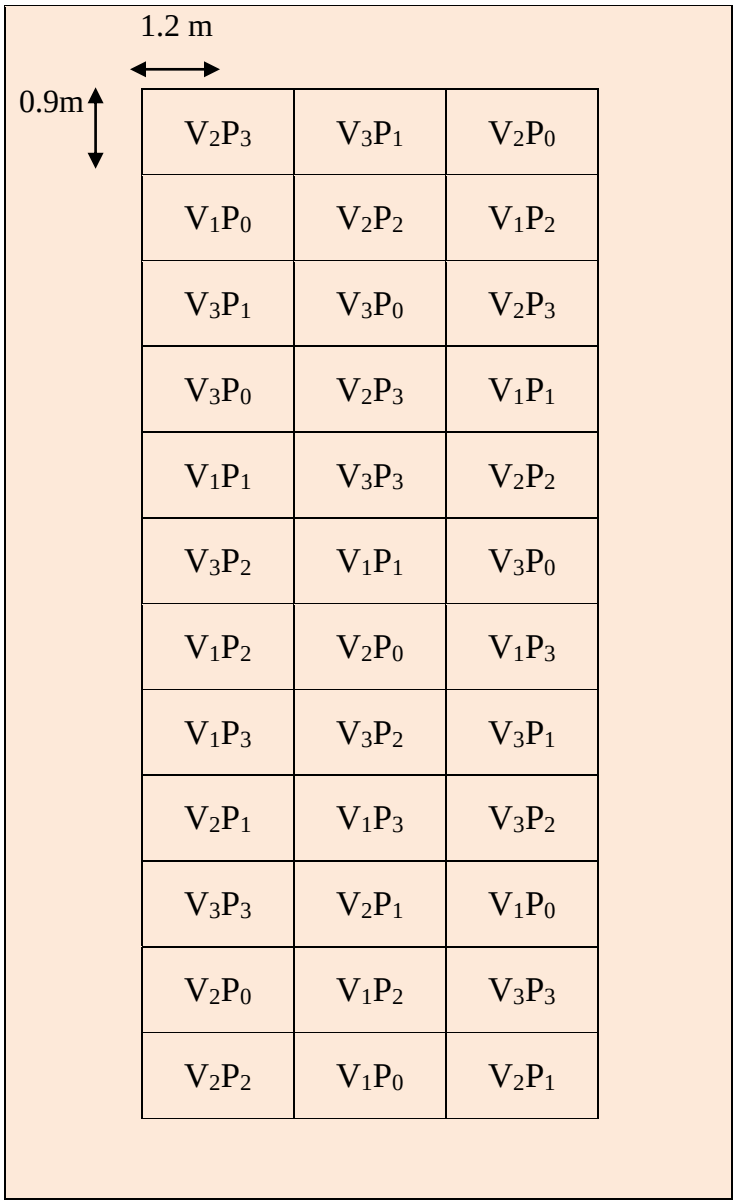
P_3= 120 Kg P_2O_5/ha

Treatments combinations

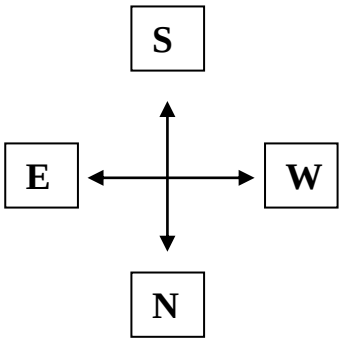
V_1P_0 , V_1P_1 ,V_1P_2 ,V_1P_3 ,V_2P_0 ,V_2P_1 ,$V2P_2$,$V2P_3$, V_3P_0 ,V_3P_1 ,V_3P_2 and V_3P_3

3.6 Design and layout of the experiment

The two factors experiment was done in the Randomized Complete Block Design (RCBD) with three replications. The experiment was divided into equal 3 blocks and each consists of 12 plots. Row to Row distance was 30 cm and plant to plant distance was 15 cm. Each unit plot was 1.2 m x 0.9 m in size. All together there were 36 unit plots in experiment. Distance between replication was 0.5 m and plot to plot was 0.5 m. The treatments were randomly assigned to each of the block.



Legend



Factor A: Nitrogen

V_1 = BARI Bush Bean-1

V_2 = BARI Bush Bean-2

V_3= BARI Bush Bean-3

Factor B: Phosphorus

P_0 = 0 kg/ha
P_1 = 80 kg/ha
P_2 = 100 kg/ha
P_3 = 120 kg/ha

Experiment layout:
Plot to plot distance = 0.5
length of land =1.2 (m)
breadth of land=0,9(m)
Replication = 3

Fig.1 Layout of the experimental field

3.7 Land preparation

At first the land was ploughed through a power-tiller on 05 November, 2015 and kept open to sunlight. Afterwards the experimental plot was prepared by five ploughings and cross ploughings. Laddering is done to break the clods and to level the soil. Weeds, stubbles and crop residues were removed from the field. Field layout was done on 08 November 2015. Finally, individual plots were prepared with spade on 10 November 2015. Drains were made around each plot and the excavated soil was used for raising the bed of plots to about 5 cm high from the soil surface.

3.8 Manures and fertilizer application

Half amount of P_2O_5 and MoP, full amount of gypsum and cow dung were applied as broadcasted as basal dose and incorporated during the final land preparation. The required amount of P_2O_5 fertilizer as per treatment (as TSP) was applied as basal in the specified plots. Nitrogen fertilizer (as urea) was applied in the specified plots in 3 splits. One third as the basal doze, another one third at 15 days interval and the rest dose at 15 days interval. The doses of fertilizers were used according to the recommendation rate of BARI which was as follows as follows:

Manure and Fertilizer	Total amount (kg/ha)
Cow dung	10 ton
Urea	150 kg
MP	160 kg
Gypsum	50 kg

The rate of TSP wasas per treatment mension in section 3.5 and applied on 3 installments. One-third was applied on 13.11.16, another one-third was applied on 29.11.16 and the rest one-third was applied on 15th November 2016.

3.9 Sowing of seeds

The seed sowing was done on 12 November, 2016 in rows maintaining spacing of 30 cm × 15 cm. Three seeds were sown in each hill and the seeds were covered with pulverized soil just after sowing and gently pressed with hands. Seeds are also sown in border to reduce border effect.

3.10 Intercultural operations

3.10.1 Gap filling

During seed sowing, 2-3 seeds were sown in the border of the plots. Seedlings were transferred to fill up the gap where seeds failed to germinate. Seedlings of about 15 cm in height were transplanted from border rows with roots plunged 5 cm below the soil in hills in the evening and watering was done on transplanted plants to protect the seedlings from wilting. Damage seedling as well as all the gaps was replaced by using healthy plants from the excess plants within two weeks.

3.10.2 Thinning of seedlings

When the plants well established, one healthy plant per hill was kept in each hill.

3.10.3 Weeding and mulching

The experimental plots were kept weed free by hand weeding. Weeding and mulching were done three times as and when necessary and the crust was broken. It also helped in soil moisture conservation**.**

3.10.4 Irrigation

Irrigation was applied whenever necessary. The young plants were irrigated by watering can. Beside this, irrigation was given six times at an interval of 10 days depending on soil moisture content.

3.10.5 Urea top dressing and earthing up

Earthing up was done four times at 10, 30, 40 and 50 days after sowing. The rest of urea was applied in 30 days after seed sowing.

3.10.6 Plant protection activities

a) Insect pests

At the early stage of growth, plants were attacked by insect pests (mainly aphids) and Malathion 57 EC was sprayed at the rate of 2ml/litter at an interval of 15 days. At the sowing time Sevin 85 SP were mixed with seeds to control ants.

b) Diseases

Seedlings were attacked by damping off and Bavistin was sprayed at the rate of 2 ml/liter at an interval of 15 days. Some plants were attacked by bean common mosaic virus (BCMV) which was an important disease of French bean. These plants were removed from the plots and destroyed immediately.

3.11 Harvesting:

Only harvest those plants those are usually 100-120 days after planting depending on variety. Bean seeds become ready to harvest as soon as the pods are brown and dry. Mature dry pods were harvested by hand picking and seeds were collected from dry pods in the last harvesting stage. Seeds were collected from dry pods and spread out in a thin layer in direct sunlight. When the moisture percentage of seed attained 7-8% then seeds were ready to store.

3.12 Collection of data

Five plants were selected randomly to avoid border effect. For this reason, the outer two lines and the outer plants of the middle lines in each unit plot were avoided. The details of data recording are given below.

3.12.1 Percent of seedling emergence

Seedling emergence was recorded after the seed sowing on 12th November, 2015. Cumulative emergence of seedling was recorded and converted into percentage. It was recorded after sowing up to 80% seedling emerge in the attaining plots.

3.12.2 Plant height (cm)

The plant height was recorded at 30, 45,60 DAS and at harvest. The plant height was taken from ground level to the tip of the largest leaf of the plants. Plant heights were recorded from 5 randomly sampled plants and mean was calculated in centimeter (cm).

3.12.3 Number of leaves per plant

The number leaves of 5 randomly selected plants from each unit plot at 15, 30, 45 and 60 days after sowing (DAS) was counted and mean were calculated.

3.12.4 Number of branches per plant

Average number of branches per plant was recorded from 5 randomly selected plants from each unit plot at 30, 45 and 60 days after sowing (DAS) and mean was recorded.

3.12.5 Leaf length (cm)

Leaf length (cm) was measured by using measuring scale of 5 randomly selected plants from each unit plot at 45 days after sowing (DAS) and mean was recorded.

3.12.6 Leaf breadth (cm)

Breadth of leaf of 5 randomly selected plants from each unit plot were measured in cm with the help of slide calipers and their average was taken at 45 days after sowing (DAS) and mean was recorded.

3.12.7 Days of first flowering

The dates of first flowering for different treatments were recorded.

3.12.8 Number of pods per plant

From 5 randomly selected plants from each unit plot the numbers of pods were counted and their mean values were recorded.

3.12.9 Number of seeds per pod

Number of seeds per dry pod was recorded from 5 randomly selected plants and the mean value was calculated

3.12.10 Length of dry pod (cm)

Five dry pods from each randomly selected plant were measured using centimeter scale and the mean value was calculated and was expressed in centimeter.

3.12.11 Diameter of dry pod

Diameters of dry pod of 5 randomly selected plants from each unit plot were measured in cm with the help of slide calipers and their average was taken.

3.12.12 Weight of seeds per plant

Weight of seed was recorded from 5 randomly selected plants and the mean value was calculated.

3.12.13 Weight of seeds per hectare

Harvesting was done at different interval and total seed were recorded in each unit plot and expressed in kilogram (kg). Finally seed yield per plot was converted to seed yield per hectare and expressed in ton.

3.12.14 Weight of 1000 seed

One Thausand dry seeds from 5 randomly selected plants plot^{-1}were weighed and their average was taken in gram (g).

One Thausand dry seeds from each plot was weighed and expressed in gm.The harvested seed from each plot was cleaned and dried properly.After that these seeds were used for quality analysis.Quality analysis was done as follows-

3.13 Germination of seeds

The standard germination test was performed by placing randomly selected 30 seeds in 120 mm diameter Petri dishes on whatman No.1. Petri dishes containing primed and control seeds were irrigated with solutions of 8 ml drought stress levels. Here whatman No.1 filter paper were used as growth media for germination. Experimental units (75 Petri dishes for each variety) were arranged in a completely randomized design with five replications. During the test filter papers in the Petri dishes were kept in saturated state with respected solution. Seeds were kept at room temperature 25°C under normal light to facilitate germination for 8 days. Germination was considered to have occurred when radicals were 2 mm long (Akbari *et al.*, 2007). Germination progress was inspected and data were collected at every 24 hr intervals and continued up to 8 days. The seedlings with short, thick and spiral formed hypocotyls and stunted primary root were considered as abnormally germinated seeds (ISTA, 2003). These types of abnormal or dead seedlings were excluded during counting. At the end of germination test (8 days), 6 seedlings from each of the treatments were selected randomly and roots and shoots were cut from the cotyledons and were transferred to brown paper. Then these seedlings were dried in an oven at 75°C for 48 hours.

Data recording

Parameters that are measured as follows:

3.13.1 Total germination (TG %)

Total germination (TG) was calculated as the number of seeds which was germinated within total days as a proportion of number of seeds shown in each treatment expressed as a percentage (Othman *et al.,* 2006).

TG (%) = (Number of germinated seed/ Total number of seed set for germination) x 100

3.13.2 Germination index (GI):

Germination index (GI) was calculated as described in the Association of Official Seed Analysts (1983) as the following formulae:

Germination index = Gt/ Tt

Where,

Gt = number of seeds germinated on day t and

Tt = the number of germinated seeds at time Ti.

3.13.3 Coefficient of velocity (CV)

Coefficient of velocity (CV) = (number of germinated seeds per day) is measured according to the method described by Scott *et al.* (1998).

