ROOT GROWTH, DRY MATTER ACCUMULATION, NUTRIENT UPTAKE AND YIELD OF MUNGBEAN VARIETIES AS INFLUENCED BY PHOSPHORUS

By

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CERTIFICATE

This is to certify that thesis entitled, "Root growth, dry matter accumulation, nutrient uptake and yield of mungbean varieties as influenced by phosphorus" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of Master of Science in Agronomy, embodies the result of a piece of *bona fide* research work carried out by Jasmine Ara Chowdhury, Roll No. 01845 Registration No. 01845 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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DEDICATED TO
MY
BELOVED PARENTS

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The Author

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ABSTRACT

An investigation was carried out to evaluate the effect of P levels on root growth, dry matter accumulation, nutrient uptake pattern and yield of mungbean varieties at the research field of Sher-e-Bangla Agricultural University, Sher-e Bangla Nagar, Dhaka during kharif II season of 2006. Four varieties of mungbean (BARI mung-2, BARI mung-6, BU mung-4 and BINA mung-5) and four levels of phosphorus (0, 9, 18 and 27 kg P ha^{-1}) were the treatment variables. The experiment was laid out in a split plot design with 3 replications. Varieties were randomly arranged to the main plot and phosphorus levels in the sub plot. Plant growth, yield and yield attributes were significantly influenced by different varieties. The highest root growth, total dry matter production, nodule number and dry weight were obtained from the variety BU mung-4. Higher pod length, pods $plant^{-1}$, seeds pod^{-1} and 1000 seed weight were also recorded for BU mung-4. The highest seed yield was found in BU mung-4. Over all performance of BU mung-4 was better than other three varieties indicating the genetic superiority. The growth, yield and yield attributes increased with increasing levels of P up to 27 kg ha^{-1}. Application of 27 kg P ha^{-1} gave the highest yield and yield attributes which was similar to 18 kg P ha^{-1}. The contents of NPK in mungbean stem, leaf and seed varied significantly due to the variations in P rates. Application of 27 kg P ha^{-1} also gave the highest content of NPK. Variety BU mung-4 responded favorably to P fertilization upto 27 kg P ha^{-1} in terms of root growth, dry matter, yield and yield attributes and it was statistically identical with 18 kg P ha^{-1}. The experimental results suggest that application of 18-27 kg P ha^{-1} for BU mung-4 would be needed for obtaining moderate yield on Grey Terrace Soil of AEZ-28.

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LIST OF ACRONYMS

AEZ	Agro- Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
CGR	Crop growth rate
cm	Centi-meter
cm^2	Centi-meter squares
DAE	Days After Emergence
et al.	And others
FAO	Food and Agricultural Organization
g	Gram (s)
HI	Harvest Index
K	Potassium
K_2O	Potassium Oxide
kg	Kilogram (s)
LAI	Leaf area index
LSD	Least Significant Difference
MP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
P	Phosphorus
P_2O_5	Phosphorus Penta Oxide
RL	Root length
RLD	Root length density
RMD	Root mass density
SAU	Sher-e- Bangla Agricultural University
TDM	Total Dry Matter
TSP	Triple Superphosphate
^0C	Degree Celsius
%	Percentage

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Pulse is the group of food legumes supplying protein to human diet. It is a part and parcel, particularly in Asian diets. Food and Agriculture Organization (FAO) recommends a consumption of 45 g pulses per head per day in diets to fulfill the protein requirement (BARI, 1999). The total cultivable land of Bangladesh is 14.08 million hectares out of which 0.73 million hectares is used for cultivation of pulses. This area constituted only 5.3% of the total cultivable land. The present production of pulse is about 0.32 million tons, which can provide only 10 g per capita per day (BBS, 2005). But to provide the above mentioned requirement of 45 g the production is to be increased even more than three folds (BARI, 1999). Mungbean (*Vigna radiata* L.) is an ancient and widely distributed leguminous crop of central, southern, and eastern Asia. It is a short duration crop with low nutrient demand (Gomez and Gomez, 1983). The capacity of biological nitrogen fixation and high seed protein content of mungbean makes it a high value crop in terms of sustainable agricultural production in the tropics. Mungbean is an excellent source of easily digestible protein of low flatulence. It complements the staple rice diet in Asia (Fernandez and Shanmugasundaram, 1988). In Bangladesh it is used as whole or split seeds as dhal (soup) but in other countries sprouted seeds are widely used as vegetable. The plants are used as animal feed, and the residues as manure. The crop is potentially useful in improving cropping systems as catch crop due to its rapid growth and early maturing characteristics.

Mungbean is the fifth most important pulse crop of Bangladesh which was grown on ~44000 hectares producing 30,000 metric tones (BBS, 2004). In Bangladesh, it is grown in the rabi, kharif-I and kharif-II season. Only 5% of the total mungbean are grown in kharif-I season (March/April.), where as 30% in Kharif-II season (Aug/Sept) and 65% are grown in late rabi, January/February (Rahman, 1994). The average yield of mungbean is very low as compared to others mungbean growing countries. The potential yield (1.1 t/ha) is much higher than the average yield of 0.6 t/ha (BBS, 2004). The reasons for low yields are non-availability of high yielding varieties, the use of low levels of inputs, lack of knowledge of new inputs and techniques, poor photosynthetic efficiency and inadequate use of plant nutrients, particularly P. Phosphorus, a key constituent of ATP has a significant role in the energy transformation in plants and in various physiological process (Sivasankar *et at.*, 1982). Phosphorus is present in nucleic acids and nucleotides, phospholipids and sugar phosphates and in many other enzymes. It also needed for energy storage and release in living cells. Phosphorus deficiency causes yield reduction by limiting plant growth (Poehlman, 1991). Crop yield is often found to be directly proportional to the root distribution or rooting pattern (Singh *et al.*, 1999). For nutrient uptake, plant depends heavily on the root morphology because root system morphology is the determinant of the functions such as soil exploitation, for water and nutrient absorption. Root development is controlled by various factors including growth hormones, soil temperature, the nutrient concentration in the root zone etc. Plant ability to root system development also differs a great deal among the genotypes. Influence of phosphorus on root development is well documented. The movement of phosphorus is less in the soil and major segment of P uptake by the plant is through root interceptions. It follows that the amount of P uptake depends on the concentration of available P and the extent of the ramification of the root system of the crop (Schenk and Barber, 1979). Root penetration is often prevented by poor aeration and low P availability (Arihara and Okada, 1991). However, phosphorus influences nutrient uptake by promoting root growth, nodulation and specific nodule activity and there by ensuring a good pod yield through increase in total dry matter (Sharma and Yadav, 1976). Mungbean responds favourably to phosphors fertilization (Das, 1993; Chowdhury, 1996). By promoting more extension and deeper root growth, P enables the crops to draw water and nutrients from deeper soil layer. In adequate P supply results in dramatic decreases in plant growth and development. Phosphorus deficiency in legume results in poor root development, poor pods setting and subsequently reduces pod yield (Jain *et al.*, 1990). Mobilization of nutrient element takes place within the plant during its life cycle. The extent of remobilization of the element however, depends on the availability of these elements (N, P and K) in the plant and demand of photosynthesis. Phosphorus is important in determining seed or grain quality and the ability of the plant to produce high yield by increasing leaf area as well as total dry matter (Douglas and Weaven, 1986). Sharma and Singh (1997) observed that the dry matter accumulation and yield of mungbean was increased significantly with increasing level of phosphorus up to 50 kg/ha P_2O_5. It might be due to the fact that P application improves the root system through accelerating various metabolic processes such as cell division, cell development and cell enlargement.

Systematic and comprehensive research effort on P in order to increase yield potential, dry matter accumulation, nutrient uptake and root growth relationships of mungbean varieties are inadequate. Information on the response of physiological characters, nutrient uptake and root growth of mungbean to the added fertilizer is scanty or sporadic. Considering the facts as stated the present investigation was carried out with the following objectives:

i) to evaluate the varietal performance in root growth and dry matter accumulation of mungbean

ii) to evaluate varietal variations in nutrient uptake pattern in relation to root growth and dry matter production

iii) to determine yield performance of mungbean varieties in relation to the root system developments and

iv) to identify the optimum phosphorus level of kharif-II mungbean for obtaining higher yield.

Chapter 2
Review of literature

CHAPTER 2

REVIEW OF LITERATURE

A good number of research works have been carried on various aspects of management practices for higher productivity of mungbean. Still intensive research work on improving its yield and quality is in progress. Grain yield and quality of mungbean are complex characters and these are contributed by many morphological and physiological events. The present study is related to grain yield of mungbean varieties as influenced by different rates of phosphorus fertilizer. The information available on this area generated from different studies have been reviewed in this chapter.

2.1 Effects of fertilizers on the physiological attributes of mungbean

2.1.1 Total dry matter

The total dry matter production is the integration of crop growth rate over the entire growth period. The pattern of assimilate distribution is determined by that of photosynthesis and environmental conditions. Total dry matter production of a crop is dependent on the source and its activities as well as the length of its growth period, during which photosynthesis continued. It is the actual assimilates of seed after maintaining the total cost of respiration. The process of photosynthesis, mineral uptake, respiration and senescence of leaves usually determine the dry weight of plant (Evans, 1975).

Reddy *et al*. (1990) set up an experiment with three cultivars of mungbean in 1987, applying 0 or 50 kg P_2O_5/ha as a basal dressing or 50 P_2O_5/ha in two equal split dressings at the sowing and flowering. They followed that application of phosphorus increased the dry matter accumulation in mungbean.

Masthan *et al*. (1999) conducted a field experiments during 1991 to 1993 at Hyderabad, Andhra Pradesh, India where kharif rice cv. Tella Hamsa was grown followed by

Rabi sunflower cv. APSH-1 and summer mungbean cv. LGG 127 and reported that the dry matter weight of mungbean increased with increasing residual kharif and Rabi P rates.

Mitra *et al*. (1999) carried out a field trial in acid soils of Tripura, India with different level of rock phosphate on mungbean varieties during the kharif (rainy) seasons of 1996 and 1997. They reported that mungbean cv. GM-9002 had greater dry matter accumulation at harvest than cv. UPM-12 or MH-309. Maximum dry matter at the harvest was recorded with the application of Mussoorie rock phosphate (50 kg P_2O_5/ha). Raundal *et al*. (1999) also reported that application of phosphorus 60 kg/ha to mungbean grown in kharif (monsoon) season significantly increased the dry matter yield.

Santhi and Kothandaraman (1995) carried out a pot experiment at Coimbatore, Tamil Nadu, India where mungbean cv. CO_3 was grown in clay loam soil that inoculated with Rhizobium and given 0, 25 or 50 kg P_2O_5/ha. They reported that inoculated with *Rhizobium* increased the dry matter yield. The dry matter yield was highest in soil-inoculated with 50 kg P_2O_5/ha.

Shukla and Dixit (1996) conducted a field trial to study the response of summer mungbean to *Rhizobium* inoculation and different levels of phosphorus. Rhizobium inoculation delayed 50% flowering, whereas it increased the dry matter accumulation and ultimately seed yield. They also reported that application of up to 40 kg P_2O_5/ha significantly increased the vigour of the plants resulted in more dry matter production.

Chowdhury *et al*. (2000) carried out a pot experiment during kharif 1995 with the mungbean line NM92 using *Rhizobium* strain TAL 303. Two levels of Rhizobium inoculation and five levels of phosphorus were tested in the study. They reported that *Rhizobium* inoculation and phosphorus application had significant effects on the dry matter yield of mungbean at its different growth stages. It was observed that the dry matter produced prior to flowering and at the flowering stages were around 20 and 50% of total dry matter attained at the maturity. Dry matter accumulation after flowering greatly influenced the seed yield, as most of the photosynthate produced at this stage was used for pod and seed development. Seed contributed the maximum dry matter content at harvest. *Rhizobium* inoculation alone and along with phosphorus application up to 75 kg P_2O_5/ha significantly increased dry matter yields. It was 65 and 45% higher over control and Rhizobium inoculation alone, respectively.

2.1.2 Crop growth rate

Crop growth rate (CGR) is the rate of dry matter production per unit area of land per unit time. It is a simple and important index of agricultural productivity (Hunt, 1978). CGR was correlated with LAI and net assimilation rate and increased with LAI (Khan, 1981).

Gopala Rao *et al.* (1993) carried out a field trial with mungbean cultivars (Pusa Baishakhi, LGG 407, LGG 410 and MS 267) grown with different levels of phosphorus (0, 25 and 50 kg P_2O_5/ha) in sandy loam soil of Bapalta, India. The soil was low in available P_2O_5 (9 kg/ha). A uniform dose of 20 kg N/ha was applied as a basal for all the treatments. They reported that CGR increased significantly with the increasing P levels from 0 to 50 kg P_2O_5/ha irrespective of varieties tested.

Patel *et al.* (1988) applied 20 kg P_2O_5/ha to mungbean grown on a loamy sand soil in 1980-82 and observed that the crop growth rate (CGR) increased significantly with the application of phosphorus. Shukla and Dixit (1996) reported that crop growth rate of mungbean increased significantly with the increasing levels of phosphorus up to 40 kg P_2O_5/ha.

Singh and Ahlawat (1998) noted that application of phosphorus up to 12.9 kg/ha to mungbean cv. PS 16 increased the crop growth rate grown on a sandy loam soil, low in organic carbon and N, and medium in P and K and with a pH of 7.8.

Raundal *et al.* (1999) carried out a field experiment on mungbean with different levels of phosphorus. They observed that application of 60 kg P_2O_5/ha to mungbean significantly increased the crop growth rate. Singh *et al.* (1999) performed an experiment on mungbean cv. NDM-1 grown at Faisabad, Uttar Pradesh, India in summer 1996. They suggested that crop growth rate generally increased up to 26.4 kg P/ha.

2.1.3 Leaf area index (LAI)

Leaf area index (LAI) is the ratio of leaf area and its ground area (Radford, 1967) and it is the functional size of the standing crop on unit land area (Hunt, 1978). It depends on the leaf growth, number of leaves per plant, population density and leaf senescence (Khan, 1981). The higher productivity of a crop depends on the persistence of high LAI over a greater part of its vegetative phase. The rate of crop photosynthesis depends on the LAI. After germination LAI increase and reaches the peak level and thereafter it declines due to increased senescence of older leaves (Katiya, 1980).

Application of P increased nodulation in mungbean owing to better root growth by which N uptake in plant was increased. As a result, increase in N uptake increased nucleic acid, amides and amino acids and hence cell multiplication, which increased LAI (Borde *et al.*, 1983).

2.1.4 Number of nodules/plant

Patel and Patel (1991) conducted a field experiment on mungbean on sandy textured soil, which was low in total N (0.04%), higher in available P (77.33 kg/ha) and rich in available K (388.15 kg/ha) with pH 7.5. They found that number of nodules/plant showed superiority at 60 kg P_2O_5/ha followed by 40 kg P_2O_5/ha.

Sarkar and Banik (1991) conducted a field experiment with mungbean grown with different rates of P. They stated that increase in P_2O_5 up to 60 kg/ha progressively increased the number of nodules/plant of mungbean. Shukla and Dixit (1996) studied in a field experiment with mungbean and reported that application of phosphorus increased the nodulation owing to better root growth, which increased the N uptake in plants.

Singh *et al.* (1999) stated that number of nodules/plant of mungbean cv. NDM-1 increased with up to 26.4 kg P/ha grown at Faisalabad, Uttar Pradesh, India in summer 1996. Ram and Dixit (2000) also found increasing phosphorus levels from 0 to 60 kg/ha increased nodulation.

2.2 Effects of fertilizers on various plant characters including yield and yield attributes of mungbean

2.2.1 Plant height

An experiment was conducted by Sardana and Verma (1987) in New Delhi, India, in 1983-84. They stated that application of nitrogen, phosphorus and potassium fertilizers resulted in significant increases in plant height of mungbean. Suhartatik (1991) also reported that NPK fertilizers significantly increased the plant height of mungbean.

In a field experiment, Yein *et al.* (1981) applied nitrogen in combination with phosphorus fertilizer to mungbean which resulted in increased plant height. Yein (1982) carried out 2-year fields trails in Assam, India on mungbean and reported that application of various levels of nitrogen plus phosphorus significantly increased the plant height.

A field experiment was carried out by Gopala Rao *et al.* (1993) to find out the response of four mungbean cultivars (Pusa Baishakhi, LGG 407, LGG 410 and MS 267) to 3 levels of phosphorus (0, 25 and 50 kg P_2O_5/ha) in sandy loam soil of Bapalta. The soil was low in available P_2O_5 (9 kg/ha). A uniform dose of 20 kg N/ha was applied as a basal for all the treatments. They observed that plant height significantly increased with the increase in P level from 0 to 50 kg P_2O_5/ha.

Ahmed *et al.* (1986) carried out an experiment with various levels of phosphorus on the growth and yield of mungbean. They noted that phosphorus application up to 60 kg/ha progressively and significantly enhanced the plant height.

Patel and Patel (1991) conducted a field experiment on the soil which was sandy in texture, low in total N (0.04%), higher in available P (77.33 kg/ha) and rich in available K (388.15 kg/ha) with the pH 7.5 and observed that plant height of mungbean showed superiority at 60 kg P_2O_5/ha followed by 40 kg P_2O_5/ha application rate.

Bayan and Saharia (1996) carried out an experiment at Assam, India on mungbean with different P levels during the kharif seasons of 1994-95. They reported that the plant height was unaffected by phosphorus application.

Sharma and Singh (1997) carried out a field experiment during 1989 and 1990 to study the effect of various levels of phosphorus (0, 25, 50 and 75 kg/ha) on the growth, yield and yield attributes of mungbean. They stated that application of phosphorus at 50 kg/ha enhanced the plant height significantly.

An experiment was conducted by Singh *et al.* (1999) on mungbean cv. NDM-1 grown at Faisabad, Uttar Pradesh, India in summer 1996 and was given 0-26.4 kg P/ha. They reported that plant height increased with up to 26.4 kg P/ha.

Shukla and Dixit (1996) conducted a field trial during 1989 and 1990 to study the response of mungbean to *Rhizobium* inoculation and different levels of phosphorus. *Rhizobium* inoculation increased the plant height of mungbean. Their study also resulted that the plant height of mungbean increased with 40 kg P_2O_5/ha, increased from 28.30 to 32.00 cm and 26.91 to 30.80 cm over the unfertilized control during the first and second seasons, respectively.

2.2.2 Number of pods/plant

A field trial was carried out by Sardana and Verma (1987) in New Delhi, India in 1983-84 and observed that application of nitrogen, phosphorus and potassium fertilizers resulted in significant increases in number of pods/plant of mungbean.

Gopala Rao *et al.* (1993) carried out a field experiment to find out the response of four-mungbean cultivars cv. Pusa Baishakhi, LGG 407, LGG 410 and MS 267 to 3 levels of phosphorus (0, 25 and 50 kg P_2O_5/ha). They reported that number of pods/plant increased significantly with increasing phosphorus levels from 0 to 50 kg/ha where a uniform dose of 20 kg N/ha was applied as a basal dose for all the treatments.

Kalita (1989) conducted an experiment in 1986-88, applying 30 kg P_2O_5/ha to mungbean and suggested that application of phosphorus increased the number of pods/plant. In another trail, Reddy *et al.* (1990) found that application of phosphorus increased the number of pods/plant in mungbean.

Bayan and Saharia (1996) reported that application of phosphorus to mungbean (*Vigna radiata* L.) unaffected the number of pods/plant. In the study of Shukla and Dixit (1996) application of phosphorus up to 40 kg P_2O_5/ha to mungbean significantly increased the number of pods/plant.

Sharma and Singh (1997) carried out a field experiment on phosphorus levels (0, 25, 50 and 75 kg/ha) during 1989 and 1990 on mungbean crop. They observed that application of phosphorus at 50 kg/ha significantly enhanced the number of pods/plant.

Masthan *et al.* (1999) stated that number of pods/plant of summer mungbean (cv. LGG 127) increased with increasing P rates. Mitra *et al.* (1999) grown mungbean in acid soils of Tripura and recorded the maximum number of pods/plant with application of 50 kg

P_2O_5/ha. Singh *et al.* (1999) also reported that number of pods/plant of mungbean (cv. NDM-1) increased with application of 26.4 kg P/ha.

2.2.3 Pod length

A field experiment conducted by Patel and Patel (1991) and reported that pod length of mungbean varieties showed superiority at 60 kg P_2O_5/ha followed by 40 kg P_2O_5/ha. They also noted that *Rhizobium* culture did not show any effect on pod length.

2.2.4 Number of seeds/pod

Gopala Rao *et al.* (1993) conducted a field trial on four mungbean cultivars (Pusa Baishakhi, LGG 407, LGG 410 and MS 267) with three levels of P (0, 25 and 50 kg P_2O_5/ha) in sandy loam soil, which contain low in available P_2O_5 (9 kg/ha). They reported that number of seeds/pod significantly increased with the increase in P levels from 0 to 50 kg P_2O_5/ha where a uniform dose of 20 kg N/ha was applied as a basal for all the treatments.

Kalita (1989) conducted field trials during 1986 to 1988, applied 30 kg P_2O_5/ha to mungbean and noted that phosphorus application increased the number of seeds/pod over the control. Reddy *et al.* (1990) carried out an experiment with three cultivars of mungbean in 1987, applying 0 or 50 kg P_2O_5/ha as a basal dressing or 50 kg P_2O_5/ha in two equal split dressings at the sowing and flowering time. Results showed that application of phosphorus increased the number of seeds/pod in mungbean.

Singh and Ahlawat (1998) reported that application of phosphorus to mungbean cv. PS 16 increased the number of seeds/pod when grown in a sandy loam soil, low in organic carbon and N, and medium in P and K and with a pH of 7.8. Mashthan *et al.* (1999) also reported that number of seeds/pod of summer mungbean cv. LGG 127 increased with increasing residual kharif and rabi phosphorus rates.

Mitra *et al.* (1999) stated that application of rock phosphate (50 kg P_2O_5/ha) to summer mungbean grown in acid soils of Tripura, India, during the kharif (rainy) seasons of 1996 and 1997, maximized the number of seeds/pod. Singh *et al.* (1999) conducted another trial on mungbean cv. NDM-1 grown at Faisalabad, Uttar Pradesh, India, in summer 1996, with 0-26.4 kg P/ha. Their study revealed that number of seeds/pod increased with up to 26.4 kg P/ha.

2.2.5 1000-seed weight

An experiment carried out in 1980-82 by Patel *et al.* (1988) on a loamy sand soil and observed that application of 20 kg P_2O_5/ha to mungbean increased 1000-seed weight. Reddy *et al.* (1990) conducted another experiment with three cultivars of mungbean in 1987, where 0 or 50 kg P_2O_5/ha was applied as a basal dressing or 50 kg P_2O_5/ha in two equal split dressings at the time of sowing and flowering. They reported that application of phosphorus increased 1000-seed weight.

Singh and Ahlawat (1998) stated that application of phosphorus to mungbean cv. PS 16 increased 1000-seed weight up to 12.9 kg/ha. Mitra *et al.* (1999) also reported that 1000-seed weight of summer mungbean might be maximized with the application of rock phosphate (50 P_2O_5/ha) when grown in acid soils of Tripura in India.

2.2.6 Seed yield

In a field trial, Vasimalai and Subramanian (1980) reported that seed yield of mungbean was significantly increased with 50 kg P_2O_5/ha and decreased with further increases in P rates. Abdulsalam and Nair (1983) grown mungbean on a sandy clay loam acidic soil (pH 5), with 0, 30 and 60 kg P_2O_5 and/or 0, 0.5 and 1 t calcium hydroxide/ha (corresponding to 0, 25 and 50% of lime requirement up to 15 cm depth). They observed that seed yield of mungbean incrased significantly by the application of phosphorus, lime and especially lime + phosphorus.

Ahmed *et al.* (1986) conducted a field experiment to investigate the effect of various levels of phosphorus on the growth and yield performance of mungbean. They found that phosphorus application up to 60 kg/ha progressively and significantly enhanced the seed yield.

Sharma and Singh (1997) carried out a field experiment during 1989 and 1990 to study the effects of various levels of phosphorus (0, 25, 50 and 75 kg/ha) on the growth, yield attributes and yield of mungbean. They found that application of phosphorus @50 kg/ha enhanced the seed yield significantly during both the years.

In a pot experiment, Rao and Rao (1993) showed that mungbean seeds received inoculation with *Rhizobium* along with the application of 40 kg P_2O_5/ha increased the seed yield. Sharma *et al.* (1993) conducted a pot experiment and reported that seed yield of mungbean cv. Pusa Baishakhi increased with the application of P up to or equivalent of 60 kg/ha; with *Rhizobium* inoculums and with a starter dose of nitrogen.

Shukla and Dixit (1996) conducted a field experiment during 1989 and 1990 to study the response of summer mungbean to *Rhizobium* inoculation and different levels of phosphorus. They found that *Rhizobium* inoculation delayed 50% flowering, whereas it increased the dry matter accumulation and ultimately seed yield. Phosphorus application at 40 kg P_2O_5/ha increased the seed yield by 17.2% over the control. Interaction between inoculation and phosphorus was also found significant for yield attributes and seed yield.

2.2.7 Straw yield

Sarkar and Banik (1991) reported that increasing levels of P_2O_5 up to 60 kg/ha resulted in correspondingly higher straw yield of mungbean. Sharma and Singh (1997) also stated that applications of phosphorus @ 50 kg/ha enhanced the straw yield of mungbean significantly.

Sharma *et al.* (1993) observed that straw yield of mungbean cv. Pusa Baishakhi increased with increase of P up to or equivalent of 60 kg P/ha and with *Rhizobium* inoculums and with a starter dose of nitrogen. Gill *et al.* (1985) conducted another experiment and observed that inoculation with *Rhizobium* significantly increased the straw yield of mungbean.

2.3 Effects of variety on growth, yield and yield attributes of mungbean

Generally, modern high yielding varieties of mungbean give higher yields compared to local varieties due to high yielding genetic make up of the modern varieties. Appropriate management practices combined with high yield varieties can increase the seed yield to a great extent.

Patel and Patel (1991) conducted a field experiment to study the response of mungbean varieties viz., Gujarat 2 and Type 44 to four levels of P_2O_5 (0, 20, 40 and 60 kg/ha) and two levels of *Rhizobium* culture (with and without inoculation) on the soil which was sandy in texture, low in total N (0.04%), higher in available P (77.33 kg/ha) and rich in available K (388.15 kg/ha) with the pH 7.5. They reported that Type 44 out yielded Gujarat 2 by recording significantly the higher seed (9.37 kg/ha) and was obtained high yield attributes viz., number of pods/plant, pod length, number of seeds/pod and seed yield/plant.

Gopala Rao *et al.* (1993) conducted a field experiment to find out the response of four-mungbean cultivars viz., Pusa Baishakhi, LGG 407, LGG410 and MS 267 to different levels of phosphorus during the rainy season of 1988-89 in sandy loam soil of Bapalta, India. They reported that Pusa Baishakhi proved superior to the other 3 varieties in respect of all growth parameters, yield components and yield. Pusa Baishakhi also gave the highest seed yield compared to the other varieties which were at par haulm yield followed the similar trend as that of seed.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

Materials were used and methodologies followed in the present investigation have been described in this chapter. The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e Banlga Nagar, Dhaka-1207 during September 3 to November 3, 2006. A brief description of the materials and methods employed in this study are presented below:

3.1 Field trial

3.1.1 Experimental site

The experimental site is located at $24^{0}41'$ N latitude and $91^{0}22'$ E longitude with an elevation of 8.6 m from sea level.

3.1.2 Soil

The soil of the experimental site belongs to Chhiata series and has been classified as Grey Terrace soil in Bangladesh Soil classification system falling under the order Inceptisol in soil taxonomy (FAO, 1988). The soil of Madhupur tract (AEZ-28) is characterized by heavy clays within 50 cm from the surface and is acidic in nature. The soil sample of the experimental plot was collected and analyzed following standard procedures. The detail information about the physico-chemical characteristics of the soil is presented in Appendix 1 and 2.

3.1.3 Land preparation

Land preparation was started 15 days before seed sowing. The land was first opened on August 18, 2006 with a disc plough and then prepared by repeated ploughing and cross-ploughing with a narrow and power tiller, followed by leveler. All kinds of weeds were removed from the field and finally leveled.

3.1.4 Design and Lay out of the experiment

Treatments were arranged in split plot design with three replications where varieties were randomly arranged to the main plots and phosphorus levels in the sub-plot. The plot size was 3m x 3m. The adjacent block and neighboring plots were separated by 1.5 and 1.0 m, respectively. The layout of the experiment is presented in Appendix-3.

3.1.5 Treatments

There were 16 treatment combinations in the experiment. Four levels of phosphorus fertilizer viz. 0, 9, 18 and 27 kg P ha^{-1} and four varieties of mungbean viz. BARI mung-2, BARI mung-6, BU mung-4 and BINA mung-5 were included in the study.

3.1.6 Fertilizer application

The plots were fertilizer with 13, 25 and 0.5 kg/ha of N, K and B along with P fertilizer as per treatment as a basal dose. The fertilizer dose was used as per BARC fertilizer recommendation guide, 2005.

3.1.7 Sowing of seeds

Mungbean seeds of studied varieties at the rate of 40 kg ha^{-1} were sown on September 3, 2006 in line maintaining line to line distance of 30 cm and plant to plant distance 10 cm.

3.1.8 Intercultural operations

The crop was thinned out at 15 DAE (days after emergence) to maintain an optimum population of 33 plants m^{-2}. Two hand weddings were done at 15 and 28 days after emergence of seedlings. No irrigation was given to the crop that drainage channels were prepared carefully to drained out excess rain water from the field. No plant protection measures were taken to the field as no such infestation was noticed.

3.1.9 Harvesting

The crop was harvested on November 3, 2006 at maturity. Ten plants from each plot were sampled randomly for collection of different plant characters and yield attributes. Grain and straw yield was recorded from inner 5 lines including the border plants. Threshing, cleaning and drying of grain were done separately plot by plot. The weights of grain and straw were recorded plot-wise.

3.1.10 Data collection

i. Leaf area and dry matter

Ten plants (avoiding the border rows & harvest area) from each plot were harvested randomly at 25, 40, 55 DAE and at harvest. These harvested plants were segmented into stem, leaf and pod for determination of leaf area and dry matter accumulation and the mean leaf area plant^{-1} was calculated. Leaf area was measured by an automatic leaf area meter (Model. AAM-8, Hayashi Denkoh Co. Ltd., Tokyo, Japan). The plant materials were oven dried at 70^{0}C to a constant weight for recording final dry weight.

ii. Root length measurement

Root of the ten plants were collected at 25, 40 and 55 DAE from each plot using core sampler. Core sampler was inserted into the soil by hammering up to 25 cm and the soil was collected. Each soil block was preserved in a bucket. On the following day, soil samples containing roots were soaked with tap water for 3-5 hours. Soil was washed with tap water and roots were recovered by passing the soil water suspension through a fine wire mesh sieve (2 mm). Roots were separated from the debris and weed. Roots were recovered manually. Roots were separated from the soil sample and root length was measured directly from the graph. Root length density (RLD) was measured followings standard formula:

$RLD = {}^{RL}/_{SV}$ cm cm^{-3} where

R_L = Total root length (cm) of the sample

S_V = Volume of the core (cm^3), where $S_V = \pi r^2 h$

r = radius of the core and h = height of the core.