$CV = 100 \times (\sum Ni / \sum Ti\ Ni)$

Where,

Ti= number of days after sowing and

Ni = number of seeds germinated on ith day.

3.13.4 Energy of emergence (EG %)

Energy of emergence (EG) was recorded on the 4th day after placement of seeds. It is the percentage of germinating seeds 4 days after planting relative to

the total number of seeds tested (Ruan *et al.*, 2002a). Energy of emergence expressed in percentage.

3.13.5 Shoot length (mm) and root length (mm)

Randomly selected 6 seedlings from each treatment were collected and cotyledons were removed from them. Shoot and root length were measured with a ruler and accuracy of measurement was 1 mm.

3.13.6 Vigour Index (VI)

Vigour Index (VI) was calculated from total germination and seedlings length by using the formula of Abdul –Baki and Anderson (1970).

VI= TG (%) x seedling length (mm) / 100

Here, TG = total germination

3.15 Statistical analyses

Statistical analyses were done by using SPSS computer package program. The analyses of variance for the characters under study were performed by F variance test. The mean differences were adjudged by using the Duncan's Multiple Range Test using of standard error probability for the interpretation of results.

CHAPTER IV

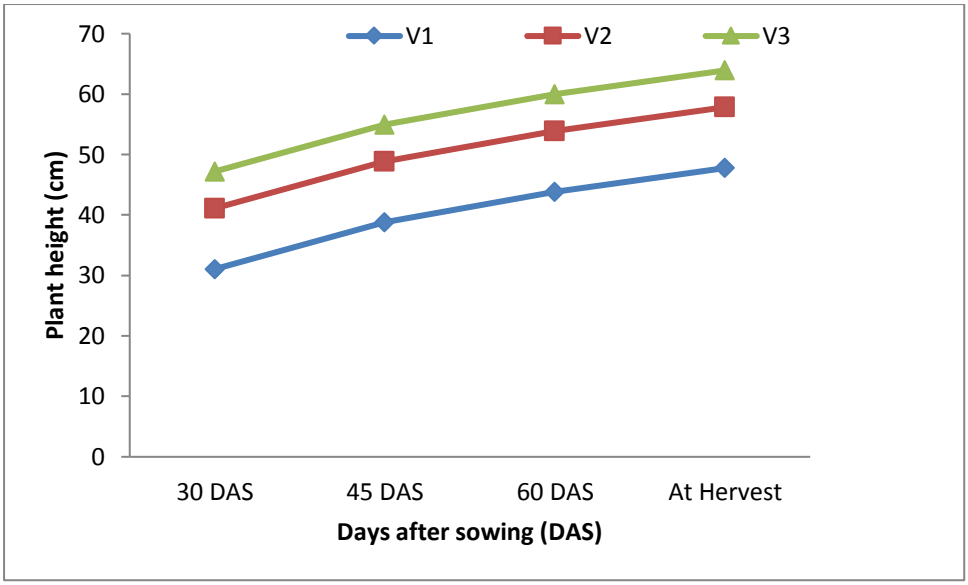
RESULTS AND DISCUSSION

The present research work was conducted during the period from November, 2015 to April, 2016 at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka to study the growth, seed yield and quality of bush bean as influenced by variety and phosphorous. The analysis of variance (ANOVA) of the data on yield contributing characters and yield of bush bean are shown in Appendixes. The result of the experiment have been presented and discussed in this chapter under the following headings:

Description of Growth,Yield and attributes data

4.1 Plant height:

Plant height is a varietal character, which is used to measure growth and development of a plant and finally produced higher yield. Plant height of different varieties of bush bean was significantly varied at 30, 45, 60 and at harvest (Fig. 2 and Appendix III). At harvest, the tallest (63.92 cm) plant was produced from V_3 (BARI bush bean-3) treatment and the shortest (47.77 cm) was found from V_1 (BARI bush bean -1) treatment. Optimum plant height can be achieved through proper management practices during growth and development stage. A study was conducted by Salam *et al*. (1997) with 13 cultivars of French bean. They reported that plant height showed wide variability except pod length. This result is in agreement with findings of Moniruzzaman *et al.* (2009) that reported at the same days, the plant height for BARI bush bean-1 and BARI bush bean-2 were 45.3 cm and 41.8 cm, respectively.



Error bar corresponds to standard error

Fig. 2 Effect of variety on plant height at different days after sowing of bush bean

Plant height of bush bean varied significantly at 30, 45, 60 days after sowing (DAS) and at harvest due to different levels of phosphorus (Fig. 2 and Appendix IV). At harvest, the tallest plant height (60.84 cm) was produced from P_3 treatment (120 kg P/ha) and the shortest (51.60 cm) plant was produced in (control) P_0 treatment.). The results also indicate that the increasing rate of phosphorus significantly increase the plant height. The present result also agrees well with that of Parmer *et al.* (1999), who obtained the highest plant height, highest no. of pod and seed of French bean with increasing rate of nitrogen and phosphorus.

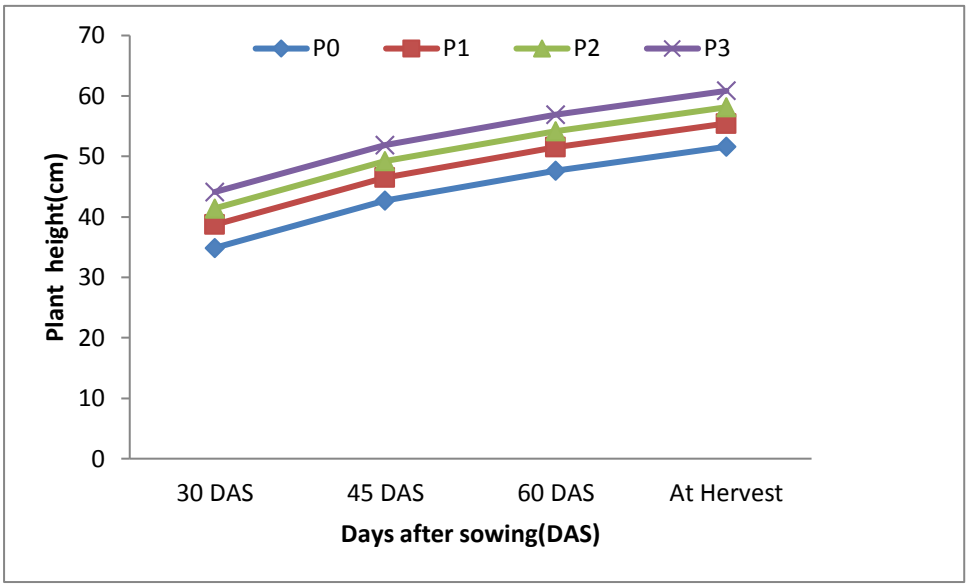


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Fig. 3 Effect of phosphorus on plant height at different days after sowing of bush bean

Combined effect of variety and phosphorus on Plant height was found statistically significant due to different days after sowing (Table 1 and Appendix IX). At harvest, the tallest (67.47 cm) plant was produced from V_3P_3 treatment (BARI Bush bean-3 and 120 kg P/ha), which was statistically similar to V_3P_2 (BARI Bush bean-3 and 100 kg P/ha) treatment combination and shortest (40.89 cm) plant was produced in (control) V_1P_0 treatment combination. Plant height may be due to the favorable influence and balanced absorption of nitrogen and phosphorus, increased role of photosynthesis, reduced transpiration and stimulation of root system.

Table1: Combined effect of variety and phosphorus on plant height at different days after sowing of bush bean

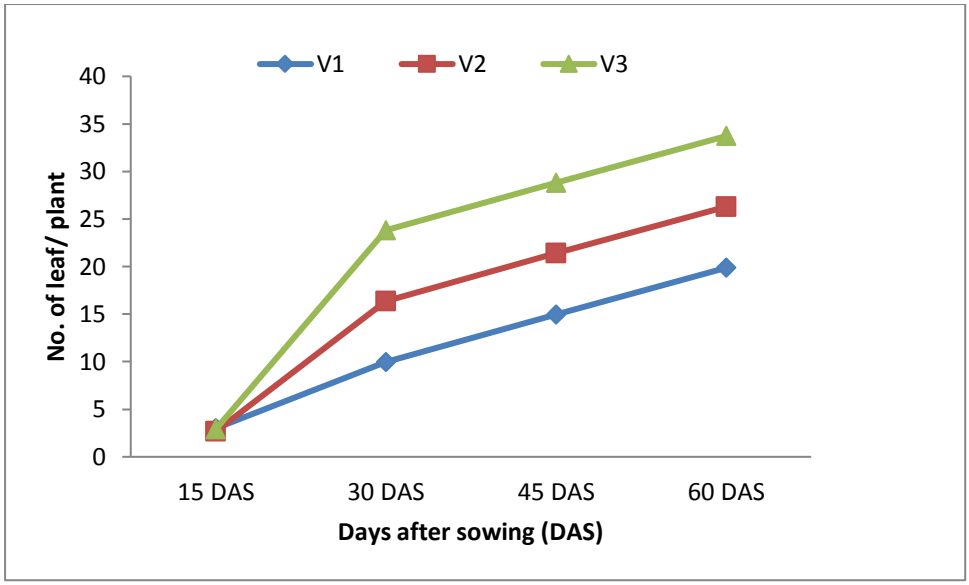
Treatments combination	Plant height			
	30 DAS	45 DAS	60 DAS	At Harvest
V_1P_0	24.17 g	31.96 g	36.95 i	40.89 i
V_1P_1	29.78 f	37.58 f	42.58 h	46.52 h
V_1P_2	32.90 f	40.69 f	45.68 g	49.63 g
V_1P_3	37.32 e	45.10 e	50.09 f	54.04 f
V_2P_0	37.12 e	44.90 e	49.89 f	53.84 f
V_2P_1	40.39 de	48.17 de	53.17 e	57.11 e
V_2P_2	42.65 cd	50.43 cd	55.42 de	59.37 de
V_2P_3	44.30 cd	52.09 bcd	57.08 cd	61.02 cd
V_3P_0	43.35 cd	51.14 cd	56.13 c-e	60.07 cd
V_3P_1	46.00 bc	53.79 bc	58.78 bc	62.73 bc
V_3P_2	48.68 ab	56.47 ab	61.46 ab	65.41 ab
V_3P_3	50.74 a	58.53 a	63.52 a	67.47 a
S.E	.370	1.437	1.012	.946

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.2 Number of leaves per plant

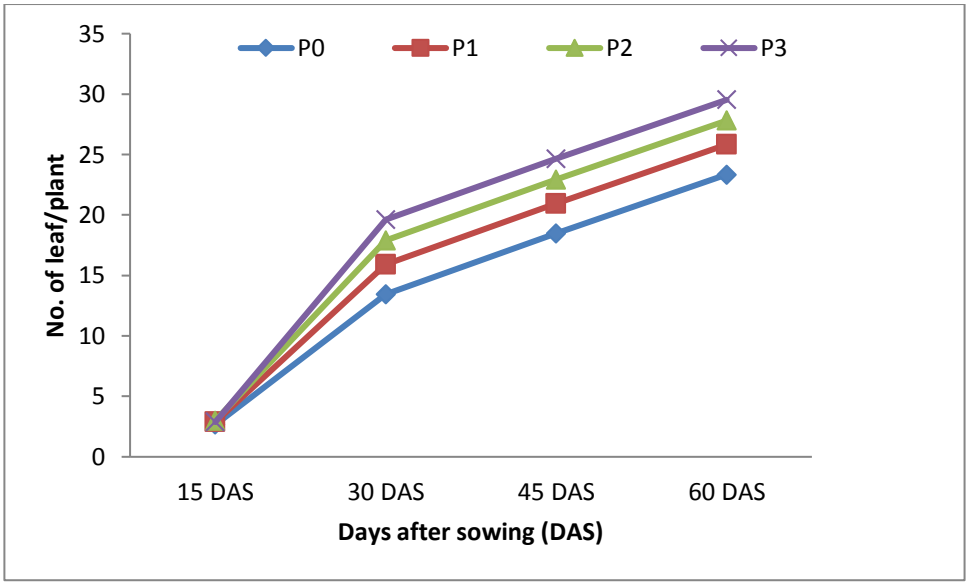
Number of leaves per plant is a vital parameter of crop plant because of its physiological role in photosynthetic activities, which is directly related to the French bean yield. Number of leaves per plant of bush bean was varied significantly at 30, 45 and 60 days after sowing (DAS) due to different varieties (Fig. 4 and Appendix IV), but at 15 DAS it showed non significant effect. At 60 DAS, the highest number of leaves (33.72) per plant was obtained from V_3 treatment (BARI bush bean-3) and the lowest (19.87) was observed from V_1 treatment (BARI bush bean-1). This variation might be due to the difference in genetic constituents as well as environmental effects.