The dry weight of root were recorded after oven drying for 72 hours (to constant weight) at 70°C

iii. Leaf area index (LAI) and crop growth rate (CGR) calculation

Leaf area index and crop growth rate were calculation following the standard formulae (Radford, 1967 and Hunt, 1978) as shown below :

a) Leaf area index (LAI) : Ratio of leaf area to its ground area

$$LAI = \frac{L_A}{P}$$

b) Crop growth rate (CGR) : Increase of plant materials per unit area per unit of time.

$$CGR = \frac{1}{P} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ (g/m}^2\text{/day)}$$

Meanings of symbols used in the above formulae (a-e) are given below:

W_1 = Total plant dry weight at time T_1

W_2 = Total plant dry weight at time T_2

L_A = Leaf area

P = Ground area

T_1-T_2 = Duration of plant sampling

iv. Number of nodule plant^{-1}

The number of nodule plant^{-1} was recorded from each plot at 50% flowering. The roots of ten plants together with the nodules were washed in water. Then the nodules were removed from the roots, placed on tissue paper and counted and finally averaged to per plant basis.

v. Plant height (cm)

The plant height of the randomly selected ten plants was measured from ground level to the top of main shoot using a meter scale.

vi. Length of pod

Ten matured pods were randomly collected from ten plant. Then the length of pods were measured and recorded.

vii. Number of seeds pod^{-1}

Ten pods were selected from ten plants and sun dried. The dried pods were threshed by hand and seeds were separated. The clean seeds were collected and counted and mean was expressed on per pod basis.

viii. 1000-grain weight

For each individual treatment, samples of well dried 1000-seeds were counted separately and weighted by a sensitive balance and mean weight was expressed in g.

ix. Pod yield

The pods harvested from each plots were separated from plants, cleaned, dried and weighed separately. Pod yields of each plot was recorded individually.

x. Grain and straw yield

Grain obtained from harvest area of each plot were dried and weighed carefully. The yield was expressed as kg ha^{-1} on approximately 14% moisture basis.

xi. Soil sampling

Initial soil sample

Soil samples were collected from a depth of 0-15 cm prior to fertilization. The samples were taken by an auger from fifteen different random by selected spots covering the full experimental area. The soil samples were mixed thoroughly to make a composite sample and the unwanted materials such as stubbles, weeds, stone etc were removed from soil. The composite soil sample was air-dried, grounded and sieved through a 10 mesh sieve. The air-dried ground composite sample was stored in the clean plastic container for subsequent physical and chemical analyses.

xii. Plant sample

Plant samples were taken at flowering, pod filling and maturity stages for chemical analysis.

xiii. Grain sample

Grain samples were collected from each plot and kept for chemical analyses.

3.2 Chemical analyses of soil, plant and grain

Soil, plant and grain samples were analyzed for both physical and chemical properties in the analytical laboratory of the Department of Soil Science, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The results were presented in Tables 4.10a, 4.10b & 4.10c; 4.11a, 4.11b & 4.11c and 4.12a, 4.20b & 4.20c. The following parameters of soil, plant and grain were analyzed by following standard methods.

3.2.1 Physical analyses of soil sample

(a) Particle-size distribution

Particle size analyses of soil was done by Hydrometer method (Black, 1965) and the textural class was determined by plotting the values of percentages of sand, silt and clay contents to the Marshall's triangular co-ordinate following USDA system.

(b) Particle density

The particle density of soil was determined by pycnometer method (Black, 1965). The particle density was calculated using the following formula:

$$\text{Particle density (PD)} = \frac{\text{Weight of soil (Solid)}}{\text{Volume of soil (solid)}} \text{ g/cc}$$

(c) Bulk density

The bulk density of soil was determined by core sampler method as

$$\text{Bulk density (BD)} = \frac{\text{Weight of oven dry soil}}{\text{Total of volume of the soil}} \text{ g/cc}$$

3.2.2 Chemical analyses of soil sample

(a) Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil: water suspension of 1:2.5 as described by Jackson (1973).

(b) Organic carbon

Organic carbon of the soil sample was determined by wet oxidation method (Walkley and Black 1935) outlined by Piper (1950).

(c) Total nitrogen

Total nitrogen content of the collected soil sample was determined by Micro Kjeldahl method (Black, 1965).

(d) Available Phosphorus

The available phosphorus was determined by method (Olsen *et al.*, 1954)

(e) Exchangeable K

Exchangeable K of soil was determined directly by a flame photometer after extraction with IN NH_4OAc, at pH 7.0 (Page *et al.*, 1982).

(f) Cation exchange capacity (CEC) of soil

Cation exchange capacity of the soil was determined by Schollenberger (1980) method.

3.2.3 Chemical analysis of plant and grain

(a) Nitrogen and protein content

Total nitrogen content was estimated by Micro Kjeldahl method (Black, 1965) using Selenium powder, $CuSO_4$. H_2O and K_2SO_4 mixture (1:10:1000) as catalyst, following Salicylic-H_2SO_4 digestion. The percentage of protein in seeds was calculated by multiplying the nitrogen percentage with 6.25 (Morrison, 1956).

(b) Phosphorus and Potassium

P and K contents were determined by nitric perchloric acid digestion method (Yamakawa, 1992).

3.3 Statistical analyses

The analyses of variance for plant characters yield, yield components and nutrient content of the plant were done following the statistical package and the mean differences in case of significant F-value were tested by the Least Significant Difference (LSD) test.

Chapter 4
Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

The yield and yield contributing characters, plant nutrient concentration, protein content of different varieties of mungbean was influenced by the application of phosphorus fertilizer that shown in Table 4.1a to 4.17b.

4.1 Root growth characteristics

4.1.1 Root length

Effect of variety

The effect of variety on root length (RL) of mungbean varied significantly at all the sampling dates (Table 4.1a). In all the varieties, RL increased over time. The variety BU Mung-4 had the highest RL at all the sampling dates, which was statistically higher over all other varieties except BARI mung-6 at 55DAE. The mean RL of BU mung-4 and BARI mung-6 were statistically similar at 55 DAE. The lowest RL was found in BINA mung-5 at all the sampling dates.

Table 4.1a. Effect of variety on root length of mungbean

Variety	Root length (cm)		
	25 DAE	40 DAE	55 DAE
BARI mung-2	43.63	107.64	112.18
BARI mung-6	52.98	131.50	137.92
BU mung-4	63.13	140.27	145.45
BINA mung-5	32.34	104.07	107.82
$LSD_{(0.05)}$	9.00	8.19	13.93

Effect of phosphorus

Root length of mungbean varied significantly due to levels of P (Table 4.1b). Application of P increased root length at all the sampling dates. RL increased with the increase in P fertilizer up to 27 kg ha^{-1} followed by 18 kg ha^{-1} irrespective of sampling dates. Maximum RL was produced at 55 DAE, which was 162 and 4% increased over P fertilizer over 25 and 40 DAE respectively. Plant treated with 0 kg P ha^{-1} had the lowest RL in all the sampling dates. Higher the amount of P applied greater was the RL. Singh *et al.* (1985) also demonstrated that higher doses of P_2O_5 (80 and 120 kg ha^{-1}) increased the RL of pigeonpea significantly over 40 and 0 kg P_2O_5 ha^{-1}.

Table 4.1b. Effect of phosphorus on root length of mungbean

P levels (kg/ha)	Root length (cm)		
	25 DAE	40 DAE	55 DAE
0	31.17	66.66	69.43
9	49.64	123.13	127.56
18	53.65	143.25	147.64
27	57.62	150.45	158.86
LSD $_{(0.05)}$	6.93	9.09	12.75

Interaction effect of variety and phosphorus levels

Varieties and P fertilizer interaction effects on RL was statistically significant at all the sampling dates (Table 4.1c). It was observed that RL increased with the increase of P levels irrespective of varieties. The highest RL was obtained from BU mung-4 with 27 kg P ha^{-1} at all dates and it was statistically identical with BU mung-4 with 18 kg P ha^{-1} and BARI mung-6 with 27 kg P ha^{-1}. The untreated control (without P) produced the smallest RL in the varieties at all dates. This table shows the beneficial effect of P fertilizer on root development.

Table 4.1c. Interaction effect of variety and phosphorus on root length of mungbean

Treatments	Root length (cm)		
	25 DAE	40 DAE	55 DAE
BARI mung-2 x P_0	25.08	49.02	50.27
BARI mung-2 x P_9	46.47	115.53	120.35
BARI mung-2 x P_{18}	50.24	132.80	137.33
BARI mung-2 x P_{27}	52.76	133.23	140.77
BARI mung-6 x P_0	35.31	82.03	87.03
BARI mung-6 x P_9	55.48	136.06	140.86
BARI mung-6 x P_{18}	59.29	150.56	151.86
BARI mung-6 x P_{27}	61.83	157.36	171.95
BU mung-4 x P_0	40.80	89.80	93.70
BU mung-4 x P_9	65.26	137.60	141.39
BU mung-4 x P_{18}	71.10	164.20	169.96
BU mung-4 x P_{27}	75.37	169.50	176.76
BINA mung-5 x P_0	23.51	45.79	46.73
BINA mung-5 x P_9	31.37	103.33	107.66
BINA mung-5 x P_{18}	33.96	125.46	130.96
BINA mung-5 x P_{27}	40.53	141.73	145.96
$LSD_{(0.05)}$	13.80	18.18	24.00

4.1.2 Root length density

Effect of variety

Root length density (RLD) of mungbean varied significantly due to variety at all three sampling dates (Table 4.2a). RLD increased progressively with the advancement of age attaining maximum at 55 DAE. BU Mung-4 had the highest RLD at all the sampling dates and it was statistically higher over all other varieties at 25 DAE. The mean RLD of varieties BU mung-4 and BARI mung-6 were statistically similar at 40 and 55 DAE. BINA mung-5 gave the lowest RLD at all the growth periode followed by BARI mung-2.

Table 4.2a. Effect of variety on root length density of mungbean

Variety	Root length density (cm cm^{-3})		
	25 DAE	40 DAE	55 DAE
BARI mung-2	0.22	0.55	0.57
BARI mung-6	0.27	0.68	0.70
BU mung-4	0.32	0.71	0.74
BINA mung-5	0.16	0.53	0.55
$LSD_{(0.05)}$	0.045	0.042	0.071

Effect of phosphorus

Root length density (RLD) of mungbean varied significantly at all the sampling dates due to levels of P (Table 4.2b). RLD increased almost linearly with the increase in P fertilizer. Application of 27 kg P ha^{-1} gave the highest RLD at all the growth period which was similar with 18 kg P ha^{-1}. Plants treated with 0 kg P ha^{-1} had the lowest RLD in all the growth. Higher the amount of P applied greater was the RLD. Singh *et al.* (1985) also demonstrated that higher doses of P_2O_5 (80 and 120 kg ha^{-1}) increased the RL of pigeonpea varieties significantly over 40 and 0 kg P_2O_5 ha^{-1}. Across the P fertilizer, RL was the highest at 55 DAE.

Table 4.2b. Effect of phosphorus on root length density of mungbean

Phosphorus (kg/ha)	Root length density (cm cm^{-3})		
	25 DAE	40 DAE	55 DAE
0	0.16	0.34	0.35
9	0.25	0.63	0.65
18	0.27	0.73	0.75
27	0.29	0.77	0.81
$LSD_{(0.05)}$	0.035	0.046	0.064

Interaction effect of variety and phosphorus levels

Interaction of variety and P levels on RLD was significant at all the sampling dates (Table 4.2c). Application of P fertilizer generally increased RLD and the effect was much more pronounced at 18 and 27 kg P ha^{-1} irrespective of varieties in all the growth period. The highest RLD was obtained from BU mung-4 with 27 kg P ha^{-1} at all the sampling dates followed by 18 kg P ha^{-1}. These two treatments however showed identical RLD. The results are in agreement with the findings of Sivasankar et al. (1982) who reported that groundnut cultivars differed significantly in their RLD due to P fertilizer application. The plants grown without added P tended to show lower values of RLD irrespective of varieties.

Table 4.2c. Interaction effect of variety and phosphorus on root length density of mungbean

Treatments	RLD (cm cm^{-3})		
	25 DAE	40 DAE	55 DAE
BARI mung-2 x P_0	0.13	0.25	0.26
BARI mung-2 x P_9	0.23	0.59	0.61
BARI mung-2 x P_{18}	0.25	0.67	0.70
BARI mung-2 x P_{27}	0.27	0.68	0.72
BARI mung-6 x P_0	0.18	0.42	0.44
BARI mung-6 x P_9	0.28	0.69	0.72
BARI mung-6 x P_{18}	0.30	0.78	0.77
BARI mung-6 x P_{27}	0.31	0.80	0.87
BU mung-4 x P_0	0.21	0.46	0.47
BU mung-4 x P_9	0.33	0.70	0.72
BU mung-4 x P_{18}	0.36	0.84	0.88
BU mung-4 x P_{27}	0.38	0.86	0.90
BINA mung-5 x P_0	0.12	0.23	0.24
BINA mung-5 x P_9	0.16	0.52	0.55
BINA mung-5 x P_{18}	0.17	0.64	0.67
BINA mung-5 x P_{27}	0.20	0.72	0.74
$LSD_{(0.05)}$	0.070	0.0926	0.122

4.1.3 Root dry weight

Effect of variety

Root dry weight (RDW) significantly influenced by the variety of mungbean at all the sampling dates (Table 4.3a). Higher the root length higher the root dry weight. The highest RDW was found in BU mung-4 at all the sampling dates (25, 40 and 55 DAE), which was statistically higher over all other varieties. Variety BINA mung-5 gave the lowest RDW at all the sampling dates.

Table 4.3a. Effect of variety on root dry weight of mungbean

Variety	Root dry weight/plant (mg)		
	25 DAE	40 DAE	55 DAE
BARI mung-2	38.56	99.19	103.73
BARI mung-6	44.65	119.91	123.59
BU mung-4	58.51	137.78	141.58
BINA mung-5	27.49	93.13	97.61
$LSD_{(0.05)}$	8.42	14.10	16.97

Effect of phosphorus

Application of P fertilizer also increased root dry weight (RDW) markedly in all the sampling dates (Table 4.3b). Root dry weight increased progressively with increasing P fertilizer up to 27 kg P ha^{-1}. It apparent that increase in P level increased the RLD and ultimately increased the root weight. The highest RDW was obtained in 27 kg P ha^{-1} at all the growth period, which was identical to 18 kg P ha^{-1} and the lowest in 0 kg P ha^{-1}.

Table 4.3b. Effect of phosphorus on total root dry weight of mungbean

P levels (kg/ha)	Root dry weight/plant (mg)		
	25 DAE	40 DAE	55 DAE
0	28.04	68.05	73.6
9	42.20	110.25	114.15
18	47.48	131.54	136.63
27	51.50	140.15	142.12
$LSD_{(0.05)}$	5.26	9.34	9.51

Interaction effect of variety and P levels

Root dry weight (RDW) was markedly influenced by the interaction effect of variety and P levels (Table 4.3c). BU mung-4 with 27 kg P ha^{-1} gave the highest RDW irrespective of sampling dates followed by BU mung-4 with 18 kg P ha^{-1}. The lowest RDW was found in BINA mung-5 with 0 kg P ha^{-1} at all the growth period.

Table 4.3c. Interaction effect of variety and phosphorus on total root dry weight of mungbean

Treatments	Root dry weight (mg)		
	25 DAE	40 DAE	55 DAE
BARI mung-2 x P_0	22.16	50.00	63.06
BARI mung-2 x P_9	41.06	102.20	106.36
BARI mung-2 x P_{18}	44.40	122.16	122.26
BARI mung-2 x P_{27}	46.63	122.40	123.26
BARI mung-6 x P_0	31.10	78.86	83.26
BARI mung-6 x P_9	42.20	119.96	124.03
BARI mung-6 x P_{18}	52.20	134.1	140.70
BARI mung-6 x P_{27}	53.10	146.73	146.40
BU mung-4 x P_0	38.90	85.60	89.30
BU mung-4 x P_9	58.86	131.10	134.73
BU mung-4 x P_{18}	64.46	163.33	167.46
BU mung-4 x P_{27}	71.83	171.10	174.83
BINA mung-5 x P_0	20.00	57.76	58.90
BINA mung-5 x P_9	26.66	87.76	91.46
BINA mung-5 x P_{18}	28.86	106.6	116.10
BINA mung-5 x P_{27}	34.43	120.40	124.00
$LSD_{(0.05)}$	10.52	18.68	19.00

4.1.4. Root mass density

Effect of variety

Effect of variety on root mass density (RMD) was significant in all the sampling period (Table 4.4a). RMD increased progressively with the advancement of age attaining maximum at 55 DAE. The highest RMD was found in BU mung-4 at all the sampling dates but differed significantly from other varieties used in this study. BINA mung-5 produced the lowest RMD at all the sampling dates.

Table 4.4a. Effect of variety on root mass density of mungbean

Variety	Root mass density (mg /cm^3)		
	25 DAE	40 DAE	55 DAE
BARI mung-2	0.19	0.51	0.52
BARI mung-6	0.23	0.61	0.63
BU mung-4	0.30	0.70	0.72
BINA mung-5	0.14	0.46	0.49
LSD $_{(0.05)}$	0.045	0.0718	0.086

Effect of phosphorus

Application of P fertilizer also increased root mass density (RMD) significantly in all the sampling period (Table 4.4b). Root mass density increased progressively with increasing P fertilizer up to 27 kg ha^{-1}. The highest root mass density was obtained in 27 kg P ha^{-1} at all the sampling dates and it was statistically identical with 18 kg P ha^{-1}. Plants treated with 0 kg P ha^{-1} had the lowest RMD in all the growth period.

Table 4.4b. Effect of phosphorus on root mass density of mungbean

P levels (kg/ha)	Root mass density (mg /cm^3)		
	25 DAE	40 DAE	55 DAE
0	0.14	0.34	0.37
9	0.22	0.56	0.58
18	0.24	0.67	0.69
27	0.26	0.71	0.72
LSD $_{(0.05)}$	0.027	0.047	0.048

Interaction effect of variety and P levels

Root mass density was significantly influenced by the interaction effect of variety and P levels (Table 4.4c). The RMD progressively increased with the advancement of growth irrespective of variety. BU mung-4 with 27 kg P ha^{-1} gave the highest root mass density at all the sampling dates followed by BU mung-4 with 18 kg P ha^{-1}. The lowest root mass density was found in BINA mung-5 with 0 kg P ha^{-1} in all the growth period.

Table 4.4c. Interaction effect of variety and phosphorus on root mass density of mungbean

Treatments	Root mass density (mg/cm^3)		
	25 DAE	40 DAE	55 DAE
BARI mung-2 x P_0	0.11	0.29	0.32
BARI mung-2 x P_9	0.21	0.52	0.54
BARI mung-2 x P_{18}	0.22	0.61	0.62
BARI mung-2 x P_{27}	0.24	0.62	0.63
BARI mung-6 x P_0	0.15	0.37	0.42
BARI mung-6 x P_9	0.22	0.61	0.63
BARI mung-6 x P_{18}	0.26	0.68	0.71
BARI mung-6 x P_{27}	0.27	0.74	0.74
BU mung-4 x P_0	0.20	0.43	0.45
BU mung-4 x P_9	0.30	0.67	0.68
BU mung-4 x P_{18}	0.34	0.83	0.85
BU mung-4 x P_{27}	0.36	0.87	0.89
BINA mung-5 x P_0	0.10	0.25	0.30
BINA mung-5 x P_9	0.13	0.45	0.46
BINA mung-5 x P_{18}	0.15	0.54	0.59
BINA mung-5 x P_{27}	0.17	0.61	0.63
$LSD_{(0.05)}$	0.053	0.095	0.0968

4.2 Number of nodules and dry weight

Effect of variety

Varieties executed significant influence on the number and dry weight of nodules $plant^{-1}$ (Table 4.5a). Nodules $plant^{-1}$ varied from 11.41 to 13.99 giving a mean of 12.49. Variety BU mung-4 produced significantly higher nodules $plant^{-1}$ than other varieties. The lowest number of nodules $plant^{-1}$ was recorded for BINA mung-5 and it was statistically identical with BARI mung-2. Nearly a similar trend was observed for nodule dry weight. This result confirmed with those of Murakami *et al*., 1990; Patel and Patel, 1991; Pal and Lal, 1993 who reported that varietal differences in nodulation in mungbean.

Table 4.5a. Effect of variety on nodule number and nodule weight of mungbean

Variety	Nodule/plant (no.)	Nodule weight/plant (mg)
BARI mung-2	11.51	11.09
BARI mung-6	13.03	12.73
BU mung-4	13.99	13.57
BINA mung-5	11.41	10.72
$LSD_{(0.05)}$	0.621	0.701

Effect of phosphorus

Significant variations in the number and dry weight of nodules were observed due to variation of phosphorus levels (Table 4.5b). Both the nodule number and weight gradually increased with increase of P levels up to 27 kg ha^{-1}. Application of 27 kg P ha^{-1} gave the highest nodule number and dry weight which was statistically similar to 18 kg P ha^{-1}. The lowest nodule number and dry weight was recorded in 0 kg P ha^{-1}. Application of higher doses of P fertilizer increased nodule weight by 42 percent. P is reported to enhance multiplication and activity of nodule bacteria in legume rhizosphere (Griffith, 1978) and to increase root density which is important for producing more nodules. High rates of P application enhanced *Rhizobial* activity, raised nodule number and their dry weight in groundnut (Sankar *et al*., 1984; Singh and Chaudhary, 1996). Singh and Bajpai (1990). Raychaudhuri *et al*. (1997) also reported similar findings in soybean. It is evident from Table 4.5b that lack of adequate phosphorus inhibited the number and mass of nodule. Similar result was reported by Pereira and Blish (1987) in common bean.

Table 4.5b. Effect of phosphorus on nodule number and nodule weight of mungbean

P levels (kg/ha)	Nodules/plant (no.)	Nodule weight/plant (mg)
0	9.91	9.60
9	11.50	11.00
18	14.12	13.64
27	14.40	13.87
LSD $_{(0.05)}$	0.345	0.340

Interaction effect of variety and phosphorus levels

Phosphorus and variety interaction was significant on total nodule number and dry weight (Figs. 4.1 and 4.2). However, nodule number and dry weight gradually increased with increase in P levels irrespective of varieties. The highest nodule number and dry weight was observed in BU mung-4 with 27 kg P ha^{-1} (Fig. 4.1), which was identical to BU mung-4 with 18 kg P ha^{-1} and BARI mung-6 with 27 kg P ha^{-1}. In contrast, BINA mung-5 with 0 kg P ha^{-1} had consistently lowest number of nodules and greater amount of dry weight. Nodule weight plant^{-1} by the interaction of variety and P levels followed a pattern similar to its nodule number (Fig. 4.2).

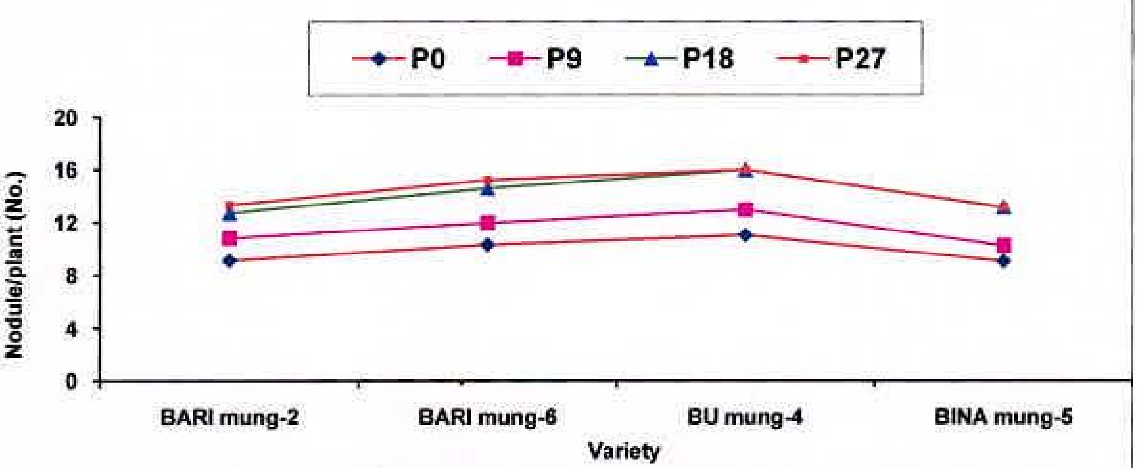


Fig. 4.1. Interaction effect of variety and phosphorus on nodule number of mungbean (LSD $_{(0.05)}$ = 0.77)

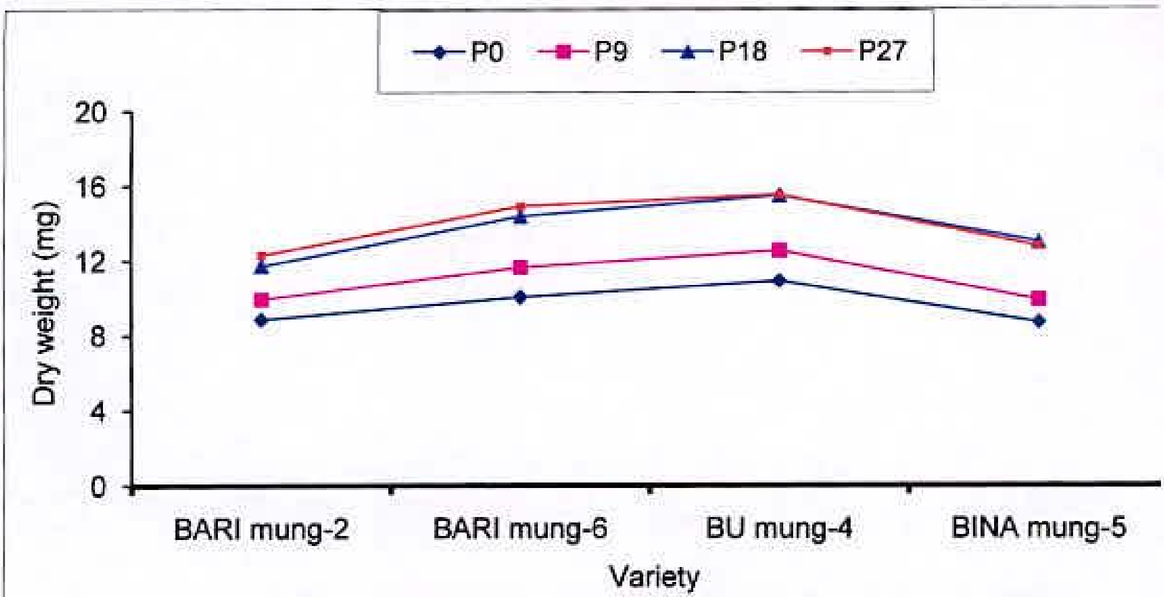


Fig. 4.2. Interaction effect of variety and phosphorus on nodule dry weight of mungbean (LSD $_{(0.05)}$ = 0.68)

4.3 Leaf area plant^{-1}

Effect of variety

Variety showed significant difference in leaf area plant^{-1} at all the sampling dates (25, 40, 55 and 65 DAE) in Table 4.6a. Leaf area plant^{-1} increased sharply with age reaching maximum at 55 and thereafter declined. The decrease in leaf area plant^{-1} at latter period may be attributed to the onset and senescence of the leaves. Variety exterted significant influence in the shape of leaf area. Variety BU mung-4 consistently produced more leaf area than other varieties irrespective of sampling dates. The lowest leaf area was found in BINA mung-5 at all the sampling dates. However, the difference in leaf area of variety BARI mung-2 and BARI mung-5 was not statistically significant at 40, 55 and 65 DAE. At 25 DAE, there were significant differences among the varieties in respect of leaf area.

Table 4.6a. Effect of variety on leaf area of mungbean

Variety	Leaf area (cm^2)/plant at different period			
	25 DAE	40 DAE	55 DAE	65 DAE
BARI mung-2	247.25	651.75	776.75	726.75
BARI mung-6	255.75	683.75	806.00	755.00
BU mung-4	263.917	720.00	841.66	790.93
BINA mung-5	233.66	633.91	749.00	691.16
$LSD_{(0.05)}$	7.75	21.66	46.09	40.06

Effect of phosphorus

The leaf area plant^{-1} was greatly influenced with increase of P levels over the growth period of mungbean (Table 4.6b). Leaf area was maximum at 55 DAE across the treatment. Leaf area increased with age reaching peak at 55 and thereafter decline. Phosphorus fertilizer application exerted significant influence on the shape of the leaf area curve. Plants grown with adequate P fertilizer showed significant variations in leaf area persisted till maturity. The difference widened as the rate of P fertilizer increased. Irrespective of P fertilizer application, leaf area decreased at maturity (65 DAE). Leaf area tended to increase with application of P up to 27 kg ha^{-1}. A well-developed root system of BU mung-4 variety might have favoured taking up relatively more nutrients that help to developed greater foliage. In general, higher doses of P (18-27 kg P ha^{-1}) retained the maximum leaf area plant^{-1} throughout the growth period than the low level of P (0 and 9 kg P ha^{-1}).

Table 4.6b. Effect of phosphorus on leaf area of mungbean

P levels (kg/ha)	Leaf area (cm^2)/plant at different growth period			
	25 DAE	40 DAE	55 DAE	65 DAE
0	175.417	534.75	626.08	576.00
9	197.50	564.25	691.75	641.97
18	307.25	784.25	904.83	852.75
27	320.41	805.25	950.75	892.58
$LSD_{(0.05)}$	18.70	18.70	22.81	6.77

Interaction effect of variety and phosphorus levels

Interaction effect of variety and phosphorus levels on leaf area was significant (Table 4.6c). Regardless of treatment variation leaf area was maximum at 55 DAE and ranged between 175.0 and 1002.0 cm^2 across the treatments. Leaf area increased with with age reaching peak at 55 DAE and thereafter decreased regardless of treatment. The highest leaf area was observed in BU-mung-4 with 27 kg P ha^{-1} at all the sampling dates, which was similar to BU-mung-4 with 18 kg P ha^{-1}. Plant grown without P fertilizer had the lowest leaf area irrespective of varieties.

Table 4.6c. Interaction effect of variety and phosphorus on leaf area of mungbean

Treatments	Leaf area (cm^2)/plant at different days			
	25 DAE	40 DAE	55 DAE	65 DAE
BARI mung-2 x P_0	175.00	514.00	615.00	565.00
BARI mung-2 x P_9	188.00	543.00	669.00	619.00
BARI mung-2 x P_{18}	307.00	767.00	891.00	841.00
BARI mung-2 x P_{27}	319.00	783.00	932.00	882.00
BARI mung-6 x P_0	179.00	544.00	645.00	595.00
BARI mung-6 x P_9	204.00	575.00	701.00	650.00
BARI mung-6 x P_{18}	313.00	801.00	925.00	875.00
BARI mung-6 x P_{27}	327.00	815.00	953.00	900.00
BU mung-4 x P_0	184.66	583.00	684.00	634.00
BU mung-4 x P_9	210.00	614.00	741.00	694.00
BU mung-4 x P_{18}	325.00	829.00	939.66	890.00
BU mung-4 x P_{27}	336.00	854.00	1002.00	943.33
BINA mung-5 x P_0	163.00	498.00	560.33	510.00
BINA mung-5 x P_9	188.00	529.00	656.00	604.66
BINA mung-5 x P_{18}	284.00	739.00	863.00	805.00
BINA mung-5 x P_{27}	299.66	769.00	916.00	845.00
$LSD_{(0.05)}$	35.40	35.40	65.60	53.40

4.4 Leaf area index

Effect of variety

Variety showed significant difference in leaf area index (LAI)at all the sampling dates (Table 4.7a). Leaf area index increased with age reaching peak at 55 and thereafter declined. BU mung-4 consistently produced more LAI than other varieties irrespective of sampling dates. The lowest LAI was found in BINA mung-5 irrespective of growth period.