Error bar corresponds to standard error

Fig. 4 Effect of variety on number of leaves per plant at different days after sowing of bush bean

Number of leaves per plant of bush bean varied significantly at 15, 30, 45 and 60 days after sowing (DAS) due to different phosphorus levels (Fig. 5 and Appendix V). At 60 DAS, the highest (29.53) number of leaves per plant was obtained from P_3 treatment (120 kg P/ha) and the lowest (23.35) was observed from (control) P_0 treatment.



Error bar corresponds to standard error

Fig.5 Effect of phosphorus on number of leaves per plant at different days after sowing of bush bean (*Phaseolus vulgaris* L.)

Combined effect of variety and phosphorus on Plant height was found statistically significant for number of leaves per plant of bush bean (Table 2 and Appendix-IX). At all days of data collection, at 60 DAS, the highest number of leaves per plant was recorded (37.04) from the V_3P_3 treatment combination (BARI Bush bean-3 and 120 kg P/ha). The lowest number of leaves per plant of bush bean was (17.9), found in V_1P_0 treatment combination (BARI Bush Bean-1 and control). The result obtained from the present supported by Varennes *et al.* (2002), Varma and Singh (2000) in respect of number of leaves per plant.

Table 2: Combined effect of variety and phosphorus on number of leaves per plant at different days after sowing of bush bean

Treatment combination	Leaf/pt(cm)				Branch/pt(cm)		
	15 DAS	30 DAS	45 DAS	60 DAS	45 DAS	60 DAS	At Harvest
V_1P_0	2.67	7.09j	12.11j	17.00j	2.46g	4.97g	6.30g
V_1P_1	3.00	9.49i	14.52i	19.41i	5.30e	7.81e	9.15e
V_1P_2	3.33	10.74h	15.75h	20.65h	7.06c	9.57c	10.91c
V_1P_3	3.00	12.52g	17.54g	22.43g	5.95d	8.45d	9.79d
V_2P_0	2.33	13.36g	18.37g	23.26g	4.53f	7.04f	8.38f
V_2P_1	2.67	15.30f	20.32f	25.21f	7.11c	9.62c	10.96c
V_2P_2	3.00	17.66e	22.68e	27.57e	9.18a	11.69a	13.03a
V_2P_3	2.67	19.20d	24.22d	29.11d	7.87b	10.38b	11.72b
V_3P_0	3.00	19.87d	24.89d	29.78d	1.43h	3.94h	5.28h
V_3P_1	3.00	22.95c	27.97c	32.86c	2.73g	5.24g	6.58g
V_3P_2	2.67	25.29b	30.31b	35.20b	4.35f	6.86f	8.20f
V_3P_3	3.00	27.13a	32.15a	37.04a	3.00g	5.51g	6.85g
S.E	.333	.419	.419	.419	.209	.209	.209

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.3 Number of branches per plant

Significant variation was observed on number of branches per plant of bush bean at 45, 60 DAS and at harvest due to variation in variety (Fig. 6 and Appendix V). At harvest, maximum (11.02) number of branch was produced from V_2 treatment (BARI Bush Bean -2) and the minimum (6.70) was observed from V_3 treatment (BARI Bush Bean-3). Dahiya *et al*. (2000) conducted a study with 48 genotypes of French bean. They observed that primary branches per plant and secondary branches per plant varied significantly due to characterized by genetic advanced.

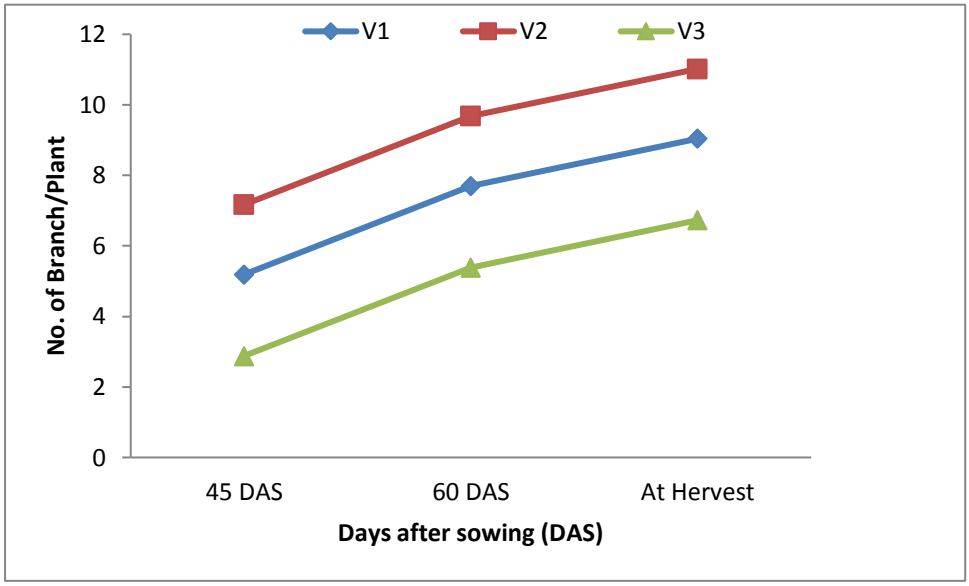


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Fig. 6 Effect of variety on number of branches per plant at different days after sowing of bush bean (*Phaseolus vulgaris* L.)

Number of branches per plant of bush bean was varied significantly at 45, 60 DAS and at harvest due to application of different levels of phosphorus (Fig. 7 and Appendix VI). At harvest, highest number of (10.72) branch was found from P_2 treatment (100 kg P/ha) where the lowest (6.66) was observed from (control) Po treatment. Phosphorus play a vital role in several physiological process *viz*, photosynthesis, respiration, energy store and transfer, cell division which will significantly enhance the axillary stalk or branching of plants. Rima (2016) conducted an experiment with four doses of phosphorous and stated that highest number of branches (11.70) at 100 kg phosphorous fertilizer. The results are supported by Dash and Dash (1987). They found that most of the growth and yield characters of bush bean influenced by phosphorus.

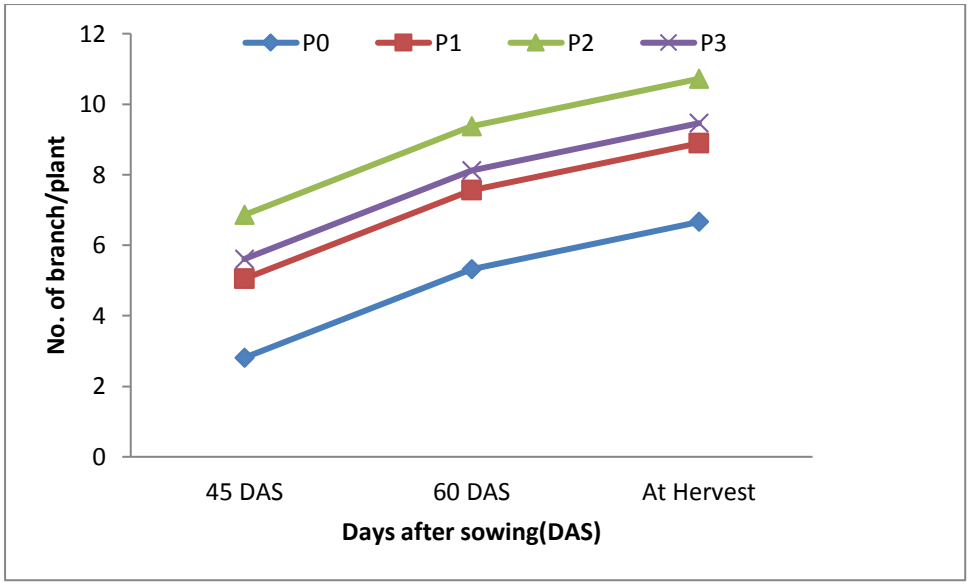

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Fig. 7 Effect of phosphorus on number of branches per plant at different days after sowing of bush bean (*Phaseolus vulgaris* L.)

Significant variation of number of branches per plant was observed at 45, 60 DAS and at harvest due to combined effect of different variety and phosphorus level (Table 2 and Appendix IX). At harvest, the highest number of branches was (13.03) recorded from V_2P_2 (BARI Bush bean-2 and 100 kg P/ha) treatment combination. The lowest (5.28) was observed from (control) V_3P_0 treatment combination.

4.4 Leaf length

Leaf length of bush bean was significantly influenced by variety (Table 3 and Appendix VII). The longest length of leaf (17.29 cm) was observed in V_3 treatment (BARI Bush bean -3) which was similar toV_2 (BARI Bush bean -2) treatment, whereas the shortest (15.40 cm) was observed in V_1 (BARI Bush bean -1). The productivity of field crops depends mainly on the size of leaf, the photosynthesis system as well as on the length of time during, which it remains active (Carr and Wardlaw, 1965).

Table 3: Effect of variety on leaf length, leaf breadth, days of germination and days of first flowering at different days after sowing of bush bean.

Treatments	Leaf Length /plant (cm)	Leaf breadth /plant(cm)	Days of germination	Days of First Flowering
V_1	15.40 b	10.81 a	6.58 a	42.08 a
V_2	16.51 ab	9.67 b	5.50 b	36.67 b
V_3	17.29 a	10.88 a	4.33 c	32.92 c
S.E	.47	.29	.17	.37

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3

Leaf length was non significantly varied due to application of different level of phosphorus (Table 4 and Appendix- VIII). The longest leaf length (17.06 cm) was found from P_1 treatment (80 kg P/ha), where the shortest (15.98 cm) was observed from P_1 treatment (100 kg P/ha).

Table 4 Effect of phosphorus on leaf length at different days after sowing of bush bean.

Treatments	Leaf Length /plant (cm) at 60 DAS	Leaf breadth /plant (cm) at 60 DAS	Days of germination	Days of First Flowering
P_0	16.02	10.57	5.66	36.44 b
P_1	17.06	10.76	5.66	36.44 b
P_2	15.98	10.00	5.11	37.44 ab
P_3	16.53	10.45	5.44	38.56 a
S.E	.547	.331	.192	.430

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

The combined effect also showed non significant variation in leaf length as a result of different variety and phosphorous application at 60 DAS (Table 5 and Appendix IX).

Table 5: Combined effect of varieties and phosphorous on leaf length, leaf breadth, days of germination and days of first flowering of bush bean (*Phaseolus vulgaris L.*) at 60 days after DAS

Treatments combination	Leaf Length /plant (cm)	Leaf breadth /pt (cm)	Days of germination	Days of First Flowering
V_1P_0	13.87	10.07 abc	6.67 a	43.67 a
V_1P_1	16.80	11.83 a	6.67 a	41.33 a
V_1P_2	15.80	10.47 abc	6.33 ab	41.67 a
V_1P_3	15.13	10.87 abc	6.67 a	41.67 a
V_2P_0	16.40	9.97 abc	5.67 abc	38.33 b
V_2P_1	17.20	9.80 bc	5.67 abc	37.00 bc
V_2P_2	15.90	9.23 c	5.33 bcd	35.33 cd
V_2P_3	16.53	9.67 c	5.33 bcd	36.00 cd
V_3P_0	17.80	11.70 ab	4.67 cde	31.67 e
V_3P_1	17.17	10.67 abc	4.67 cde	32.33 e
V_3P_2	16.27	10.30 abc	3.67 e	33.67 de
V_3P_3	17.93	10.83 abc	4.33 de	34.00 de
S.E	0.95	0.57	0.33	0.75

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.4 Leaf breadth:

Leaf breadth was showed statistically significant variation at 60 DAS by variety (Table 3 and Appendix VII). At 60 DAS maximum leaf breadth (10.88 cm) was found from (BARI Bush Bean -3) V_3 treatment, which is statistically identical to V_1 (BARI Bush Bean -1) and the minimum was observed (9.67 cm) from (BARI Bush Bean -2) V_2 treatment. This difference might be due to the variation in genetic constituents as well as environmental effects. Leaf breadth is the protected means of trapping solar energy and converting it into food and other useful materials so that it can play a great role in the crop production.

At 45 DAS, variation in leaf breadth was statistically non significant due to the different levels of application of phosphorus (Table 4 and Appendix VIII).

Combined effect of variety and different doses of phosphorus was significantly varied in case of leaf breadth of bush bean (Table 5and Appendix IX). The largest leaf breadth (11.83 cm) was produced from V_1P_1 (BARI -1 and 80 kg P/ha) treatment combination, which was statistically similar to V_1P_0, V_1P_2, V_1P_3 V_2P_0, V_3P_1, V_3P_2 and V_3P_3 treatments. The smallest (9.23 cm) leaf breadth was produced by V_2P_2 (BARI Bush Bean -1 and 100 kg P/ha) treatment combination. The result indicated that, the different variety and application of phosphorus markedly influence the leaf breadth due to variation in genetic constitutions and increase the metabolic activity.

4.6 Days of germination:

Days of germination was showed statistically significant variation due to various type of variety (Table 3 and Appendix VII).The highest days of germination (6.58 days) was identified from V_1 treatment and shortest days of germination (4.33) was observed from V_3 treatment.

Variation in days of germination was statistically non significant due to the different levels of phosphorus (Table 4 and Appendix VIII).

Significant variation of days of germination was observed due to combined effect of different variety and phosphorus levels (Table 5 and Appendix IX). The longest (6.67) days of germination was observed from V_1P_1 treatment combination (BARI Bush Bean -1 and 80 kg P/ha), which was statistically identical to V_1P_0 and V_1P_3 and statistically similar to V_1P_2, V_2P_0 and V_2P_1. The shortest (3.67 days) days of germination was required for germination by V_3P_2 treatment combination (BARI Bush Bean -3 and 100 kg P/ha).

4.7 Days to first flowering

Days to first flowering was given statistically significant variation due to the different variety (Table 3 and Appendix VII). The longest (42.08 days) required for first flower initiation was identified from V_1 (BARI Bush Bean -1)

treatment. The shortest (32.92 days) for first flowering was obtained from V_1 (BARI Bush Bean -1) treatment. The flowering time is a very necessary part which plays an exigent role in the life of a plant Vergara *et al*., (1964). Korla *et al*. (1997) analyzed that days to required first flowering showed little differences among the various cultivars of French bean.

Day to first flowering was showed statistically significant variation due to the phosphorus application (Table 4 and Appendix VIII). The longest period (38.56 days) was required for first flower initiation from P_3 (120 kg P/ha) treatment which was statistically similar to P_2 (100 kg P/ha) treatment. On the other hand, the shortest period (36.44 days) for first flowering from P_0 (control) treatment, which was statistically identical to P_1 treatment.

Days to first flowering was showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 5 and Appendix IX). The longest period (41.67 days) was required for first flower initiation from V_1P_3 (BARI Bush Bean -1 and 120 kg P/ha) treatment combination and which was statistically identical to V_1P_0, V_1P_1 and V_1P_2 treatment combination. On the other hand, the shortest period (31.33 days) was required for first flower initiation from V_3P_1 treatment combination, which was statistically identical to V_3P_0 treatment combination.

4.8 Number of pods per plant

Marked variation in the number of pods per plant among the varieties was recorded statistically significant (Table 6 and Appendix VII). The maximum (27.83) number of pods per plant was recorded for V_2 (BARI Bush Bean -2) treatment. On the other hand, V_3 (BARI Bush Bean -3) showed the minimum (10.20) result in numbers of pods. Singh *et al.* (1993) found significant variation in number of pods per plant with an experiment of seven French bean genotypes.

Table 6: Effect of variety on number of pods per plant, number of dry seeds per pod of bush been

Treatments	Number of Pods per plant	Number of seeds per dry pod
V_1	19.32 b	6.25 a
V_2	27.83 a	5.84 b
V_3	10.20 c	4.75 c
S.E	.40	.01

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3

Number of pods per plant varied significantly due to application of phosphorus (Table 7 and Appendix VIII). The highest (21.92) number of pods per plant of bush bean was found from P_2 (100 kg P/ha) treatment and the lowest (16.27) number of pods per plant of bush bean was observed from P_0 (control) condition.

Table 7: Effect of phosphorous on pods per plant, number of dry seeds per pod of bush been

Treatments	Number of Pods per plant	Number of seeds per dry pod
P_0	16.27 d	4.85 c
P_1	18.24 c	5.61 b
P_2	21.92 a	6.00 a
P_3	20.04 b	6.00 a
S.E	.47	.01

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

Number of pods per plant showed statistically significant variation due to the combined effect of variety and phosphorus level (Table 8 and Appendix IX). The highest pods per plant (31.43) was produced from V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination. On the other hand, the lowest number of pods per plant (7.93) was recorded from V_3P_0 (BARI Bush Bean -3

and control) treatment combination, which is statistically identical to V_3P_1 (BARI Bush Bean -3 and 80 kg P/ha) treatment combination.

Table 8: Combined effects of variety and phosphorous level on pods per plant, number of dry seeds per pod of bush bean

Treatments combination	Number of Pods per plant	Number of seeds per dry pod
V_1P_0	16.97 f	5.00 e
V_1P_1	19.00 ef	6.00 b
V_1P_2	21.57 cd	7.00 a
V_1P_3	19.77 de	7.00 a
V_2P_0	23.90 c	5.55 d
V_2P_1	27.00 b	5.87 c
V_2P_2	31.43 a	6.00 b
V_2P_3	29.00 b	6.00 b
V_3P_0	7.93 h	4.00 f
V_3P_1	8.73 h	5.00 e
V_3P_2	12.77 g	5.00 e
V_3P_3	11.37 g	5.00 e
S.E	.81	.01

Different letter (s) corresponds to significant differences at $\leq$ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.9 Number of seeds per dry pod

Total number of seeds per dry pod varied significantly due to different variety (Table 6 and Appendix VII). The maximum (6.25) number of seeds per pod of bush bean was obtained for V_1 (BARI Bush Bean -1) treatment and the minimum (4.75) number of seeds per dry pod of bush bean was found from V_3 (BARI Bush Bean -3) treatment. Shila (2016) showed the same result in case of BARI Bush Bean -1.

A significant variation was found in number of seeds per dry pod of bush bean due to different phosphorus levels (Table 7 and Appendix VIII).

The highest (6.00) number of seeds per dry pod of bush bean was found from P_2 treatment (120 kg P/ha) which was statistically identical to P_3 treatment (150

kg P/ha). The lowest (4.85) number of seeds per dry pod of bush bean was observed P_0 (control) treatment.

Number of seeds per dry pod showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 8 and Appendix IX). The highest number of seeds per dry pod (7.00) required from V_1P_2 (BARI Bush Bean -1 and 100 kg P/ha) treatment combination, which is statistically identical to V_1P_3 (BARI Bush Bean -1 and 120 kg P/ha) treatment combination. On the other hand, the lowest number of seeds per dry pod (4.75) found from V_3P_0 (BARI Bush Bean -3 and control) treatment combination.

4.10 Length of dry pod

Length of dry pod was found statistically significant due to different variety (Table 9 and Appendix VII). The V_1 (BARI Bush Bean-1) treatment showed the longest (14.59 cm) dry pod length of bush bean which was statistically identical to V_3 (BARI Bush Bean-3) treatment and the shortest (11.08 cm) dry pod length of Bush bean was observed in V_2 (BARI Bush bean-2) treatment. Fruit size is supposed to be one of the important criteria in selecting a new variety. Korla *et al.* (1997) reported that, twenty seven French bean (*Phaseolus vulgaris* L.) genotypes were varied in yield components such as days to, pod length, pod breadth and pod per plant. Similar results were reported by Roy *et al*. (2006).

Table 9: Effect of variety on length of dry pod, diameter of dry pod and weight of 1000 seed of bush bean

Treatments	Length of dry pod (cm)	Diameter of dry pod (cm)	Weight of seed per plant (g)
V_1	14.59 a	1.03 b	23.17b
V_2	11.08 b	.69 c	26.65a
V_3	14.52 a	1.06 a	16.03c
S.E	.05	.01	.46

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3

Significant variation on length of dry pod of bush bean was observed due to application of different levels of phosphorus (Table 10 and Appendix-VIII). The longest (14.23 cm) length of dry pod of bush bean was observed from P_2 treatment (100 kg P /ha). The shortest length (12.42 cm) of dry pod was observed from P_0 (control) treatment.

Table 10: Effect of phosphorous level on length of dry pod, diameter of dry pod and weight of 1000 seed of bush bean

Treatments	Length of dry pod (cm)	Diameter of dry pod (cm)	Weight of seed per plant (g)
P_0	12.42 d	.81 d	16.97d
P_1	13.23 c	.92 c	21.10c
P_2	14.23 a	1.01 a	25.99a
P_3	13.71 b	.97 b	23.75b
S.E	.060	.008	.536

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

Length of dry pod showed statistically significant variation due to the combined effect of variety and different levels of phosphorus (Table 11 and Appendix IX). The longest (15.90 cm) length of dry pod was found from V_1P_2 (BARI Bush Bean -1 and 100 kg P/ha) treatment combination, which is statistically identical. On the other hand, the shortest length of (10.28 cm) dry pod was observed from V_2P_0 (BARI Bush Bean -2 and control of phosphorous) treatment combination.

Table 11: Combined effect of variety and phosphorous length of dry pod, diameter of dry pod and weight of 1000 seed of bush bean

Treatments combination	Length of dry pod (cm)	Diameter of dry pod (cm)	Weight of seed per plant (g)
V_1P_0	13.40 e	.84 f	18.63f
V_1P_1	14.34 d	1.04 d	22.81de
V_1P_2	15.90 a	1.14 b	26.96bc
V_1P_3	14.71 c	1.08 c	24.31cd
V_2P_0	10.28 h	.67 g	21.01ef
V_2P_1	11.15 g	.69 g	26.50bc
V_2P_2	11.55 f	.70 g	30.68a
V_2P_3	11.34 fg	.70 g	28.43ab
V_3P_0	13.58 e	.90 e	11.26h
V_3P_1	14.20 d	1.03 d	14.00g
V_3P_2	15.24 b	1.20 a	20.34ef
V_3P_3	15.07 b	1.12 bc	18.51f
S.E	.103	.015	.929

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.11 Diameter of dry pod

Seed diameter of dry pod varied significantly due to different variety (Table 9 and Appendix VII). The thickest (1.06 cm) diameter of bush bean dry pod was obtained from V_3 (BARI Bush Bean -3) treatment. The shortest (0.69 cm) diameter of bush bean dry pod was found from V_2 (BARI Bush Bean -2) treatment.

A significant variation was found in case of seed diameter of dry pod of Bush bean due to application of different levels of phosphorus (Table 10 and Appendix VIII). The thickest (1.06 cm) diameter of bush bean dry pod was found from P_2 treatment (100 kg P /ha). The shortest (0.81 cm) diameter of bush bean dry pod was observed from P_0 (control) treatment.

Diameter of dry pod showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 11 and Appendix

IX). The thickest (1.20 cm) diameter of dry pod was found from V_3P_2 (BARI Bush Bean -3 and 100 kg P/ha) treatment combination. On the other hand, the shortest diameter (0.67 cm) of dry pod was observed from V_2P_0 (BARI Bush Bean -2 and control) treatment combination, which was statistically identical to V_2P_1, V_2P_2 and V_2P_3.

4.12 Weight of seed per plant (g)

Weight of bush bean seed per plant varied significantly due to different variety (Table 9 and Appendix VII). The highest (26.65 gm) weight bush bean seed per plant was obtained from V_2 (BARI Bush Bean -2) treatment and the lowest (16.03 gm) weight of bush bean seed per plant was found from V_3 (BARI Bush bean -3) treatment.

Significant variation was found in case of weight bush bean seed per plant due to application of different levels of phosphorus (Table 10 and Appendix VIII). The highest (25.99 gm) weight of bush bean seed per plant was found from P_2 treatment (100 kg P /ha). The lowest (16.97 gm) weight of bush bean seed per plant was observed from P_0 (control) treatment.

Weight of bush bean seed per plant showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 10 and Appendix IX). The highest (30.68 g) weight of bush bean seed per plant was found from V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination, which was statistically similar to V_2P_3 treatment combination. On contrary, the lowest weight of bush bean seed (11.26 g) per plant was observed from V_3P_0 (BARI Bush Bean -3 with control) treatment combination.

Weight of Thousand Seed

4.13 Weight of 1000 seed

Weight of thousand bush bean seed varied significantly due to different variety (Table 12 and Appendix VII). The highest weight of 1000 bush bean seed (356.00 g) was obtained from V_3 (BARI Bush Bean -3) treatment and the

lowest weight of 1000 bush bean seed (224.00 g) was found from V_2 treatment (BARI Bush Bean -2).

Significant variation was found in case of weight of 1000 bush bean seed due to application of different levels of phosphorus (Table 13 and Appendix VIII). The highest weight of 1000 bush bean seed (289.22 gm) was found from P_2 treatment (100 kg P /ha) and the lowest weight of 1000 bush bean seed (271.78 gm) was observed from P_0 (control) treatment.

Weight of thousand bush bean seed showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 14 and Appendix IX). The highest weight of 1000 bush bean seed (365.67 g) was found from V_3P_2 (BARI Bush Bean -3 and 100 kg P/ha) treatment combination. On the other hand, the lowest weight of 1000 bush bean seed (230.33 gm) dry pod was observed from V_2P_2 (BARI Bush bean -2 with control treatment) treatment combination.

4.14 Weight of Seed per plot

Weight of bush bean seed per plot varied significantly due to different variety (Table 12 and Appendix VII). The highest (373.70 gm) weight bush bean seed per plot was obtained from V_2 (BARI Bush Bean -2) treatment. The lowest (228.96 gm) weight of bush bean seed per plot was found from V_3 (BARI Bush Bean -3) treatment.