Table 4.7a. Effect of variety on leaf area index of mungbean

Variety	Leaf area index at different growth period			
	25 DAE	40 DAE	55 DAE	65 DAE
BARI mung-2	0.82	2.17	2.59	2.42
BARI mung-6	0.85	2.28	2.69	2.52
BU mung-4	0.88	2.40	2.81	2.64
BINA mung-5	0.78	2.11	2.50	2.30
LSD $_{(0.05)}$	0.03	0.07	0.15	0.13

Effect of phosphorus

The leaf area index was greatly influenced with increase of P levels over the growth period of mungbean (Table 4.7b). Leaf area index was maximum at 55 DAE across the treatment. Leaf area index increased with age reaching peak at 55 and thereafter decreased. Phosphorus fertilizer application exerted significant influence on the shape of the leaf area index curve. Plants grown with adequate P fertilizer showed significant variations in leaf area index persisted till 55 DAE. The difference widened as the rate of P fertilizer increased. Irrespective of varieties or P fertilizer application, leaf area index decreased at maturity (65 DAE). Leaf area index tended to increase with application of P up to 27 kg ha^{-1}. That the progressive increase in LAI of 27 kg P ha^{-1} application might be due to higher leaf area.

Generally, plants treated with moderate to high levels of P (18-27 kg P ha^{-1}) retained the maximum LAI throughout the growth stage than the low level of P (0 and 9 kg P ha^{-1}).

Table 4.7b. Effect of phosphorus on leaf area index of mungbean

P levels (kg/ha)	Leaf area index at different growth period			
	25 DAE	40 DAE	55 DAE	65 DAE
0	0.58	1.78	2.09	1.92
9	0.66	1.88	2.31	2.14
18	1.02	2.61	3.02	2.84
27	1.07	2.68	3.17	2.98
$LSD_{(0.05)}$	0.06	0.06	0.08	0.02

Interaction effect of variety and phosphorus levels

Interaction effect of variety and phosphorus levels on leaf area index was significant at all the sampling dates (Table 4.7c). LAI increased sharply reaching maximum at 55 DAE and then decreased irrespective of treatment differences. LAI decreased at the 55 DAE reflecting the loss of some existing leaves through senescence. The highest LAI was observed in BU-mung-4 with 27 kg P ha^{-1} at all the sampling dates, which was similar to BU-mung-4 with 18 kg P ha^{-1}. Varieties grown without P gave the lowest LAI in all the growth period.

Table 4.7c. Interaction effect of variety and phosphorus on leaf area index of mungbean

Treatments	Leaf area index at different growth period			
	25 DAE	40 DAE	55 DAE	65 DAE
BARI mung-2 x P_0	0.58	1.71	2.05	1.88
BARI mung-2 x P_9	0.63	1.81	2.23	2.06
BARI mung-2 x P_{18}	1.02	2.56	2.97	2.80
BARI mung-2 x P_{27}	1.06	2.61	3.11	2.94
BARI mung-6 x P_0	0.60	1.81	2.15	1.98
BARI mung-6 x P_9	0.68	1.92	2.34	2.17
BARI mung-6 x P_{18}	1.04	2.67	3.08	2.92
BARI mung-6 x P_{27}	1.09	2.72	3.18	3.00
BU mung-4 x P_0	0.62	1.94	2.28	2.11
BU mung-4 x P_9	0.70	2.05	2.47	2.31
BU mung-4 x P_{18}	1.08	2.76	3.13	2.97
BU mung-4 x P_{27}	1.12	2.85	3.34	3.14
BINA mung-5 x P_0	0.54	1.66	1.87	1.70
BINA mung-5 x P_9	0.63	1.76	2.19	2.02
BINA mung-5 x P_{18}	0.95	2.46	2.88	2.68
BINA mung-5 x P_{27}	1.00	2.56	3.05	2.82
$LSD_{(0.05)}$	0.12	0.12	0.22	0.18

4.5 Total dry matter production

Effect of variety

The mean effect of variety on total dry matter (TDM) accumulation was found significant (Table 4.8a). Regardless of the treatment differences, TDM increased progressively over time. The highest TDM was observed in BU mung-4 at all the sampling dates compared to all other varieties and the lowest from BINA mung-5 (Table 4.8a). In the present investigation, all the varieties had a lag phase in early growth stage (25 DAE) and thereafter plants continued to increase dry matter up to maturity. However, the difference in dry matter accumulation was minimum in the beginning of the growth cycle, but over time the differences widened. From Table 4.8a, it was evident that a greater portion of TDM was accumulated during the period between 40-55 DAE across the varieties.

Table 4.8a. Effect of variety on total dry matter production of mungbean

Variety	Total Dry Matter/plant (g) at different growth period		
	25 DAE	40 DAE	55 DAE
BARI mung-2	0.67	2.77	4.73
BARI mung-6	0.68	2.86	5.41
BU mung-4	0.81	3.73	7.18
BINA mung-5	0.55	2.38	4.29
LSD (0.05)	0.08	0.31	0.88

Effect of phosphorus levels

Application of phosphorus fertilizer caused marked variation in total dry matter accumulation (Table 4.8b). TDM increased progressively with increasing P fertilizer up to 27 kg ha^{-1} at all the growth period. The highest TDM was observed in plants treated with 27 kg P ha^{-1} and it was statistically identical with 18 kg P ha^{-1} irrespective of growth period. On the contrary, the plants grown without or 9 kg P ha^{-1} produced the lowest dry matter at all the sampling dates. It was apparent that the plants grown without or with lower levels of P fertilizer suffered from nutrient stress during the generative phase when the nutrient demand of the crop was high resulting in the lowest TDM. However, the overall changes in TDM production were related to changes in the growth of individual components as indicated by the differences in plant height, number of branches, leaf area and pod size. Moreover, increased P level up to 18-27 kg ha^{-1} attributed for the well developed root system which helped for nutrient uptake, photosynthesis and nitrogen fixation resulting in more dry matter production. Singh and Ahuja (1985) reported that phosphorus fertilizer application enhanced vigorous root growth, nodulation, increased leaf area and accumulation of more dry matter in groundnut. Similar results were reported by Sivasankar *et al.* (1982); Kumari and Singh (1990); Savani *et al.* (1995) in groundnut; Gupta and Rai (1989); Das (1993) in mungbean. Regression analysis was performed to find the response of TDM in relation to RLD, regardless of treatment differences. The response function was illustrated in Fig. 4.3. The R^2 (0.69) value suggested that 69% of the variation in TDM could be attributed to the differences in RLD.

Table 4.8b. Effect of phosphorus on total dry matter production of mungbean

P levels (kg/ha)	Total Dry Matter/plant (g) at different growth period		
	25 DAE	40 DAE	55 DAE
0	0.58	2.32	4.54
9	0.62	2.67	4.76
18	0.73	3.36	6.07
27	0.79	3.39	6.24
LSD $_{(0.05)}$	0.07	0.18	0.67

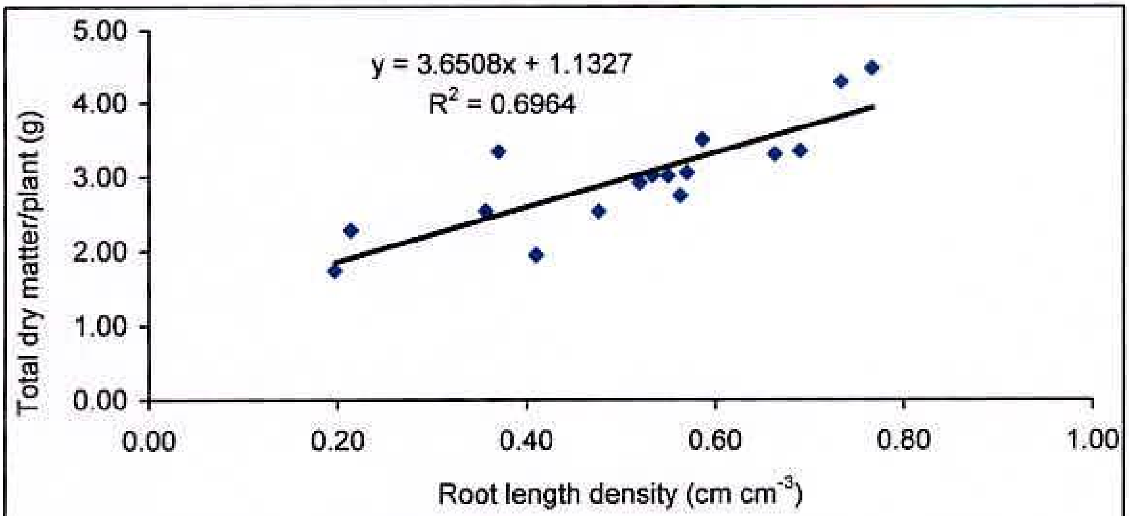


Fig. 4.3. Functional relationship between root length density and total dry matter of mungbean

Interaction effect of variety and phosphorus levels

The variety and phosphorus interaction effect on TDM production was significant (Table 4.8c). TDM increased progressively with the progressive increase in P fertilizer but the dry matter yield per unit area did not decline with the increase in P fertilizer across the varieties. However, highest rate of TDM production was found from 40 to 55 DAE irrespective of varieties and P levels. Increase of TDM production at this growth phase might be due to increased photosynthesis rate resulting in higher leaf area and thereby increased TDM production. Application of 27 kg P ha^{-1} had higher TDM with BU mung-4 at all the sampling dates, which was similar to BU mung-4 with 18 kg P ha^{-1}. The lowest TDM was received form 0 kg P ha^{-1} for all the four varieties irrespective of growth period. In general, higher the level of P greater was the TDM accumulation in all the growth period in all the varieties.

Table 4.8c. Interaction effect of variety and phosphorus on total dry matter production of mungbean

Treatments	Total dry matter/plant (g) at different growth period		
	25 DAE	40 DAS	55 DAE
BARI mung-2 x P_0	0.63	2.00	4.22
BARI mung-2 x P_9	0.65	2.44	4.51
BARI mung-2 x P_{18}	0.70	3.28	5.07
BARI mung-2 x P_{27}	0.71	3.35	5.11
BARI mung-6 x P_0	0.56	2.24	4.82
BARI mung-6 x P_9	0.60	2.56	5.07
BARI mung-6 x P_{18}	0.78	3.32	5.81
BARI mung-6 x P_{27}	0.78	3.32	5.94
BU mung-4 x P_0	0.66	2.99	6.38
BU mung-4 x P_9	0.70	3.39	6.42
BU mung-4 x P_{18}	0.82	4.24	7.82
BU mung-4 x P_{27}	1.04	4.31	8.09
BINA mung-5 x P_0	0.48	2.00	2.73
BINA mung-5 x P_9	0.51	2.30	3.04
BINA mung-5 x P_{18}	0.60	2.59	5.57
BINA mung-5 x P_{27}	0.60	2.61	5.82
$LSD_{(0.05)}$	0.23	0.36	1.34

4.6 Crop growth rate

Effect of variety

Significant effect of various variety on crop growth rate (CGR) of mungbean were observed during 25, 40 and 55 DAE (Table 4.9a). CGR increased progressively with time reaching maximum at 55 DAE regardless of variety. Among the varieties, BU mung-4 registered a maximum CGR during the whole growth period which was significantly higher over all other varieties. The lowest CGR was found in BINA mung-5 and it was not significantly different from BARI mung-2 at 55 DAE. Variety BARI mung-2 and BARI mung-6 produced statistically identical CGR at 25 and 40 DAE.

Table 4.9a. Effect of variety on crop growth rate (CGR) of mungbean

Variety	Crop growth rate ($g/m^2/day$) at different growth period		
	25 DAE	40 DAE	55 DAE
BARI mung-2	0.89	4.67	4.36
BARI mung-6	0.91	4.84	5.67
BU mung-4	1.08	6.49	7.67
BINA mung-5	0.73	4.07	4.24
$LSD_{(0.05)}$	0.10	0.35	0.70

Effect of phosphorus

The effect of phosphorus on CGR was found significant (Table 4.9b). Phosphorus promotes early root formation and translocation of carbohydrates. Application of 27 kg P ha^{-1} gave the highest CGR at 25 and 55 DAE, and 18 kg P ha^{-1} at 40 DAE. Plants growth without P gave the lowest CGR at 25 and 40 DAE, and 9 kg P ha^{-1} at 55 DAE. This result was conformity of findings reported by Shukla and Dixit (1996) that CGR of mungbean increased significantly with the increasing levels of phosphorus up to 40 kg P_2O_5 ha^{-1}.

Table 4.9b. Effect of phosphorus on crop growth rate of mungbean

Phosphorus (kg/ha)	Crop growth rate ($g/m^2/day$) at different growth period		
	25 DAE	40 DAE	55 DAE
0	0.77	3.87	4.93
9	0.83	4.56	4.64
18	0.97	5.84	6.02
27	1.05	5.78	6.33
$LSD_{(0.05)}$	0.09	0.25	0.88

Interaction effect of variety and phosphorus levels

CGR of mungbean varieties differed significantly due to the interaction of variety and phosphorus levels at different growth period (Table 4.9c). The highest CGR at 25 and 55 DAE were obtained from BU mung-4 with 27 kg P ha^{-1}. On the contrary, BU mung-4 with 18 kg P ha^{-1} produced the highest CGR at 40 DAE. The lowest CGR was obtained in BINA mung-5 with 0 kg P ha^{-1} at 25 and 55 DAE while BARI mung-2 with 0 kg P ha^{-1} produced the lowest CGR at 40 DAE.

Table 4.9c. Interaction effect of variety and phosphorus on crop growth rate of mungbean

Treatments	Crop growth rate ($g/m^2/day$) at different growth period		
	25 DAE	40 DAS	55 DAE
BARI mung-2 x P_0	0.84	3.04	4.93
BARI mung-2 x P_9	0.87	3.98	4.60
BARI mung-2 x P_{18}	0.93	5.73	3.98
BARI mung-2 x P_{27}	0.95	5.87	3.91
BARI mung-6 x P_0	0.75	3.73	5.73
BARI mung-6 x P_9	0.80	4.36	5.58
BARI mung-6 x P_{18}	1.04	5.64	5.53
BARI mung-6 x P_{27}	1.04	5.64	5.82
BU mung-4 x P_0	0.88	5.18	7.53
BU mung-4 x P_9	0.93	5.98	6.73
BU mung-4 x P_{18}	1.09	7.60	7.96
BU mung-4 x P_{27}	1.39	7.27	8.40
BINA mung-5 x P_0	0.64	3.38	1.62
BINA mung-5 x P_9	0.68	3.98	1.64
BINA mung-5 x P_{18}	0.80	4.42	6.62
BINA mung-5 x P_{27}	0.80	4.47	7.13
$LSD_{(0.05)}$	0.30	0.50	0.52

4.7 Nutrient content in leaf, stem and seed of mungbean

The leaf, stem and seed of mungbean were chemically analyzed for N, P and K content. The data were statistically analyzed and have been presented in Tables 4.10a to 4.12c.

4.7.1 Nitrogen content

Effect of variety

The contents of N in leaf, stem at different growth period (25, 40 and 55 DAE) and seed was insignificant among the varieties (Table 4.10a). Numerically higher N content in leaf, stem and seed was reduced from BU mung-4 and the lowest was in BINA mung-5.