Table 12: Effect of variety on weight of 1000 seed (g), weight of seed per plot and weight of seed per hectare (t) of bush bean

Treatments	Weight of thousand seed (g)	Weight of seed/ plot (g)	Seed yield (t/ha)
V_1	264.83 b	333.63 b	3.089 b
V_2	224.00 c	373.70 a	3.46 a
V_3	356.00 a	228.96 c	2.12 c
S.E	.64	4.58	.04

Different letter (s) corresponds to significant differences at $\leq$ 0.05 by Duncan's multiple nange tests
Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3

Significant variation was found in case of weight bush bean seed per plot due to application of different levels of phosphorus (Table 13 and Appendix VIII). The highest (371.04 gm) weight of bush bean seed per plot was found from P_2 treatment (100 kg P /ha). The lowest (240.13 gm) weight of bush bean seed per plot was observed from P_0 (control) treatment.

Table 13: Effect of phosphorous level on weight of 1000 seed, weight of seed per plot and weight of seed per hectare (t) of bush bean

Treatments	Weight of thousand seed (g)	Weight of seed/plot(g)	Seed yield (t/ha)
P_0	16.97 d	240.13 d	2.22 d
P_1	21.10 c	299.99 c	2.78 c
P_2	25.99 a	371.04 a	3.44 a
P_3	23.75 b	337.22 b	3.12 b
S.E	.54	5.29	.05

Different letter (s) corresponds to significant differences at $\leq$ 0.05 by Duncan's multiple nange tests
Here, P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

Weight of bush bean seed per plot showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 14 and Appendix IX). The highest (431.57 gm) weight of bush bean seed per plot was found from V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination.Which was statistically similar with V_2P_3 (405.45).On contrary, the lowest weight of bush bean seed (162.44 gm) per plot was observed from V_3P_0 (BARI Bush Bean -3 and 00 kg P/ha) treatment combination.

Table 14: Combined effect of variety and phosphorous level on weight of 1000 seed, weight of seed per plot and weight of seed per hectare (t) of bush bean

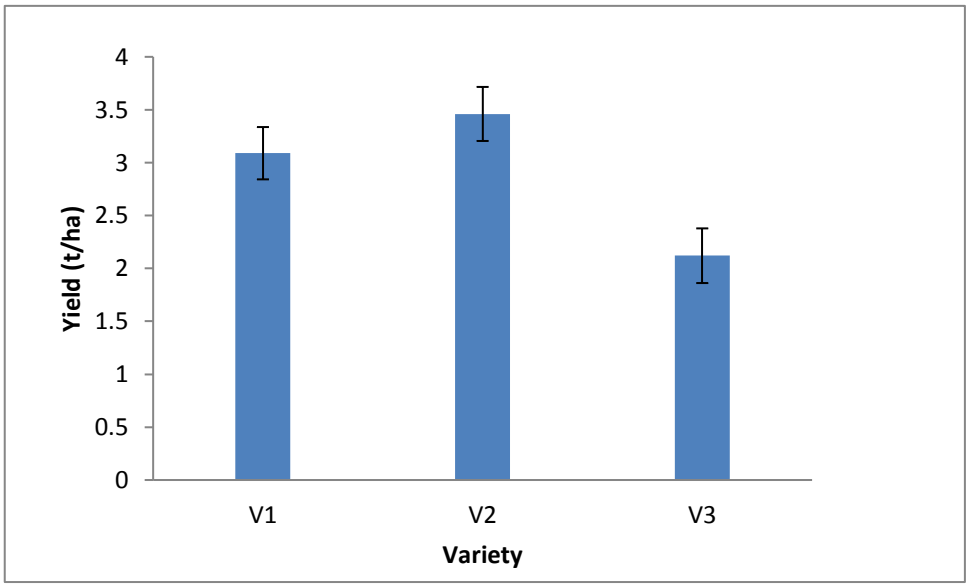
Treatments combination	Weight of thousand seed (g)	Weight of seed/ plot (g)	Seed yield (t/ha)
V_1P_0	257.00 g	262.04 f	2.42 f
V_1P_1	262.67 f	331.21 d	3.07 d
V_1P_2	271.67 e	388.85 b	3.60 b
V_1P_3	268.00 e	352.39 cd	3.26 cd
V_2P_0	216.00 j	295.91e	2.74 e
V_2P_1	222.33 i	361.88 c	3.35 c
V_2P_2	230.33 h	431.57 a	3.99 a
V_2P_3	227.33 h	405.45 ab	3.75 ab
V_3P_0	342.33 d	162.44 h	1.50 h
V_3P_1	354.67 c	206.88 g	1.92 g
V_3P_2	365.67 a	292.71e	2.71 e
V_3P_3	361.33 b	253.82 f	2.35 f
S.E	1.28	9.17	.09

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.15 Seed yield

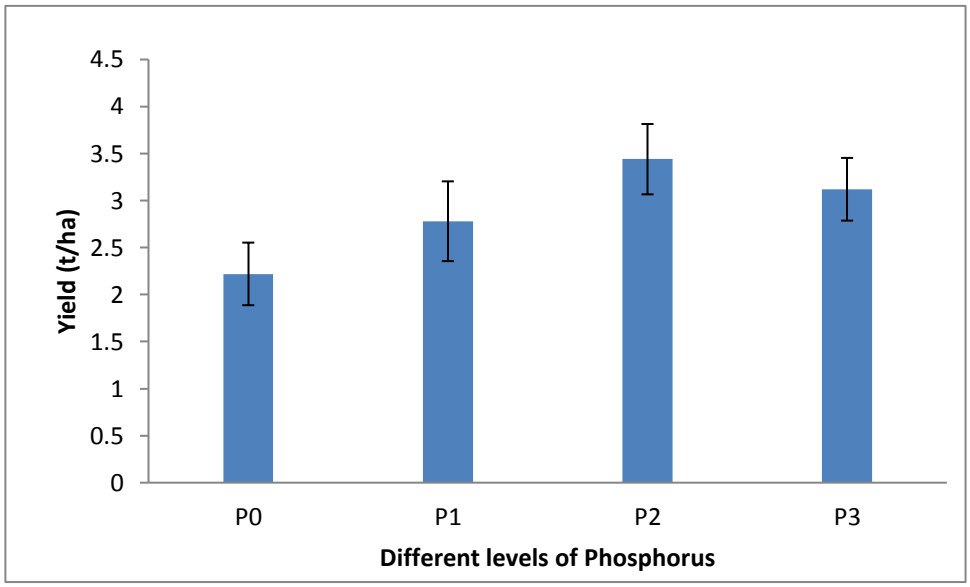
Weight of bush bean seed per hectare varied significantly due to different variety (Fig. 8 and Appendix VII). The highest weight (3.46 t/ha) of bush bean seed was obtained from V_2 (BARI Bush Bean -2) treatment. The lowest weight (2.12 t/ha) of bush bean seed per hectare was found from V_3 treatment (BARI Bush Bean -3).



Error bar corresponds to standard error

Fig. 8 Effect of variety on weight of seed per hectare of bush bean (*Phaseolus vulgaris* L.)

Significant variation was found in case of weight bush bean seed per hectare due to application of different levels of phosphorus (Fig. 9 and Appendix IX). The highest (3.44 t/ha) weight of bush bean seed was found from P_2 treatment (100 kg P /ha). The lowest (2.22 t/ha) weight of bush bean seed was observed from P_0 (control) treatment.



Error bar corresponds to standard error

Fig. 9 Effect of phosphorous on weight of seed per hectare of bush bean (*Phaseolus vulgaris* L.)

Weight of bush bean seed per hectare showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 14 and Appendix IX). The highest weight (3.99 t/ha) of bush bean seed was obtained from V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination, which was statistically similar to V_2P_3. On contrary, the lowest weight of bush bean seed (1.50 t/ha) was observed from V_3P_0 (BARI Bush Bean -3 and 00 kg P/ha) treatment combination.

Description of Seed Quality attributes data

4.16 Effect on total germination (%)

Effect on total germination of bush bean seed varied significantly due to different variety (Table 15 and Appendix VII). The highest (94.58 %) total germination of bush bean seed was observed from V_2 (BARI Bush Bean -2) treatment, which was identical to V_1 (BARI Bush Bean -1) treatment and the lowest (84.58 %) total germination of bush bean seed was observed from V_3 treatment (BARI Bush Bean -3).

Table 15: Effect of variety on total germination, energy of emergence, vigour index

Treatments	Total germination(%)	Energy of emergence(%)	Vigour Index(%)
V_1	91.67 a	98.75 a	22.79 b
V_2	94.58 a	100.00 a	26.14 a
V_3	84.58 b	86.67 b	17.74 c
S.E	1.25	.68	.35

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3

Significant variation was obtained in case of total germination of bush bean seed due to application of different levels of phosphorus (Table 16 and Appendix VIII). The highest (96.67 %) total germination of bush bean seed was found from P_2 treatment (100 kg P /ha) and the lowest (86.67%) total germination of bush bean seed was observed from P_0 (control) treatment, which was similar to P_0 (120 kg P/ha) treatment(86.67%).

Table 16: Effect of phosphorous level on total germination, energy of emergence and vigour index

Treatments	Total germination(%)	Energy of emergence(%)	Vigour Index(%)
P_0	86.67 c	94.44 b	20.46 c
P_1	91.67 b	95.00 ab	22.62 b
P_2	96.67 a	97.22 a	24.16 a
P_3	86.11 c	93.89 b	21.64 b
S.E	1.443	.786	.398

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

Total germination of bush bean seed showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 17 and Appendix IX). The highest (100 %) total germination of bush bean seed was found from V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination,

which was statistically similar to V_1P_2 treatment combination and statistically similar to V_1P_1, V_2P_1, and V_2P_3. On contrary, the lowest total germination of bush bean seed (80 %) was observed from V_3P_3 (BARI Bush Bean -3 and 00 kg P/ha) treatment combination, which was statistically similar to V_1P_0, V_1P_3, V_3P_0 and V_3P_1.

Table 17: Combined effect of variety and phosphorous level on total germination, energy of emergence and vigour index

Treatments combination	Total germination(%)	Energy of emergence(%)	Vigour Index(%)
V_1P_0	86.67 cde	96.67	20.48 de
V_1P_1	95.00 ab	100.00	23.46 c
V_1P_2	100.00 a	100.00	25.57 b
V_1P_3	85.00 de	98.33	21.65 cd
V_2P_0	90.00 bcd	100.00	23.16 c
V_2P_1	95.00 ab	100.00	26.58 ab
V_2P_2	100.00 a	100.00	28.17 a
V_2P_3	93.33 abc	100.00	26.65 ab
V_3P_0	83.33 de	86.67	17.76 f
V_3P_1	85.00 de	85.00	17.83 f
V_3P_2	90.00 bcd	91.67	18.77 ef
V_3P_3	80.00 e	83.33	16.61 f
S.E	2.50	1.36	.69

Different letter (s) corresponds to significant differences at $\leq$ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.17 Effect on energy of emergence (%)

Effect on energy of emergence of bush bean seed varied significantly due to different variety (Table 15 and Appendix VII). The highest (100 %) energy of emergence of bush bean seed was observed from V_2 (BARI Bush Bean -2) treatment, which was statistically similar to V_1 (BARI Bush Bean -1) treatment and the lowest (86.67 %) total germination of bush bean seed was observed in V_3 (BARI Bush Bean -3) treatment.

Significant variation was obtained in case of total germination of bush bean due to application of different levels of phosphorus (Table 16 and Appendix VIII). The highest (97.22 %) total germination of bush bean seed was found from P_2 treatment (100 kg P /ha), which was statistically identical to 80 kg P/ha and the lowest (86.67%) total germination of bush bean seed was observed from P_0 (control) treatment.

Total germination of bush bean seed showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 17 and Appendix IX). The highest (100 %) total germination of bush bean seed was found from V_2P_2 (BARI Bush bean -2 and 100 kg P/ha) treatment combination, which was statistically similar to V_1P_1, V_1P_2, V_2P_0, V_2P_1 and V_2P_3 and statistically similar to V_1P_0, and V_1P_3. On contrary, the lowest total germination of bush bean seed (80 %) was observed from V_3P_0 (BARI Bush Bean -3 and 00 kg P/ha) treatment combination, which was statistically similar to V_3P_3 and V_3P_1.

4.18 Effect on vigour index

Effect on vigour index of bush bean seed varied significantly due to different variety (Table 15 and Appendix VII). The highest (26.14) vigour index of bush bean seed was observed from V_2 (BARI Bush bean -2) treatment and the lowest (17.74) vigour index of bush bean seed was observed from V_3 (BARI Bush bean -3) treatment. Grandi *et al*. (1999) found that P enrichment by soaking seeds in 200mM KH_2PO_4 solution improved the seedlings establishment.

Significant variation was obtained in case of vigour index of bush bean seed due to application of different levels of phosphorus (Table 16 and Appendix VIII). The highest (24.16) vigour index of bush bean seed was found from P_2 treatment (100 kg P /ha) and the lowest (20.46) vigour index of bush bean seed was observed from P_0 (control) treatment.

Vigour index of bush bean seed showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 17 and Appendix IX). The highest (100 %) vigour index of bush bean seed found from V_2P_2 (BARI Bush bean -2 and 100 kg P/ha) treatment combination and statistically similar to V_2P_1 and V_2P_3. On contrary, the lowest vigour index of bush bean seed (17.76) was observed from V_3P_0 (BARI Bush bean -3 and 00 kg P/ha) treatment combination, which was statistically similar to V_3P_0 ,V_3P_3 and V_3P_1 treatment combination. The increased vigour of P-enriched seed might be due to increased P content both inside the seeds and on the seed surfaces which leads to better establishment of seedlings (Bolland and Baker, 1988; Zhang *et al*., 1990; Thomson and Bolger, 1993; Ros *et al*., 1997). Similarly, the increase in seedling vigour due to salicylic acid may be due to enhanced oxygen uptake and the efficiency of mobilizing nutrients from the cotyledons to the embryonic axis (Kathiresan *et al*., 1984) and decreased catalase and peroxidase levels as recorded in pea seedlings (Srivastava and Dwivedi, 1998).

4.19 Effect on germination index

Effect on germination index of bush bean seed varied significantly due to different variety (Table 18 and Appendix VII). The highest (30.06) germination index of bush bean seed was observed from V_2 (BARI Bush Bean -2) treatment, which was statistically identical to V_1 (BARI Bush Bean -1) treatment and the lowest (19.78) germination index of bush bean seed was observed from V_3 (BARI Bush Bean -3) treatment.

Table 18: Effect of variety on germination index and coefficient of velocity

Treatments	Germination Index	Coefficient of velocity
V_1	27.95 b	19.14 b
V_2	30.06 a	19.44 a
V_3	19.78 c	17.89 c
S.E	0.238	0.05

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3

Significant variation was obtained in case of germination index of bush bean seed due to application of different levels of phosphorus (Table 19 and Appendix VIII). The highest germination index of bush bean seed (28.46) was found from P_2 treatment (100 kg P /ha). The lowest germination index of bush bean seed (24.60) was observed from P_0 (control) treatment, which was similar to P_3 (120 kg P/ha) treatment.

Table 19: Effect of phosphorous level on germination index and coefficient of velocity

Treatments	Germination Index	Coefficient of velocity
P_0	24.60 c	18.66 b
P_1	26.09 b	18.83 b
P_2	28.46 a	19.03 a
P_3	24.57 c	18.78 b
S.E	0.274	0.057

Different letter (s) corresponds to significant differences at $\leq$ 0.05 by Duncan's multiple nange tests
Here, P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

Germination index of bush bean seed showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 20 and Appendix IX). The highest (32.69) germination index of bush bean seed found from V_1P_2 treatment combination (BARI Bush Bean -1 and 100 kg P/ha), which was statistically similar to V_2P_2 treatment combination, which mean germination index was 31.46 also. On contrary, the lowest germination index of bush bean seed (19.30) was observed from V_3P_0 (BARI Bush Bean -3 and 00 kg P/ha) treatment combination, which was statistically similar to V_3P_3 and V_3P_1.

Table 20: Combined effect of variety and phosphorous level on germination index and coefficient of velocity

Treatments combination	Germination Index	Coefficient of velocity
V_1P_0	26.42 d	19.01
V_1P_1	28.01 c	18.96
V_1P_2	32.69 a	19.69
V_1P_3	24.69 e	18.91
V_2P_0	28.10 c	19.17
V_2P_1	30.55 b	19.59
V_2P_2	31.46 ab	19.45
V_2P_3	30.13 b	19.53
V_3P_0	19.30 g	17.80
V_3P_1	19.70 g	17.93
V_3P_2	21.23 f	17.95
V_3P_3	18.88 g	17.90
S.E	0.48	NS

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.20 Effect on coefficient of velocity

Effect on coefficient of velocity of bush bean seed varied significantly due to different variety (Table 18 and Appendix VII). The highest (19.44) coefficient of velocity of bush bean seed was observed from V_2 (BARI Bush Bean -2) treatment and the lowest (17.89) coefficient of velocity of bush bean seed was observed in V_3 (BARI Bush Bean -3) treatment.

Significant variation was obtained in case of coefficient of velocity of bush bean seed due to application of different levels of phosphorus (Table 19 and Appendix VIII). The highest coefficient of velocity of bush bean seed (19.03) was found from P_2 treatment (100 kg P /ha) and the lowest coefficient of velocity of bush bean seed (18.66) was observed from P_0 (control) treatment, which was similar to P_3 (120 kg P/ha) treatment.

Coefficient of velocity of bush bean seed showed statistically non significant variation due to the combined effect of variety and phosphorus application (Table 20 and Appendix IX).

4.21 Effect on shoot length

Effect on shoot length (cm) of bush bean seed varied significantly due to different variety (Table 21 and Appendix VII). The highest (11.53 cm) shoot length (cm) of bush bean seed was observed from V_2 (BARI Bush Bean -2) treatment and the lowest (8.05 cm) shoot length (cm) of bush bean seed was observed from V_3 treatment (BARI Bush Bean -3).

Table 21: Effect of varieties on shoot length and root length

Treatments	Shoot length(cm)	Root length(cm)
V_1	10.56 b	14.27 b
V_2	11.53 a	16.09 a
V_3	8.05 c	12.93 c
S.E	0.13	0.14

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3

Significant variation was obtained in case of shoot length (cm) of bush bean seed due to application of different levels of phosphorus (Table 22 and Appendix VIII). The highest (10.16) shoot length (cm) of bush bean seed was found from P_2 treatment (100 kg P /ha), which was statistically similar to 120 kg p/ha and similar to 80 kg p/ha. On contrary, the lowest (9.07) shoot length (cm) of bush bean seed was observed from P_0 (control) treatment.

Table 22: Effect of phosphorous level on shoot length and root length

Treatments	Shoot length(cm)	Root length(cm)
P_0	9.70 b	13.86 b
P_1	10.11 ab	14.45 a
P_2	10.16 a	14.68 a
P_3	10.22 a	14.72 a
S.E	.15	.17

Different letter (s) corresponds to significant differences at ≤ 0.05 by Duncan's multiple nange tests
Here, P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

Shoot length (cm) of bush bean seed showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 23 and Appendix IX). The highest (11.73) shoot length (cm) of bush bean seed found from V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination, which was statistically identical to V_2P_1 and V_2P_3. On contrary, the lowest shoot length (cm) of bush bean seed (8.36) was observed from V_3P_0 (BARI Bush Bean -3 and 00 kg P/ha) treatment combination, which was statistically similar to V_3P_3, V_3P_2 and V_3P_1.

Table 23: Combined effect of variety and phosphorous level on shoot length and root length

Treatments combination	Shoot length(cm)	Root length(cm)
V_1P_0	10.30 b	13.33 e
V_1P_1	10.50 b	14.20 d
V_1P_2	10.70 b	14.87 cd
V_1P_3	10.76 b	14.70 cd
V_2P_0	10.43 b	15.30 bc
V_2P_1	11.96 a	16.03 ab
V_2P_2	11.73 a	16.43 a
V_2P_3	12.00 a	16.60 a
V_3P_0	8.36 c	12.97 e
V_3P_1	7.86 c	13.13 e
V_3P_2	8.06 c	12.77 e
V_3P_3	7.90 c	12.87 e
S.E	0.26	0.29

Different letter (s) corresponds to significant differences at $\leq$ 0.05 by Duncan's multiple nange tests

Here, V_1 = BARI Bush Bean-1, V_2 = BARI Bush Bean-2, V_3= BARI Bush Bean-3
P_0 = 0 kg/ha, P_1 = 80 kg/ha, P_2= 100 kg/ha, P_3 = 120 kg/ha

4.22 Effect on root length

Effect on root length (cm) of bush bean seed varied significantly due to different variety (Table 21 and Appendix VII). The highest root length (cm) of bush bean seed (16.09 cm) was observed from V_2 (BARI Bush Bean -2) treatment and the lowest root length (cm) of bush bean seed (12.93 cm) was observed from V_3 treatment (BARI Bush bean -3).

Significant variation was obtained in case of root length (cm) of bush bean seed due to application of different levels of phosphorus (Table 22 and Appendix VIII). The highest root length (cm) of bush bean seed (14.72) was found from P_3 treatment (120 kg P /ha), which was statistically similar to P_2 treatment (100 kg P /ha) and similar to P_1 treatment (80 kg P /ha). On contrary, the lowest root length (cm) of bush bean seed was (13.86) observed from P_0 (control) treatment.

Root length (cm) of bush bean seed showed statistically significant variation due to the combined effect of variety and phosphorus application (Table 23 and Appendix IX). The highest (14.43) root length (cm) of bush bean seed found from V_2P_3 (BARI Bush Bean -2 and 120 kg P/ha) treatment combination, which was statistically similar to V_2P_2 treatment combination and similar to V_2P_1 treatment combination. On contrary, the lowest root length (cm) of bush bean seed (12.97) was observed from V_3P_0 (BARI Bush bean -3 and 00 kg P/ha) treatment combination, which was statistically similar to V_3P_3,V_3P_2 V_3P_1 and V_1P_0 treatments combination.

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was carried out at the Horticultural farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, to study the growth, seed yield and quality of bush bean as influenced by variety and phosphorous, during the period from November 2016 to March 2017. Two factors were involved in this experiment, namely. Factor A: three varieties of bush bean (BARI Bush Bean -1, BARI Bush Bean -2 and BARI Bush Bean -3) and Factor B: four levels of Phosphorus (0, 80, 100 and 120 kg/ha).

The two factors experiment was laid out in a Randomized Complete Block (RCBD) design containing twelve treatments with 3 replications. The unit plot size was 1.2 m x 0.9 m. There were twelve numbers of treatments and total numbers of plots were thirty-six. Data were collected based on the following parameters- plant height, number of leaves per plant, number of branches per plant, leaf length at 45 DAS, leaf breadth at 45 DAS, days of germination, days of first flowering, number of pods per plant, number of seed per pod, weight of seed per plant, weight of seed per plot, weight of seed per hectare, length of dry pod, diameter of dry pod, weight of thousand seed. The data on germination parameters of bush bean like total germination percentage, mean germination time, germination index, coefficient of velocity, energy of emergence and growth parameters like plumule length, root length, and vigour index. The collected data were analyzed statistically by variances (ANOVA) of data on different characters and yield of bush bean.

Most of the parameters significantly influenced by different varieties and it was revealed the result of the experiment.

At harvest, maximum plant height was (63.92cm), the highest number of leaves per plant was (33.72), maximum leaf breadth was (10.88 cm) were found from

V_3 (BARI Bush bean-3) treatment. The minimum plant height was found in Bush bean-1 (47.77cm), the lowest number of leaves per plant was (19.87), the minimum leaf breadth was (9.67 cm), observed from (BARI Bush Bean -1) V_1 treatment. Maximum numbers of branch was (11.02), the longest length of leaf was (17.29 cm), the maximum number of pods per plant (27.83), the highest weight bush bean seed per plant was (26.65 g), the highest weight bush bean seed per plot was (373.70 g), the highest weight of bush bean seed per hectare was (3.46 ton), the highest total germination of bush bean seed was (94.58 %), the highest energy of emergence of bush bean seed was (100 %), the highest vigour index of bush bean seed was (26.14), the highest germination index of bush bean seed was (30.06), the highest coefficient of velocity of bush bean seed was (19.44), the highest shoot length (cm) of bush bean seed was (11.53 cm), the highest (16.09 cm) root length (cm) of bush bean seed was produced from V_2 (BARI Bush Bean -2) treatment, the minimum numbers of branch (6.70), the minimum number of pods per plant (10.20), The longest diameter of bush bean dry pod was (1.06 cm), the highest weight of 1000 bush bean seed was (356.00 gm), the lowest weight of bush bean seed per plant was (16.03 g), the lowest weight of bush bean seed per plot was (228.96 g), the lowest weight of bush bean seed per hectare was (2.12 ton), the lowest total germination of bush bean seed was (94.58 %), the lowest total germination of bush bean seed was (86.67 %), the lowest vigour index of bush bean seed was (17.74), the lowest germination index of bush bean seed was (19.78), the lowest coefficient of velocity of bush bean seed was (17.89), the lowest shoot length (cm) of bush bean seed was (8.05 cm), the lowest root length (cm) of bush bean seed was (12.93 cm) was observed from V_3 (BARI Bush Bean-3) treatment. The shortest diameter of bush bean dry pod was (0.69 cm), the lowest weight of 1000 bush bean seed was (224.00 g) found from V_2 (BARI Bush bean -2) treatment.