Table 4.10a. Effect of variety on leaf, stem and seed N content of mungbean

Variety	Leaf N content (%)			Stem N content (%)			Seed N content (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
BARI mung-2	2.93	2.83	2.46	2.85	2.70	2.31	3.54
BARI mung-6	2.90	2.81	2.48	2.87	2.71	2.32	3.56
BU mung-4	2.96	2.85	2.48	2.88	2.73	2.36	3.60
BINA mung-5	2.91	2.81	2.45	2.82	2.70	2.31	3.53
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Effect of phosphorus

Nitrogen content in leaf, stem and seed of four varieties varied significantly due to application of P fertilizer (Table 4.10b). The percent content of N in leaf and stem of mungbean varieties was higher at 25 DAE that decreased with advancement of plant growth. The greater reduction of N from leaf and stem was possibly due to N nutrient remigration to the reproductive organ. Reproductive organs (seed), on the other hand continued accumulating nutrient element till maturity. The declined of N content in plant component was more in P deficient plant than in adequate fertilized plant of mungbean. At pre-flowering stage (25 DAE), most of the N content was in the leaf indicating the potentials of dry matter production in crop plants. Application of P fertilizer enhanced plant tissue N content in all the varieties. It was apparent that leaf N % was more associated with the P nutrition of the plant. Generally, higher the level of P fertilizer application, greater was the N content in plant tissue. The results were in agreement with those of Nerson *et al.* (1990) who reported that N supply was dependent on the abundance of P. A positive effect of P fertilizer on N content in plant had also been reported by Rathee and Chahal (1977), Reddy and Patil (1980). However, the highest N content of leaf, stem and seed was obtained with 27 kg P ha^{-1}, which was similar to 18 kg P ha^{-1}. The lowest N content of leaf, stem and seed was obtained with 0 kg P ha^{-1} irrespective of growth period. The increase of N content in mungbean varieties at higher levels might be due to accelerated metabolic activity of the fertilized plants resulting in increased absorbing power of root system. At maturity, most of N content was in the seed regardless of treatment (Table 4.10b). This suggests that translocation of N from vegetative tissue to the seed occurred at seed filling period.

Table 4.10b. Effect of phosphorus on leaf, stem and seed N content of mungbean

P levels (kg/ha)	Leaf N content (%)			Stem N content (%)			Seed N content (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
0	2.76	2.63	2.31	2.71	2.63	2.23	3.43
9	2.88	2.78	2.42	2.80	2.69	2.30	3.53
18	3.03	2.93	2.56	2.93	2.75	2.37	3.61
27	3.04	2.95	2.58	2.98	2.77	2.39	3.67
$LSD_{(0.05)}$	0.215	0.208	0.208	0.050	0.026	0.026	0.138

Interaction effect of variety and phosphorus levels

Interaction effect of variety and phosphorus level on N content of leaf, stem and seed was insignificant (Table 4.10c). Numerically the maximum N content of leaf, stem at 25, 40 and 55 DAE and seed at maturity was found in BU mung-4 with 27 kg P ha^{-1} and minimum in BINA mung-5 with 0 kg P ha^{-1}.

Table 4.10c. Interaction effect of variety and phosphorus on leaf, stem and seed N content of mungbean

Treatments	Leaf N content (%)			Stem N content (%)			N content in seed (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
BARI mung-2 x P_0	2.81	2.74	2.33	2.70	2.56	2.21	3.44
BARI mung-2 x P_9	2.89	2.78	2.38	2.80	2.69	2.33	3.53
BARI mung-2 x P_{18}	3.02	2.84	2.44	2.89	2.81	2.45	3.60
BARI mung-2 x P_{27}	3.07	2.85	2.48	2.92	2.84	2.48	3.62
BARI mung-6 x P_0	2.83	2.72	2.35	2.62	2.50	2.22	3.40
BARI mung-6 x P_9	2.93	2.81	2.39	2.77	2.66	2.33	3.52
BARI mung-6 x P_{18}	3.05	2.84	2.45	2.92	2.82	2.49	3.62
BARI mung-6 x P_{27}	3.09	2.87	2.48	2.92	2.84	2.50	3.68
BU mung-4 x P_0	2.77	2.72	2.33	2.67	2.55	2.21	3.44
BU mung-4 x P_9	2.91	2.82	2.44	2.80	2.71	2.32	3.55
BU mung-4 x P_{18}	3.10	2.88	2.53	2.98	2.87	2.49	3.63
BU mung-4 x P_{27}	3.13	2.92	2.55	3.00	2.89	2.50	3.78
BINA mung-5 x P_0	2.82	2.72	2.31	2.65	2.51	2.20	3.43
BINA mung-5 x P_9	2.88	2.77	2.40	2.77	2.67	2.32	3.51
BINA mung-5 x P_{18}	2.94	2.83	2.46	2.92	2.82	2.45	3.59
BINA mung-5 x P_{27}	3.03	2.87	2.46	2.92	2.82	2.45	3.62
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.7.2 Phosphorus content

Effect of variety

The contents of P in leaf, stem and seed was insignificant among the varieties (Table 4.11a). Numerically the maximum P content of leaf, stem at 25, 40 and 55 DAE and seed at maturity was found in BU mung-4 and minimum was in BINA mung-5.

Table 4.11a. Effect of variety on leaf, stem and seed P content of mungbean

Variety	Leaf P content (%)			Stem P content (%)			Seed P content (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
BARI mung-2	0.63	0.53	0.43	0.49	0.39	0.33	0.43
BARI mung-6	0.64	0.54	0.45	0.51	0.39	0.33	0.42
BU mung-4	0.66	0.56	0.46	0.51	0.41	0.33	0.43
BINA mung-5	0.62	0.52	0.42	0.52	0.38	0.32	0.39
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Effect of phosphorus

Phosphorus content at different growth stages of mungbean varieties varied significantly due to the variation of P levels (Table 4.11b). P content was high in leaf and stem in the early growth phase and then decreased up to maturity (Table 4.11b). This might be due to greater rate of P absorption than dry matter accumulation during early growth phase and later the dry matter accumulation increased more rapidly than absorption of the P nutrient. This indicated that the higher P content was needed at early growth, which ultimately translocated to reproductive organ for high seed yield. Similar observation was also made by Mishra and Singh (1989). The P content in plant components at different growth period and in seed was highest up to 27 kg P ha^{-1} and the lowest from 0 kg P ha^{-1} for all varieties (Table 4.11b). Phosphorus helps nutrient uptake through strong root development. So in absence of added P, root development was impaired that eventually led to the lower P uptake and lower P content. At maturity most P content was in the seed with increasing levels of P irrespective of varieties (Table 4.11b) indicating remobilization of P from vegetative tissues to pods past the generative phase of mungbean. Das (1993) also found the increasing trend of P_2O_5 in the grain of mungbean with the increasing levels of phosphorus. Similar result was also reported by Nelson (1980) in groundnut. Leaf P content was positive associated with total dry matter production of mungbean varieties (Fig. 4.4). This indicated that P content in the leaf had direct bearing on the increase in TDM.

Table 4.11b. Effect of phosphorus on leaf, stem and seed P content of mungbean

Phosphorus (kg/ha)	Leaf P content (%)			Stem P content (%)			Seed P content (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
0	0.58	0.47	0.38	0.43	0.33	0.28	0.34
9	0.60	0.50	0.40	0.47	0.36	0.32	0.40
18	0.67	0.58	0.48	0.54	0.43	0.35	0.46
27	0.69	0.60	0.49	0.56	0.44	0.37	0.48
LSD $_{(0.05)}$	0.027	0.046	0.053	0.070	0.046	0.026	0.040

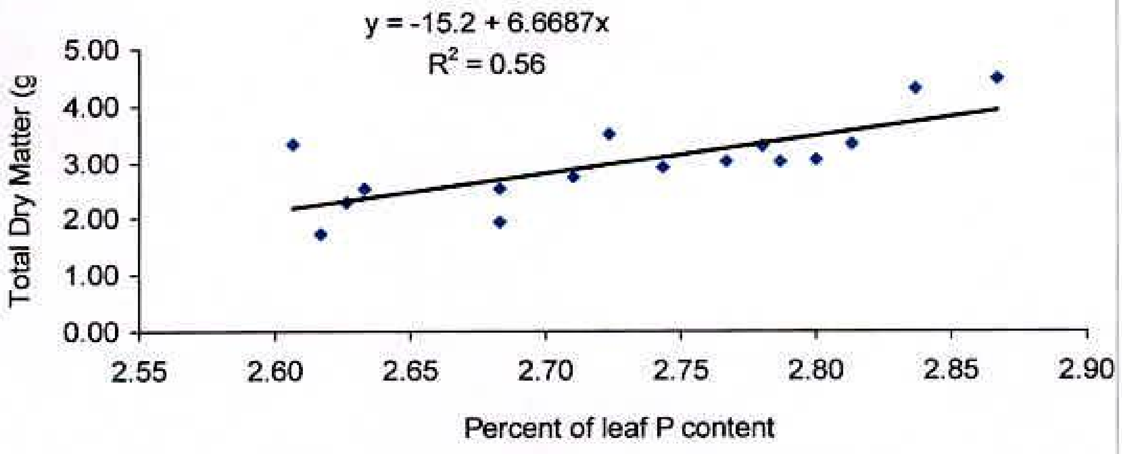


Fig. 4.4. Relationship between leaf P content (%) and total dry matter of mungbean

Interaction effect of variety and phosphorus levels

Interaction effect of variety and phosphorus level on P content of leaf, stem and seed was insignificantly (Table 4.11c). Numerically the highest P content in leaf, steam at 25, 40 and 55 DAE and seed at maturity was found in BU mung-4 with 27 kg P ha^{-1} and highest in BINA mung-5 with 0 kg P ha^{-1}.

Table 4.11c. Interaction effect of variety and phosphorus on leaf, stem and seed P content of mungbean

Treatments	Leaf P content (%)			Stem P content (%)			Seed P content (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
BARI mung-2 x P_0	0.57	0.46	0.37	0.42	0.33	0.28	0.35
BARI mung-2 x P_9	0.60	0.50	0.39	0.46	0.37	0.32	0.43
BARI mung-2 x P_{18}	0.65	0.56	0.46	0.53	0.41	0.36	0.47
BARI mung-2 x P_{27}	0.70	0.61	0.50	0.66	0.43	0.36	0.48
BARI mung-6 x P_0	0.57	0.47	0.38	0.44	0.32	0.29	0.34
BARI mung-6 x P_9	0.61	0.52	0.42	0.48	0.35	0.33	0.40
BARI mung-6 x P_{18}	0.69	0.59	0.50	0.55	0.42	0.36	0.48
BARI mung-6 x P_{27}	0.69	0.60	0.49	0.56	0.45	0.36	0.47
BU mung-4 x P_0	0.61	0.51	0.41	0.47	0.35	0.28	0.32
BU mung-4 x P_9	0.63	0.53	0.44	0.50	0.38	0.32	0.40
BU mung-4 x P_{18}	0.69	0.60	0.49	0.56	0.47	0.34	0.49
BU mung-4 x P_{27}	0.70	0.61	0.50	0.58	0.44	0.39	0.50
BINA mung-5 x P_0	0.56	0.45	0.35	0.41	0.32	0.26	0.33
BINA mung-5 x P_9	0.58	0.48	0.37	0.44	0.35	0.30	0.37
BINA mung-5 x P_{18}	0.67	0.57	0.47	0.53	0.42	0.36	0.41
BINA mung-5 x P_{27}	0.68	0.58	0.49	0.56	0.43	0.37	0.46
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.7.3 Potassium content

Effect of variety

The contents of K in leaf, stem and seed were insignificant among the varieties (Table 4.12a). The maximum K content in leaf, stem at different growth period (25, 40 and 55 DAE) and seed was found in BU mung-4 and minimum from BINA mung-5.

Table 4.12a. Effect of variety on leaf, stem and seed K content of mungbean

Variety	Leaf K content (%)			Stem K content (%)			Seed K content (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
BARI mung-2	1.36	1.25	1.14	1.44	1.55	1.14	1.28
BARI mung-6	1.37	1.28	1.16	1.46	1.56	1.20	1.32
BU mung-4	1.39	1.28	1.15	1.48	1.59	1.23	1.34
BINA mung-5	1.32	1.22	1.10	1.41	1.52	1.17	1.21
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Effect of phosphorus

The content of K in leaf, stem and seed of mungbean exhibited marked variation due to variable levels of P fertilizer (Table 4.12b). Regardless of treatment differences, K content in leaf was highest at early stage that decreased with time (Table 4.12b). Conversely, reproductive organs continued accumulating K content till maturity (55 DAE). Potassium content in the stem of different varieties increased till pod development stage (40 DAE). However, at all the growth stages stem contained higher proportion of K regardless of treatment. Potassium is highly mobile in the soil-plant system and it thus participates in physiological and biochemical processes within plant and finally stored in stem, although it varied with the variation in applied P. The decline of K content later in the growth might be due to dilution effect. Potassium content in seed also showed maximum (Table 4.12b). Plants treated with 27 kg P ha^{-1} had the highest content of K at different growth period and the lowest from 0 kg P ha^{-1}.

Table 4.12b. Effect of phosphorus on leaf, stem and seed K content of mungbean

P levels (kg/ha)	Leaf K content (%)			Stem K content (%)			Seed K content (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
0	1.17	1.08	0.96	1.24	1.34	1.01	1.19
9	1.34	1.25	1.13	1.43	1.54	1.20	1.26
18	1.42	1.31	1.19	1.51	1.64	1.26	1.33
27	1.50	1.39	1.27	1.60	1.70	1.31	1.35
$LSD_{(0.05)}$	0.046	0.109	0.113	0.200	0.100	0.106	0.110

Interaction effect of variety and phosphorus levels

Interaction effect of variety and phosphorus level on K content in leaf, stem and seed was insignificant (Table 4.12c). Numerically the maximum K content in leaf, stem at 25, 40 and 55 DAE and seed at maturity was found in BU mung-4 with 27 kg P ha^{-1} and minimum in BINA mung-5 with 0 kg P ha^{-1}.

Table 4.12c. Interaction effect of variety and phosphorus on leaf, stem and seed K content of mungbean

Treatments	Leaf K content (%)			Stem K content (%)			Seed K content (%)
	25 DAE	40 DAE	55 DAE	25 DAE	40 DAE	55 DAE	
BARI mung-2 x P_0	1.15	1.06	0.95	1.23	1.33	1.00	1.19
BARI mung-2 x P_9	1.34	1.24	1.13	1.43	1.55	1.20	1.24
BARI mung-2 x P_{18}	1.42	1.32	1.20	1.51	1.65	1.26	1.34
BARI mung-2 x P_{27}	1.51	1.40	1.27	1.60	1.70	1.30	1.35
BARI mung-6 x P_0	1.16	1.07	0.95	1.23	1.33	1.00	1.25
BARI mung-6 x P_9	1.36	1.29	1.26	1.45	1.56	1.22	1.29
BARI mung-6 x P_{18}	1.44	1.34	1.21	1.54	1.66	1.28	1.37
BARI mung-6 x P_{27}	1.52	1.44	1.31	1.62	1.72	1.32	1.39
BU mung-4 x P_0	1.22	1.12	1.03	1.30	1.40	1.07	1.24
BU mung-4 x P_9	1.38	1.27	1.14	1.47	1.56	1.23	1.33
BU mung-4 x P_{18}	1.43	1.31	1.19	1.52	1.66	1.27	1.39
BU mung-4 x P_{27}	1.52	1.40	1.27	1.64	1.73	1.35	1.40
BINA mung-5 x P_0	1.14	1.05	0.94	1.22	1.32	1.00	1.14
BINA mung-5 x P_9	1.29	1.20	1.08	1.38	1.50	1.16	1.18
BINA mung-5 x P_{18}	1.39	1.28	1.17	1.47	1.60	1.23	1.24
BINA mung-5 x P_{27}	1.46	1.34	1.22	1.57	1.68	1.24	1.27
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.8 Nutrient (N, P and K) uptake

Nutrient (N, P and K) uptake by grains was calculated from the yield data and nutrient content. The total uptake was calculated as sum total of grains.

Effect of variety

The tested mungbean varieties differed significantly in N, P and K uptake by grain (Table 4.13a). The highest N, P and K uptake by grain were obtained from BU mung-4 which was significantly higher over all other varieties. The lowest N, P and K uptake were observed by BINA mung-5 and it was statistically identical with BARI mung-2 and BARI mung-6 in case of N uptake. However, the grain of variety BARI mung-2 and BARI mung-6 had shown similar trend in P and K uptake.