In case of V_1, it was taken (6.58 days) highest time to germinate. On the other hand, V_3 was taken (4.33 days) shortest time to germinate. The longest period

(42.08 days) required for first flower initiation from V_1 (BARI Bush Bean -1) treatment. The shortest period (32.92 days) for first flowering was obtained from V_1 (BARI Bush Bean -1) treatment.

The maximum number of seeds per pod was (6.25), the longest (14.59 cm) pod length was obtained for V_1 (BARI Bush Bean -1) treatment. The minimum (4.75) number of seeds per pod of French bean was found for V_3 (BARI Bush bean -3) treatment. The shortest (11.08 cm) dry pod length of bush bean was observed in V_2 (BARI Bush bean-2) treatment.

On growth of yield contributing characters of bush bean, phosphorous played an important role. At harvest, the tallest plant height was (60.84 cm), the highest number of leaves per plant was (29.53), the largest leaf breadth was (10.76 cm), the highest number of seeds per dry pod (6.00) produced from P_3 treatment (120 kg P/ha). Highest number of branch was (10.72), the longest leaf length was (17.06 cm), the highest number of pods per plant (21.92), the longest length of dry pod (14.23 cm), the longest diameter of bush bean dry pod was (1.06 cm), the highest weight of 1000 bush bean seed was (289.22 g), the highest weight of bush bean seed per plant was (25.99 g), the highest weight of bush bean seed per plot was (371.04 g), the highest weight of bush bean seed per hectare was (3.44 ton), the highest total germination of bush bean seed was (96.67 %), the highest total germination of bush bean seed was (97.22 %), the highest vigour index of bush bean seed was (24.16), the highest germination index of bush bean seed was (28.46), the highest coefficient of velocity of bush bean seed was (19.03), the highest shoot length (cm) of bush bean seed was (10.1), the highest root length (cm) of bush bean seed was (14.43) found from P_2 treatment (100 kg P/ha).

The shortest plant was (51.60 cm), the lowest number of leaves per plant was (23.35), the lowest number of branch (6.66), shortest leaf length was (15.98 cm), the smallest leaf breadth (10.45 cm), the lowest number of flowers per plant (16.27), the lowest number of seeds per dry pod (4.85), the shortest length

of dry pod (12.42 cm), the shortest diameter of bush bean dry pod was (0.81 cm), the lowest weight of 1000 bush bean seed was (271.78 g), the lowest weight of bush bean seed per plant was (16.97 g), the lowest weight of bush bean seed per plot was (240.13 g), the lowest weight of bush bean seed per hectare was (2.22 ton), the lowest total germination of bush bean seed was (86.67%), the lowest total germination of bush bean seed was (86.67%), the lowest total germination of bush bean seed was (86.67%), the lowest vigour index of bush bean seed was (20.46), the lowest germination index of bush bean seed was (24.60), the lowest coefficient of velocity of bush bean seed was (18.66), the lowest shoot length (cm) of bush bean seed was (9.07), the lowest root length (cm) of bush bean seed was (13.86) was produced from P_0 treatment (control).

The longest period (38.56 days) was required for first flower initiation from P_3 (120 kg P/ha) treatment. The shortest period (39.267 days) for first flowering was found from Po (control) treatment.

Combined effect of variety and different levels of phosphorous application showed significant effect on growth and yield of bush bean at different days after sowing (DAS). At harvest, the tallest plant was (67.47 cm), the highest number of leaves per plant was recorded (37.04), produced from V_3P_3 treatment combination (BARI Bush Bean-3 and 120 kg P/ha). The highest number of branch was (13.03), the longest length of leaf was (17.93 cm), the highest pod per plant (31.43), the highest weight of bush bean seed per plant was (30.68 gm), the highest weight of bush bean seed per plot was (431.57 g), the highest weight of bush bean seed per hectare was (3.99 ton), the highest total germination of bush bean seed was (100 %), the highest total germination of bush bean seed was (100%), the highest vigour index of bush bean seed was (100%), the highest shoot length (cm) of bush bean seed was (11.73) were recorded from V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination. The longest (6.67) days of germination was produced from V_1P_1 (BARI Bush Bean -1 and 80 kg P/ha) treatment combination. The highest

number of seeds per dry pod was (7.00), the longest length of dry pod was (15.90 cm), the highest germination index of bush bean seed was (32.69) required from V_1P_2 (BARI Bush Bean -1 and 100 kg P/ha) treatment combination. The longest period (41.67 days) required for first flower initiation from V_1P_3 (BARI Bush Bean -1 and 120 kg P/ha) treatment combination.

At harvest, shortest plant was (40.89 cm) and the lowest number of leaves per plant was (17) produced from V_1P_0 treatment combination. The lowest number of branch was (5.28), the lowest number of pod per plant (7.93), the lowest weight of bush bean seed was (230.33 g), the lowest weight of bush bean seed per plot was (162.44 gm), the lowest weight of bush bean seed per hectare was (1.50 ton), the lowest vigour index of bush bean seed (17.76) the lowest number of dry pod per plant (4.75), the lowest total germination of bush bean seed was (80 %), the lowest germination index of bush bean seed was (19.30), the lowest shoot length (cm) of bush bean seed was (8.36), the lowest root length (cm) of bush bean seed was (12.97) observed from V_3P_0 (BARI Bush Bean -3 and control) treatment combination. The lowest length of leaf was (13.87 cm) observed from (control) V_1P_0 treatment combination. The shortest days of germination was (3.67), the longest diameter of dry pod was (1.20 cm) produced by V_3P_2 (BARI Bush bean -3 and 100 kg P/ha) treatment combination. The shortest diameter of (.67 cm) dry pod was observed from V_2P_0 (BARI Bush Bean -2 and control) treatment combination.

The highest (365.67 g) weight of 1000 bush bean seed found from V_3P_2 (BARI Bush bean -3 and 100 kg P/ha) treatment combination and the lowest weight of 1000 bush bean seed (230.33 gm) dry pod was observed from V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination.

The lowest total germination of bush bean seed (80 %) was observed from V_3P_3 (BARI Bush Bean -3 and 00 kg P/ha) treatment combination. The highest root length (14.43 cm) of bush bean seed found from V_2P_3 (BARI Bush Bean -2 and 120 kg P/ha) treatment combination.

Conclusion:

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

- BARI Bush Bean -3 (V_3) variety was the more promising for vegetative and reproductive growth as a new variety than BARI Bush Bean -1 (V_1) and BARI Bush Bean -2 (V_2), in this investigation.
- The level of phosphorus (100 kg/ha) was found higher seed yield of bush bean.
- During the investigation, V_2P_2 (BARI Bush Bean -2 and 100 kg P/ha) treatment combination was observed better seed yield of bush bean than others.

Considering the situation of the present experiment for regional adaptability and other performances, further study might be needed to conduct in different agro-ecological zones (AEZ) of Bangladesh. However, the experiment was conducted in one season only and hence the results should be considered as a tentative. Similar experiment should be carried out with more variables to reconfirm the recommendation.

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APPENDICES

Appendix I the mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	5.45-6.61
Total N (%)	:	0.09
Available P (µ gm/gm)	:	18.49
Exchangeable K (meq)	:	0.09
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.38
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.85

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

Appendix II Monthly records of temperature, rainfall, and relative humidity of the experiment site during the period from November 2015 to March 2016

Year	Month	Air temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2015	November	29.5	18.6	24.0	69.5	0.0	233.2
	December	26.9	16.2	21.5	70.6	0.0	210.5
2016	January	24.5	13.9	19.2	68.5	1.0	194.1
	February	28.9	18.0	23.4	61.0	2.0	221.5
	March	33.6	29.5	31.6	72.7	3.0	227.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-121

Appendix III Effect of variety on plant height at different days after sowing of bush bean

Treatments	Plant height(cm)			
	30 DAS	45 DAS	60 DAS	At Harvest
V_1	31.05c	38.83c	43.83c	47.77c
V_2	41.11b	48.90b	53.89b	57.84b
V_3	47.20a	54.98a	59.98a	63.92a
S.E	.685	.719	.506	.473

Appendix IV Effect of phosphorus on plant height at different days after sowing of bush bean

Treatments	Plant height			
	30 DAS	45 DAS	60 DAS	At Harvest
P_0	34.88d	42.66d	47.66d	51.60d
P_1	38.73c	46.52c	51.51c	55.45c
P_2	41.41b	49.19b	54.20b	58.13b
P_3	44.12a	51.91a	56.90a	60.84a
S.E	.791	.830	.584	.546

Appendix V Effect of variety on number of leaves per plant at different days after sowing of bush bean

Treatments	Leaves/plant(cm)				Branch/plant(cm)		
	15 DAS	30 DAS	45 DAS	60 DAS	45 DAS	60 DAS	At Harvest
V_1	3.00	9.96c	14.98c	19.87c	5.19b	7.70b	9.04b
V_2	2.67	16.38b	21.40b	26.29b	7.17a	9.68a	11.02a
V_3	2.912	23.81a	28.83a	33.72a	2.88c	5.38c	6.73c
S.E	.167	.210	.210	.210	.105	.105	.105

Appendix VI Effect of phosphorus on number of leaves at different days after sowing of bush bean

Treatments	Leaves/plant(cm)				Branch/plant(cm)		
	15 DAS	30 DAS	45 DAS	60 DAS	45 DAS	60 DAS	At Harvest
P_0	2.66	13.44d	18.46d	23.35d	2.81d	5.32d	6.66d
P_1	2.88	15.92c	20.94c	25.83c	5.05c	7.56c	8.89c
P_2	3.00	17.89b	22.92b	27.81b	6.86a	9.38a	10.72a
P_3	2.88	19.62a	24.64a	29.53a	5.61b	8.12b	9.46b
S.E	.19	.24	.25	.23	.12	.13	.11

Appendix VII Effect on variety on different parameters

Analysis of variance on plant height at 30 DAS

SV	df	SS	MS	F-value	Significant level
A	2	1596.372	798.186	44.641	.000
B	33	590.044	17.880		
AB	35	2186.417			

Analysis of variance on plant height at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	2	1596.372	798.186	43.634	.000
B	33	603.666	18.293		
AB	35	2200.038			

Analysis of variance on plant height at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	2	1596.372	798.186	49.817	.000
B	33	528.740	16.022		
AB	35	2125.113			

Analysis of variance on plant height at harvest

SV	df	SS	MS	F-value	Significant level
A	2	1596.372	798.186	50.716	.000
B	33	519.365	15.738		
AB	35	2115.738			

Analysis of variance leaf per plant at 15 DAS

SV	df	SS	MS	F-value	Significant level
A	2	.722	.361	1.243	.302
B	33	9.583	.290		
AB	35	10.306			

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Analysis of variance leaf per plant at 30 DAS

SV	df	SS	MS	F-value	Significant level
A	2	1152.982	18.250	7.575	.002
B	33	207.682	2.409		
AB	35	1360.664			

Analysis of variance leaf per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	2	1152.982	576.491	91.602	.000
B	33	207.682	6.293		
AB	35	1360.664			

Analysis of variance leaf per plant at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	2	1152.982	576.491	91.602	.000
B	33	207.682	6.293		
AB	35	1360.664			

Analysis of variance branch per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	2	110.946	55.473	21.478	.000
B	33	85.232	2.583		
AB	35	196.178			

Analysis of variance branch per plant at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	2	110.946	55.473	21.478	.000
B	33	85.232	2.583		
AB	35	196.178			

Analysis of variance branch per plant at harvest

SV	df	SS	MS	F-value	Significant level
A	2	110.946	55.473	21.478	.000
B	33	85.232	2.583		
AB	35	196.178			

Analysis of variance leaf length per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	2	21.682	10.841	4.159	.025
B	33	86.018	2.607		
AB	35	107.700			

Analysis of variance leaf breadth per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	2	11.072	5.536	5.560	.008
B	33	32.858	.996		
AB	35	43.930			

Analysis of variance days of germination

SV	df	SS	MS	F-value	Significant level
A	2	30.389	15.194	47.378	.000
B	33	10.583	.321		
AB	35	40.972			

Analysis of variance days of first flowering

SV	df	SS	MS	F-value	Significant level
A	2	509.722	254.861	109.940	.000
B	33	76.500	2.318		
AB	35	586.222			

Analysis of variance pod per plant

SV	df	SS	MS	F-value	Significant level
A	2	1866.367	933.184	142.143	.000
B	33	216.649	6.565		
AB	35	2083.016			

Analysis of variance number of seed per plant

SV	df	SS	MS	F-value	Significant level
A	2	14.434	7.217	21.812	.000
B	33	10.919	.331		
AB	35	25.353			

Analysis of variance weight of seed per plant

SV	df	SS	MS	F-value	Significant level
A	2	703.965	351.982	24.209	.000
B	33	479.805	14.540		
AB	35	1183.770			

Analysis of variance weight of seed per plot

SV	df	SS	MS	F-value	Significant level
A	2	281585.959	140792.979	24.209	.000
B	33	191921.878	5815.814		
AB	35	473507.837			