Table 4.13a. Effect of variety on grain nutrient uptake of mungbean

Variety	Nutrient uptake by grain (kg/ha)		
	N	P	K
BARI mung-2	35.97	4.43	13.05
BARI mung-6	37.51	4.50	13.90
BU mung-4	43.38	5.22	16.17
BINA mung-5	32.90	3.69	11.26
LSD $_{(0.05)}$	5.24	0.24	1.420

Effect of phosphorus

The uptake of N, P and K were also significantly influenced due to application of phosphorus (Table 4.13b). Increase in the rate of applied P fertilizer enhanced N, P and K in the plants and consequently increased total uptake by grains. The highest N, P and K uptake by grain were obtained in 27 kg P ha^{-1}, which was similar to 18 kg P ha^{-1}. The lowest N, P and K uptake were recorded in the control plot (without added P).

Table 4.13b. Effect of phosphorus on grain nutrient uptake of mungbean

P levels (kg/ha)	Nutrient uptake by grain (kg/ha)		
	N	P	K
0	29.91	2.91	10.49
9	34.72	3.93	12.44
18	41.81	5.37	15.50
27	43.31	5.62	15.95
LSD $_{(0.05)}$	3.16	0.27	1.56

Interaction effect of variety and phosphorus levels

The interaction effect of variety and phosphorus on N, P and K uptake by grain was significant (Table 4.13c). Increase in the level of P fertilizer up to 27 kg ha^{-1} generally increased N, P and K uptake by grain irrespective of varieties. The highest N, P and K uptake by grain was recorded in BU mung-4 with 27 kg P ha^{-1} followed by BU mung-4 with 18 kg P ha^{-1}. On the other hand, significantly lowest N, P and K uptake was apparent by grain of mungbean with 0 kg P ha^{-1} across the varieties.

Table 4.13c. Interaction effect of variety and phosphorus on grain nutrient uptake of mungbean

Treatments	Nutrient uptake by grain (kg/ha)		
	N	P	K
BARI mung-2 x P_0	28.52	2.91	9.94
BARI mung-2 x P_9	32.97	4.01	11.58
BARI mung-2 x P_{18}	40.96	5.34	15.24
BARI mung-2 x P_{27}	41.44	5.49	15.45
BARI mung-6 x P_0	30.80	3.08	10.96
BARI mung-6 x P_9	34.53	3.92	12.63
BARI mung-6 x P_{18}	41.77	5.53	15.80
BARI mung-6 x P_{27}	42.94	5.48	16.22
BU mung-4 x P_0	35.32	3.28	12.73
BU mung-4 x P_9	39.90	4.49	14.26
BU mung-4 x P_{18}	47.95	6.47	18.36
BU mung-4 x P_{27}	50.38	6.66	18.66
BINA mung-5 x P_0	25.03	2.40	8.33
BINA mung-5 x P_9	31.51	3.32	10.59
BINA mung-5 x P_{18}	36.58	4.17	12.63
BINA mung-5 x P_{27}	38.48	4.88	13.50
$LSD_{(0.05)}$	6.20	0.55	3.10

4.9 Protein content in seed

Effect of variety

Protein content in seeds did not vary significantly among the varieties (Table 4.14a). Numerically BU mung-4 had the highest protein content (22.49) and the lowest was in BINA mung-5(22.09%).

Table 4.14a. Effect of variety on grain protein content of mungbean

Variety	Protein content in grain (%)
BARI mung-2	22.15
BARI mung-6	22.20
BU mung-4	22.49
BINA mung-5	22.09
LSD $_{(0.05)}$	NS

NS = Not significant

Effect of phosphorus

The effect of phosphorus on protein content was insignificant (Table 4.14b) though the maximum protein content (22.95%) was observed in 27 kg P ha^{-1} and the minimum protein content (21.40%) was observed in 0 kg P ha^{-1}.

Table 4.14b. Effect of phosphorus on grain protein content of mungbean

P levels (kg/ha)	Protein content in grain (%)
0	21.40
9	22.02
18	22.55
27	22.95
LSD $_{(0.05)}$	NS

NS = Not significant

Interaction effect of variety and phosphorus levels

Interaction of variety and phosphorus was not significant in case of protein content in grain of mungbean (Table 4.14c). Numerically the highest protein content (23.65%) in grain was obtained from BU mung-4 with 27 kg P ha^{-1} and the lowest (21.40%) in BINA mung-5 with 0 kg P ha^{-1} (Table 4.14c).

Table 4.14c. Interaction effect of variety and phosphorus on grain protein content of mungbean

Treatments	Protein content in grain (%)
BARI mung-2 x P_0	21.50
BARI mung-2 x P_9	22.00
BARI mung-2 x P_{18}	22.50
BARI mung-2 x P_{27}	22.60
BARI mung-6 x P_0	21.20
BARI mung-6 x P_9	22.00
BARI mung-6 x P_{18}	22.60
BARI mung-6 x P_{27}	23.00
BU mung-4 x P_0	21.50
BU mung-4 x P_9	22.18
BU mung-4 x P_{18}	22.68
BU mung-4 x P_{27}	23.60
BINA mung-5 x P_0	21.40
BINA mung-5 x P_9	21.93
BINA mung-5 x P_{18}	22.43
BINA mung-5 x P_{27}	22.60
LSD $_{(0.05)}$	NS

NS = Not significant

4.10 Protein yield

Effect of variety

Protein yield in seeds varied significantly among the varieties (Table 4.15a). The BU mung-4 variety produced the highest protein yield (271.07 kg ha^{-1}) which was significantly higher over all other varieties. On the contrary, BINA mung-5 gave the lowest protein yield (205.48 kg ha^{-1}). However, variety BARI mung-2 and BARI mung-6 produced similar protein yield.

Table 4.15a. Effect of variety on grain protein yield of mungbean

Variety	Grain protein yield (kg/ha)
BARI mung-2	224.79
BARI mung-6	234.27
BU mung-4	271.07
BINA mung-5	205.48
$LSD_{(0.05)}$	10.99

Effect of phosphorus

The effect of phosphorus on protein yield was significant (Table 4.15b). Increase in P fertilizer generally tended to increase protein yield. Application of 27 kg P ha^{-1} produced significantly higher protein yield (270.49 kg ha^{-1}) and it was not significantly different from 18 kg P ha^{-1}. Plants grown without or lower rates of P had the lowest protein yield.

Table 4.15b. Effect of phosphorus on grain protein yield of mungbean

P levels (kg/ha)	Grain protein yield (kg/ha)
0	186.99
9	216.88
18	261.25
27	270.49
$LSD_{(0.05)}$	10.210

Interaction effect of variety and phosphorus levels

Interaction of variety and phosphorus was not significant in protein yield (Table 4.15c). This might be due to similar response of 4 varieties with phosphorus on protein yield. Numerically maximum protein yield was found in BU mung-4 with 27 kg P ha^{-1} and minimum was in BINA mung-5 with 0 kg P ha^{-1}.

Table 4.15c. Interaction effect of variety and phosphorus on grain protein yield of mungbean

Treatments	Grain protein yield (kg/ha)
BARI mung-2 x P_0	178.88
BARI mung-2 x P_9	205.48
BARI mung-2 x P_{18}	256.05
BARI mung-2 x P_{27}	258.77
BARI mung-6 x P_0	192.07
BARI mung-6 x P_9	215.82
BARI mung-6 x P_{18}	260.80
BARI mung-6 x P_{27}	268.41
BU mung-4 x P_0	220.80
BU mung-4 x P_9	249.30
BU mung-4 x P_{18}	294.60
BU mung-4 x P_{27}	314.58
BINA mung-5 x P_0	156.22
BINA mung-5 x P_9	196.93
BINA mung-5 x P_{18}	228.56
BINA mung-5 x P_{27}	240.23
$LSD_{(0.05)}$	NS

NS = Not significant

4.11 Crop characters

4.11.1 Plant height

The plant height was affected by variety and P levels. Plant height contributes final seed yield and TDM production.

Effect of variety

Plant height was significantly influenced by variety (Table 4.16a). The tallest plant was recorded by BARI mung-2 which was significantly different from all other varieties. The shortest plant was obtained from BU mung-4 and it was statistically identical with BARI mung-6 and BINA mung-5.

Effect of phosphorus

Phosphorus fertilizer had significant influence on plant height (Table 4.16b). Generally P application tended to increase plant height across the varieties. The tallest plant height (35.41 cm) was resulted from 27 kg P ha^{-1}, which was statistically higher over all other P doses except 18 kg P ha^{-1} (33.62 cm). Plants grown without P fertilizer produced the shortest plant height (29.40 cm). Similar results were obtained by Patel and Patel (1991) who reported that plant height significant increased with the increase in P level from 0 to 60 kg P_2O_5 per hectare.

Interaction of variety and phosphorus level

Variety x P fertilizer interaction effect on the plant height was not statistically significant (Table 4.16c). Numerically the tallest plant was obtained from BARI mung-2 with 27 kg P ha^{-1} and the shortest plant (28.26 cm) was found in BU mung-4 with 0 kg P ha^{-1}.

4.11.2 Pod length

Pod length is an important factor which contributes towards seed yield by containing seed. Variety and phosphorus level had a significant effect on pod length.

Effect of variety

The length of pod significantly varied among the varieties (Table 4.16a). The variety BU mung-4 produced significantly longest pod compared with the other varieties. BARI mung-6 recorded an intermediate pod length. BARI mung-2 and BINA mung-5 produced statistically similar pod length.

Effect of phosphorus

Pod length was greatly increased with increased of P levels (Table 4.16b). The longest pod (7.82 cm) was obtained from 27 kg P ha^{-1}, which was identical to 18 kg P ha^{-1} (7.56 cm). The shortest pod was obtained from 0 kg P ha^{-1} (6.75 cm). This result was confirmed by Patel and Patel (1991) who reported that pod length was increased up to 27 kg P ha^{-1}.

Interaction effect of variety and phosphorus levels

In the study, the interaction between variety and P levels had significant influence on pod length (Table 4.16c). Application of P fertilizer tended to increase pod length linearly up to 27 kg ha^{-1} irrespective of varieties. The longest pod (9.06) was observed in BU mung-4 with 27 kg P ha^{-1} followed by BU mung-4 with 18 kg P ha^{-1}. The shortest pod (5.73 cm) was found in BINA mung-5 with 0 kg P ha^{-1}.

4.11.3 Pods $plant^{-1}$

The number of pods $plant^{-1}$ contributes towards the final seed yield in mungbean and its was affected by variety and P levels in this study.

Effect of variety

Pods $plant^{-1}$ affected significantly influenced by the variety (Table 4.16a). The result showed that superior number pods $plant^{-1}$ (8.75) was recorded with BU mung-4 which significantly higher over all other varieties. The least number of pods $plant^{-1}$ was obtained from BINA mung-5.

Effect of phosphorus

Phosphorus fertilizer significantly increase the number of pods plant^{-1} (Table 4.16b). The highest number of pods plant^{-1} (8.85) was found by applying 27 kg P ha^{-1} that similar with 18 kg P ha^{-1}. The lowest number pods plant^{-1} was found in 0 kg P ha^{-1}. Sharma and Singh (1997) observed that application of phosphorus at 50 kg P_2O_5 ha^{-1} significantly enhanced the number of pods plant^{-1}.

Interaction effect of variety and phosphorus levels

Variety and P levels interaction effect on pods plant^{-1} was statistically significant (Table 4.16c). The mean number of pods plant^{-1} varied from 6.66 to 9.70 due to different levels of P. The highest number of pods plant^{-1} (9.70) was received from BU mung-4 with 27 kg P ha^{-1} followed by BU mung-4 with 18 kg P ha^{-1}, BARI mung-6 with 27 kg P ha^{-1} and BARI mung-2 with 27 kg P ha^{-1}. BINA mung-5 with 0 kg P ha^{-1} gave the lowest (6.66) pods plant^{-1}.

4.11.4 Seeds pod^{-1}

The number of Seeds pod^{-1} contributes materially towards seed yield, which was affected by variety and phosphorus.

Effect of variety

The effect of variety on seeds pod^{-1} was significant. The number of seeds pod^{-1} differed significantly among the varieties (Table 4.16a). BU mung-4 produced the highest number of seed pod^{-1} (10.50) which was statistically similar to BARI mung-6 and dissimilar to other varieties. BARI mung-2 and BINA mung-5 produced the lower but identical mature seeds pod^{-1}.

Effect of phosphorus

Number of seeds pod^{-1} varied significantly due to variation of P levels (Table 4.16b) up to 27 kg P ha^{-1}. Phosphorus fertilizer significantly increased the number of seeds pod^{-1}. Similar results were obtained by Mitra *et al.* (1999). Their study revealed that number of seeds pod^{-1} increased with up to 27 kg P ha^{-1}. The highest number of seed pod^{-1} (10.14) was found in 27 kg P ha^{-1} which was similar to 18 kg P ha^{-1} (9.87). The lowest number of seeds pod^{-1} (8.62) was obtained from 0 kg P ha^{-1} followed by 9 kg P ha^{-1}.

Interaction effect of variety and phosphorus levels

Interaction effect of variety and phosphorus on the number of seeds pod^{-1} was statistically significant (Table 4.16c). Number of seeds pod^{-1} increased with the increasing of P fertilizer reaching maximum at 27 kg P ha^{-1}. The highest number of seeds pod^{-1} (11.36) was observed in BU mung-4 with 27 kg P ha^{-1} followed by BU mung-4 with 18 kg P ha^{-1}. Significantly the lowest seeds pod^{-1} was obtained from 0 kg P ha^{-1} irrespective of varieties.

4.11.5 1000-seed weight

Seed weight is an important yield determinant and plays a decisive role in expressing the yield potential its of variety (Sana *et al.*, 2003).

Effect of variety

Significant variation in 1000-seed weight was observed among the varieties (Table 4.16a) and varied from 35.61 to 49.24 g; the lowest being recorded for BINA mung-5. The highest 1000-seed (49.24 g) was obtained in BU mung-4 which was significantly higher over all other varieties.

Effect of phosphorus

Phosphorus fertilizer significantly increased the 1000-seed weight (Table 4.16b). The result showed that 1000-seed weight was highest (40.81 g) in 27 kg P ha^{-1} being statistically similar to 18 kg P ha^{-1} but dissimilar to others. The lowest 1000-seed weight (37.98 g) was obtained in 0 kg P ha^{-1} which was identical to 9 kg P ha^{-1}. This result was confirmed with the findings of Reddy *et al.* (1990).

Interaction effect of variety and phosphorus levels

The interaction effect of variety and phosphorus was significant in respect of 1000-seed weight (Table 4.16c). There was always a linear increase in 1000-seed weight with the increase of P fertilizer irrespective of varieties. The highest 1000-seed weight (50.16 g) was found in BU mung-4 with 27 kg P ha^{-1}, closely followed by BU mung-4 with 18 kg P ha^{-1}. BINA mung-5 with 0 kg P ha^{-1} gave the lowest 1000- seed weight (27.60 g).