Analysis of variance weight of seed per hectare

SV	df	SS	MS	F-value	Significant level
A	2	11.492	5.746	24.022	.000
B	33	7.893	.239		
AB	35	19.385			

Analysis of variance length of dry pod

SV	df	SS	MS	F-value	Significant level
A	2	96.607	48.303	85.759	.000
B	33	18.587	.563		
AB	35	115.193			

Analysis of variance diameter of dry pod

SV	df	SS	MS	F-value	Significant level
A	2	.999	.499	52.840	.000
B	33	.312	.009		
AB	35	1.311			

Analysis of variance weight of 1000 seed

SV	df	SS	MS	F-value	Significant level
A	2	109610.889	54805.444	1020.835	.000
B	33	1771.667	53.687		
AB	35	111382.556			

Analysis of variance of total germination

SV	df	SS	MS	F-value	Significant level
A	2	634.722	317.361	8.637	.001
B	33	1212.500	36.742		
AB	35	1847.222			

Analysis of variance of energy of emergence

SV	df	SS	MS	F-value	Significant level
A	2	1301.389	650.694	78.679	.000
B	33	272.917	8.270		
AB	35	1574.306			

Analysis of variance of vigour index

SV	df	SS	MS	F-value	Significant level
A	2	428.602	214.301	56.149	.000
B	33	125.951	3.817		
AB	35	554.553			

Analysis of variance of germination index

SV	df	SS	MS	F-value	Significant level
A	2	708.283	354.142	77.815	.000
B	33	150.186	4.551		
AB	35	858.469			

Analysis of variance of coefficient of velocity

SV	df	SS	MS	F-value	Significant level
A	2	16.065	8.032	118.442	.000
B	33	2.238	.068		
AB	35	18.303			

Analysis of variance of shoot length

SV	df	SS	MS	F-value	Significant level
A	2	77.607	38.803	118.529	.000
B	33	10.803	.327		
AB	35	88.410			

Analysis of variance of root length

SV	df	SS	MS	F-value	Significant level
A	2	60.302	30.151	74.151	.000
B	33	13.418	.407		
AB	35	73.720			

Appendix VIII Effect on phosphorous on different parameters

Analysis of variance on plant height at 30 DAS

SV	df	SS	MS	F-value	Significant level
A	3	419.683	139.894	2.534	.074
B	32	1766.734	55.210		
AB	35	2186.417			

Analysis of variance on plant height at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	3	419.683	139.894	2.514	.076
B	32	1780.356	55.636		
AB	35	2200.038			

Analysis of variance on plant height at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	3	419.683	139.894	2.625	.067
B	32	1705.430	53.295		
AB	35	2125.112			

Analysis of variance on plant height at harvest

SV	df	SS	MS	F-value	Significant level
A	3	419.683	139.894	2.639	.066
B	32	1696.055	53.002		
AB	35	2115.738			

Analysis of variance on leaf per plant at 15 DAS

SV	df	SS	MS	F-value	Significant level
A	3	.528	.176	.576	.635
B	32	9.778	.306		
AB	35	10.306			

Analysis of variance on leaf per plant at 30 DAS

SV	df	SS	MS	F-value	Significant level
A	3	190.750	63.583	1.739	.179
B	32	1169.914	36.560		
AB	35	1360.664			

Analysis of variance on leaf per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	3	190.750	63.583	1.739	.179
B	32	1169.914	36.560		
AB	35	1360.664			

Analysis of variance on leaf per plant at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	3	190.750	63.583	1.739	.179
B	32	1169.914	36.560		
AB	35	1360.664			

Analysis of variance on branch per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	3	77.667	25.889	6.990	.001
B	32	118.511	3.703		
AB	35	196.178			

Analysis of variance on branch per plant at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	3	77.667	25.889	6.990	.001
B	32	118.511	3.703		
AB	35	196.178			

Analysis of variance on branch per plant at harvest

SV	df	SS	MS	F-value	Significant level
A	3	77.667	25.889	6.990	.001
B	32	118.511	3.703		
AB	35	196.178			

Analysis of variance on leaf length per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	3	6.833	2.278	.723	.546
B	32	100.867	3.152		
AB	35	107.700			

Analysis of variance on leaf breadth per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	3	2.872	.957	.746	.533
B	32	41.058	1.283		
AB	35	43.930			

Analysis of variance on days of germination

SV	df	SS	MS	F-value	Significant level
A	3	1.861	.620	.508	.680
B	32	39.111	1.222		
AB	35	40.972			

Analysis of variance on days of first flowering

SV	df	SS	MS	F-value	Significant level
A	3	27.333	9.111	.522	.670
B	32	558.889	17.465		
AB	35	586.222			

Analysis of variance on pod per plant

SV	df	SS	MS	F-value	Significant level
A	3	158.536	52.845	.879	.462
B	32	1924.480	60.140		
AB	35	2083.016			

Analysis of variance on number of seed per plant

SV	df	SS	MS	F-value	Significant level
A	3	7.936	2.645	4.860	.007
B	32	17.417	.544		
AB	35	25.353			

Analysis of variance on weight of seed per plant

SV	df	SS	MS	F-value	Significant level
A	3	406.244	135.415	5.573	.003
B	32	777.525	24.298		
AB	35	1183.770			

Analysis of variance on weight of seed per plot

SV	df	SS	MS	F-value	Significant level
A	3	84880.876	28293.625	6.411	.002
B	32	141225.858	4413.308		
AB	35	226106.734			

Analysis of variance on weight of seed per hectare

SV	df	SS	MS	F-value	Significant level
A	3	7.277	2.426	6.411	.002
B	32	12.108	.378		
AB	35	19.385			

Analysis of variance on length of dry pod

SV	df	SS	MS	F-value	Significant level
A	3	15.913	5.304	1.710	.185
B	32	99.280	3.103		
AB	35	115.193			

Analysis of variance on diameter of dry pod

SV	df	SS	MS	F-value	Significant level
A	3	.211	.070	2.047	.127
B	32	1.100	.034		
AB	35	1.311			

Analysis of variance on weight of 1000 seed

SV	df	SS	MS	F-value	Significant level
A	3	1558.333	519.444	.151	.928
B	32	109824.222	3432.007		
AB	35	111382.556			

Analysis of variance on total grmination

SV	df	SS	MS	F-value	Significant level
A	3	658.333	219.444	5.907	.003
B	32	1188.889	37.153		
AB	35	1847.222			

Analysis of variance on energy of emergence

SV	df	SS	MS	F-value	Significant level
A	3	57.639	19.213	.405	.750
B	32	1516.667	47.396		
AB	35	1574.306			

Analysis of variance on vigour index

SV	df	SS	MS	F-value	Significant level
A	3	66.284	22.095	1.448	.247
B	32	488.268	15.258		
AB	35	554.553			

Analysis of variance on germination index

SV	df	SS	MS	F-value	Significant level
A	3	90.325	30.108	1.254	.307
B	32	768.144	24.004		
AB	35	858.469			

Analysis of variance on coefficient of velocity

SV	df	SS	MS	F-value	Significant level
A	3	.642	.214	.388	.763
B	32	17.661	.552		
AB	35	18.303			

Analysis of variance on shoot length

SV	df	SS	MS	F-value	Significant level
A	3	1.526	.509	.187	.904
B	32	86.884	2.715		
AB	35	88.410			

Analysis of variance on root length

SV	df	SS	MS	F-value	Significant level
A	3	4.233	1.411	.650	.589
B	32	69.487	2.171		
AB	35	73.720			

Appendix IX Combined effect on variety and phosphorous on different parameters

Analysis of variance on plant height at 30 DAS

SV	df	SS	MS	F-value	Significant level
A	11	2051.321	186.484	33.129	.000
B	24	135.095	5.629		
AB	35	2186.417			

Analysis of variance on plant height at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	11	2051.321	186.484	30.095	.000
B	24	148.717	6.197		
AB	35	2200.038			

Analysis of variance on plant height at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	11	2051.321	186.484	30.095	.000
B	24	148.717	6.197		
AB	35	2200.038			

Analysis of variance on plant height at harvest

SV	df	SS	MS	F-value	Significant level
A	11	2051.321	186.484	30.095	.000
B	24	148.717	6.197		
AB	35	2200.038			

Analysis of variance on leaf per plant at 15 DAS

SV	df	SS	MS	F-value	Significant level
A	11	2.306	.210	.629	.787
B	24	8.000	.333		
AB	35	10.306			

Analysis of variance on leaf per plant at 30 DAS:

SV	df	SS	MS	F-value	Significant level
A	11	64.000	122.547	232.501	.000
B	24	52.000	.527		
AB	35	116.000			

Analysis of variance on leaf per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	11	103.639	122.547	232.501	.000
B	24	278.667	.527		
AB	35	382.306			

Analysis of variance on leaf per plant at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	11	1348.014	122.547	232.501	.000
B	24	12.650	.527		
AB	35	1360.664			

Analysis of variance on branch per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	11	193.028	17.548	133.699	.000
B	24	3.150	.131		
AB	35	196.178			

Analysis of variance on branch per plant at 60 DAS

SV	df	SS	MS	F-value	Significant level
A	11	193.028	17.548	133.699	.000
B	24	3.150	.131		
AB	35	196.178			

Analysis of variance on branch per plant at harvest:

SV	df	SS	MS	F-value	Significant level
A	11	193.028	17.548	133.699	.000
B	24	3.150	.131		
AB	35	196.178			

Analysis of variance on leaf length per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	11	43.100	3.918	1.456	.213
B	24	64.600	2.692		
AB	35	107.700			

Analysis of variance on leaf breadth per plant at 45 DAS

SV	df	SS	MS	F-value	Significant level
A	11	20.290	1.845	1.873	.096
B	24	23.640	.985		
AB	35	43.930			

Analysis of variance on days of germination

SV	df	SS	MS	F-value	Significant level
A	11	32.972	2.997	8.992	.000
B	24	8.000	.333		
AB	35	40.972			

Analysis of variance on days of first flowering

SV	df	SS	MS	F-value	Significant level
A	11	546.222	49.657	29.794	.000
B	24	40.000	1.667		
AB	35	586.222			

Analysis of variance on pod per plant

SV	df	SS	MS	F-value	Significant level
A	11	2036.203	185.109	94.901	.000
B	24	46.813	1.951		
AB	35	2083.016			

Analysis of variance on number of seed per plant

SV	df	SS	MS	F-value	Significant level
A	11	25.341	2.304	4821.829	.000
B	24	.011	.000		
AB	35	25.353			

Analysis of variance on weight of seed per plant

SV	df	SS	MS	F-value	Significant level
A	11	1121.687	101.972	39.420	.000
B	24	62.082	2.587		
AB	35	1183.770			

Analysis of variance on weight of seed per plot

SV	df	SS	MS	F-value	Significant level
A	11	220058.845	20005.350	79.388	.000
B	24	6047.889	251.995		
AB	35	226106.734			

Analysis of variance on weight of seed per hectare

SV	df	SS	MS	F-value	Significant level
A	11	18.866	1.715	79.388	.000
B	24	.519	.022		
AB	35	19.385			

Analysis of variance on length of dry pod

SV	df	SS	MS	F-value	Significant level
A	11	114.424	10.402	324.336	.000
B	24	.770	.032		
AB	35	115.193			

Analysis of variance on diameter of dry pod

SV	df	SS	MS	F-value	Significant level
A	11	1.295	.118	185.116	.000
B	24	.015	.001		
AB	35	1.311			

Analysis of variance on weight of 1000 seed

SV	df	SS	MS	F-value	Significant level
A	11	111264.556	10114.960	2057.280	.000
B	24	118.000	4.917		
AB	35	111382.556			

Analysis of variance on total germination

SV	df	SS	MS	F-value	Significant level
A	11	1397.222	127.020	6.774	.000
B	24	450.000	18.750		
AB	35	1847.222			

Analysis of variance on energy of emergence

SV	df	SS	MS	F-value	Significant level
A	11	1440.972	130.997	23.580	.000
B	24	133.333	5.556		
AB	35	1574.306			

Analysis of variance on vigour index

SV	df	SS	MS	F-value	Significant level
A	11	520.325	47.302	33.168	.000
B	24	34.228	1.426		
AB	35	554.553			

Analysis of variance on germination index

SV	df	SS	MS	F-value	Significant level
A	11	842.198	76.563	112.935	.000
B	24	16.271	.678		
AB	35	858.469			

Analysis of variance on coefficient of velocity

SV	df	SS	MS	F-value	Significant level
A	11	17.605	1.600	55.043	.000
B	24	.698	.029		
AB	35	18.303			

Analysis of variance on shoot length

SV	df	SS	MS	F-value	Significant level
A	11	83.443	7.586	36.656	.000
B	24	4.967	.207		
AB	35	88.410			

Analysis of variance on root length

SV	df	SS	MS	F-value	Significant level
A	11	67.807	6.164	25.018	.000
B	24	5.913	.246		
AB	35	73.720			