Table 4.16a. Effect of variety on the yield attributes of mungbean

Variety	Plant height (cm)	Pod length (cm)	Pods/plant (no.)	Seeds/pod (no.)	1000 seed weight (g)
BARI mung-2	34.85	6.27	7.71	9.63	35.61
BARI mung-6	31.67	8.20	8.01	10.08	43.81
BU mung-4	31.20	8.47	8.75	10.50	49.24
BINA mung-5	32.27	6.34	7.45	9.35	29.31
LSD $_{(0.05)}$	1.16	0.22	0.14	0.82	3.00

Table 4.16b. Effect of phosphorus on the yield contributing characters of mungbean

P levels (kg/ha)	Plant height (cm)	Pod length (cm)	Pods/plant (no.)	Seeds/pod (no.)	1000 seed weight (g)
0	29.40	6.75	7.01	8.62	37.98
9	31.58	7.15	7.73	8.79	38.56
18	33.62	7.56	8.33	9.87	40.63
27	35..41	7.82	8.85	10.14	40.81
LSD $_{(0.05)}$	1.89	0.30	0.60	0.48	1.64

Table 4.16c. Interaction effect of variety and phosphorus on the yield attributes of mungbean

Treatments	Plant height (cm)	Pod length (cm)	Pods/plant (no.)	Seeds/pods (no.)	1000 seed weight (g)
BARI mung-2 x P_0	32.26	5.86	6.80	9.16	34.93
BARI mung-2 x P_9	34.00	6.10	7.36	9.75	35.46
BARI mung-2 x P_{18}	35.63	6.46	8.06	9.76	36.26
BARI mung-2 x P_{27}	37.50	6.65	8.63	9.86	36.46
BARI mung-6 x P_0	28.60	7.60	7.16	9.76	42.86
BARI mung-6 x P_9	30.53	7.93	7.96	9.90	43.62
BARI mung-6 x P_{18}	33.21	8.53	8.20	10.30	44.33
BARI mung-6 x P_{27}	34.36	8.73	8.73	10.36	44.46
BU mung-4 x P_0	28.26	7.80	7.43	9.50	48.12
BU mung-4 x P_9	30.70	8.36	8.46	9.93	48.36
BU mung-4 x P_{18}	32.16	8.65	9.40	11.21	49.66
BU mung-4 x P_{27}	33.70	9.06	9.70	11.36	50.16
BINA mung-5 x P_0	28.50	5.73	6.66	8.62	27.60
BINA mung-5 x P_9	31.00	6.20	7.15	8.79	28.05
BINA mung-5 x P_{18}	33.50	6.60	7.66	9.87	29.00
BINA mung-5 x P_{27}	36.10	6.83	8.33	10.14	29.26
$LSD_{(0.05)}$	NS	0.50	1.10	0.97	3.20

NS = Not significant

4.12 Seed yield

Effect of variety

The different varieties of mungbean varied significantly in terms of seed yield (Table 4.17a). The highest seed yield (121.25 kg ha^{-1}) was recorded in BU mung-4 that was statistically higher than all other varieties. BINA mung-5 gave the lowest seed yield (927.5 kg ha^{-1}). BU mung-4 produced higher dry weight, root nodules and pods $plant^{-1}$, which resulted in higher seed yield. BARI mung-6 recorded the second highest seed yield (1052.16 kg ha^{-1}) which was followed by BARI mung-2. The present result was in agreement with Samanta *et al.* (1999) who reported that varieties of mungbean differed significantly in seed yield.

Table 4.17a. Effect of variety on seed yield of mungbean

Variety	Seed yield (kg ha^{-1})
BARI mung-2	1012.25
BARI mung-6	1052.16
BU mung-4	1201.25
BINA mung-5	927.50
$LSD_{(0.05)}$	88.30

Effect of phosphorus

Seed yield of mungbean differed significantly due to the variation of P levels (Table 4.17b). In crease of seed yield with the increase of levels of P up to 27 kg ha^{-1}. The highest seed yield (1117 kg ha^{-1}) was obtained from 27 kg P ha^{-1} which was similar to 18 kg P ha^{-1}. Significantly the lowest seed yield was found in 0 kg P ha^{-1}. The increase in seed yield with increasing fertilizer might be attributed to increase nodules $plant^{-1}$ and nodule dry weight resulting in higher dry matter accumulation during the growth period and translocation of more photosynthate to the seed (Rani and Kodandaramaiah, 1997). Moreover, the higher yield advantage with increasing P levels (18-27 kg ha^{-1}) might be due to increase number of pods $plant^{-1}$, seeds pod^{-1} and 1000-seed weight.

Table 4.17b. Effect of phosphorus on seed yield of mungbean

Phosphorus (kg/ha)	Seed yield (kg/ha)
0	873.75
9	984.25
18	1158.16
27	1177.00
$LSD_{(0.05)}$	61.14

Interaction effect of variety and phosphorus levels

The interaction effects of different variety and phosphorus was significant in terms of seed yield (Fig. 4.5). Fertilizer P generally increased seed yield irrespective of varieties. BU mung-4 with 27 kg P ha^{-1} gave the highest seed yield (1333.0 kg ha^{-1}) which was identical to BU mung-4 with 18 kg P ha^{-1}. The yield advantage of fertilizer (18-27 kg ha^{-1}) application mainly due to more pods plant^{-1} and largest seed. Moreover, application of 18-27 kg P ha^{-1} enhanced seed yield in BU mung-4 which bears high root length might be increased feeding gone or root system. As a result more nutrients become available to plants resulte in higher biomass and yield. When the varieties grown without added or with lower levels of P fertilizer produced significantly the lowest seed yield.

Phosphorus rate was positive associated with grain yield of mungbean varieties (fig:4.6). This indicated that P rate had direct bearing on the increase in grain yield of mungbean.

Regrassion analysis was performed to find the response of grain yield in relation with root length density. The response function was illustrated in Fig:4.7. Linear relationship was found between grain yield and root length density. The R^2 (0.85) value suggested that 85% of the variation in grain yield could be attributed to the differences in RLD

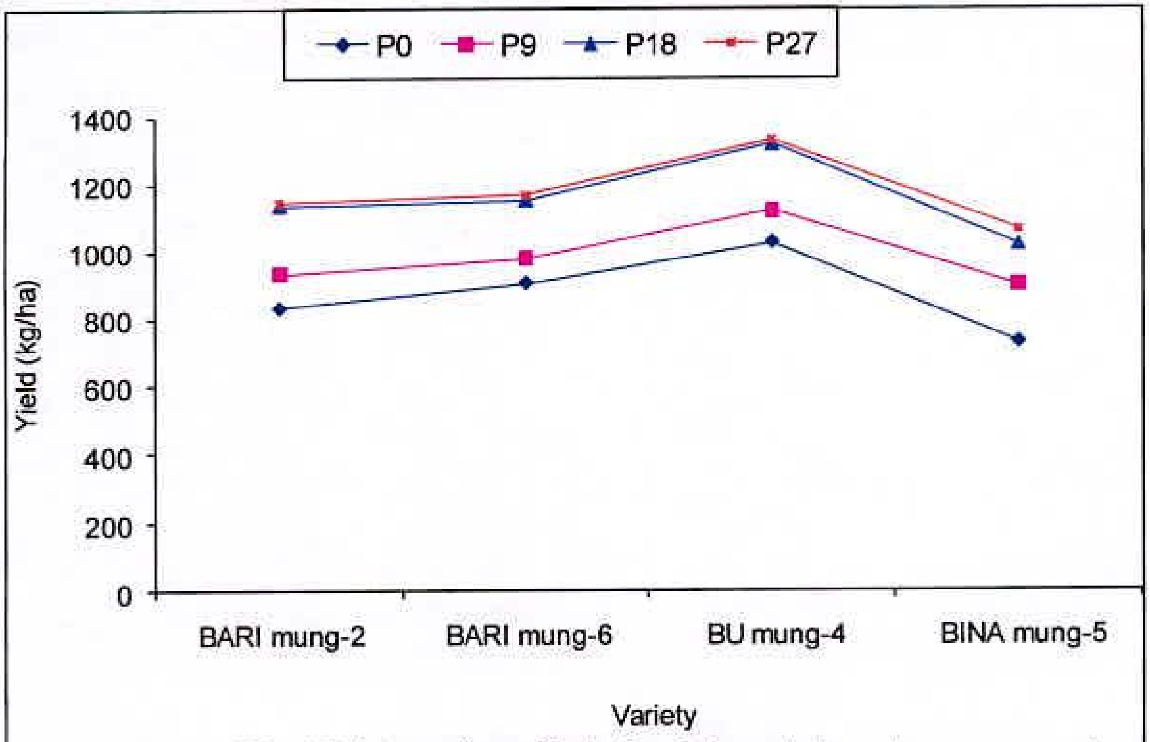


Fig. 4.5. Interaction effect of variety and phosphorus on seed yield of mungbean (LSD $_{(0.05)}$ = 122.28)

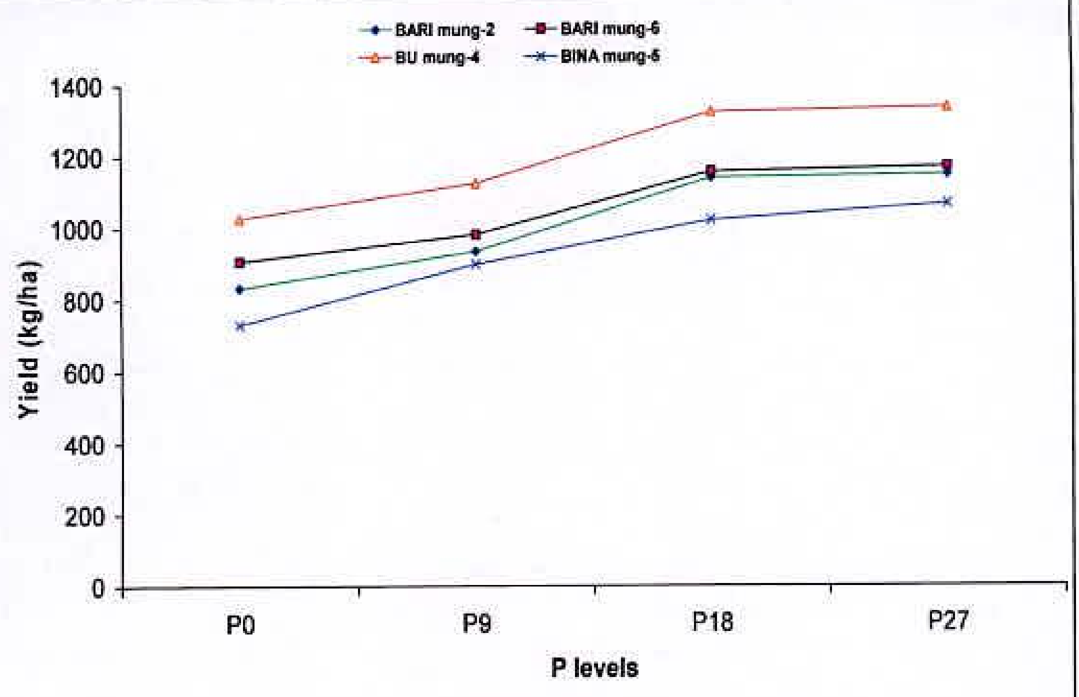


Fig. 4.6. Response of grain yield of mungbean to phosphorus levels

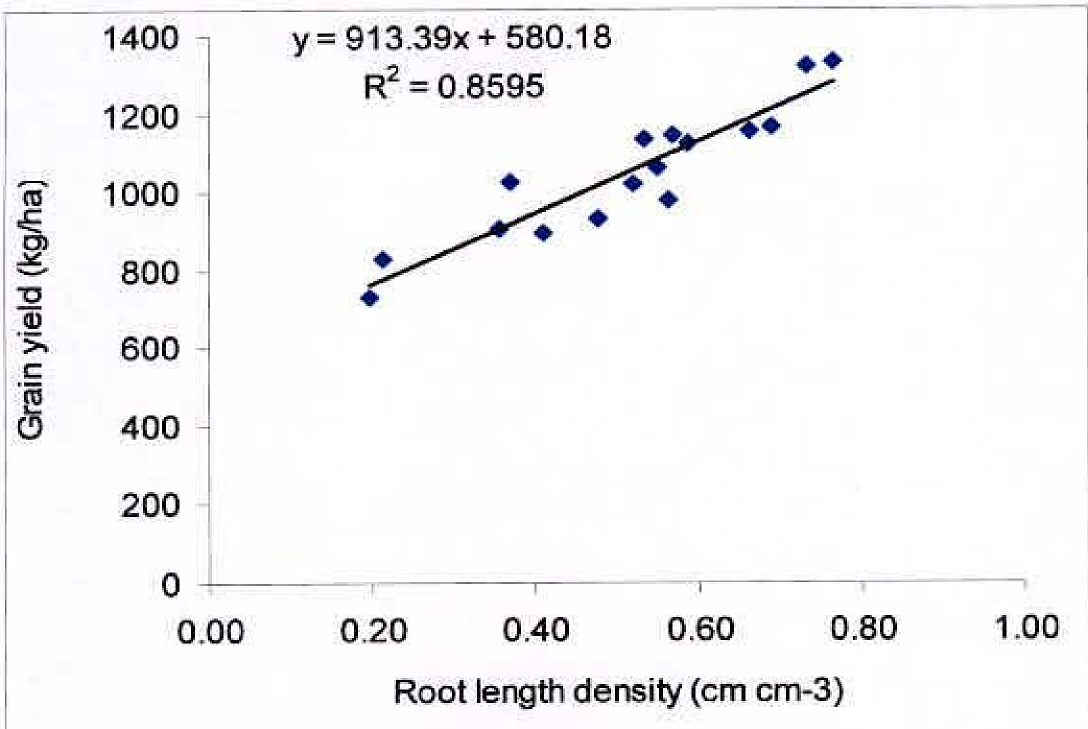


Fig. 4.7. Relationship between grain yield and root length density (RLD)

Chapter 5

Summary and conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

SUMMARY

An experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e Bangla Nagar, Dhaka during September to November, 2006. The objectives of the study were (i) to evaluate the varietal performance on root growth and dry matter accumulation of mungbean, (ii) to evaluate varietal variations in nutrient uptake pattern in relation to root growth and dry matter production, (iii) to determine yield performance of mungbean varieties in relation to the root system developments and (iv) to identify the optimum phosphorus level of kharif-II mungbean for obtaining maximum yield. The experiment was designed with 16 treatment combinations with four levels of phosphorus (0, 9, 18 and 27 kg P ha^{-1}) and four varieties of mungbean (BARI mung-2, BARI mung-6, BU mung-4 and BINA mung-5). The trial was set up in a split plot design with 3 replications, where varieties were randomly arranged to the main plot and phosphorus levels in the sub plot. Unit plot size was 3m x 3m. The plots were fertilized with 13, 25 and 0.05 kg/ha of N, K and B along with P fertilizer as per treatment as a basal dose. Seeds were sown in lines on the 3rd September, 2006 with 30 x 10 cm spacing. The intercultural operations were done as and when required. The crop was harvested on November 3, 2006.

The parameters were recorded as leaf area, root length, root dry weight, root length density, root mass density, total dry matter, nodule number, nodule weight, plant height, pod length, pods $plant^{-1}$, seeds pod^{-1}, 1000-seed weight and seed yield. Leaf, stem and seed samples were chemically analyzed for NPK content. All the data were statistically analyzed following F text and LSD at 5% level. Significant influence of the mungbean varieties were observed on leaf area, root length, root dry weight, root length density, root mass density, total dry matter, nodule number, nodule weight and nutrient uptake. The highest leaf area,

root length, root dry weight, root length density, root mass density, total dry matter, nodule number, nodule weight of the mungbean obtained from BU mung-4 and the lowest from BINA mung-5. Higher plant height, pod length, pods plant^{-1}, seeds pod^{-1}, 1000-seed weight was also recorded in BU mung-4. BU mung-4 had greater yield potential than other three varieties.

Application of P fertilizer produced significant effect on the yield attributes of mungbean varieties. The tallest plant height was recorded in 27 kg P ha^{-1} that was followed by 18 kg P ha^{-1}. 27 kg P ha^{-1} treatment also recorded the highest pods plant^{-1}, seed pod^{-1} and 1000-seed weight which was insignificant with 18 kg P ha^{-1}. Application of 27 kg P ha^{-1} fertilized gave the highest seed yield (1177 kg ha^{-1}) which was significantly higher over all other P levels except 18 kg P ha^{-1}. Application of 27 kg P ha^{-1} with BU mung-4 produced the highest leaf area, root length, root dry weight, root length density, root mass density, total dry matter, nodule number, nodule weight. The highest seed yield as well as yield attributes such as pod length, pods plant^{-1}, seeds pod^{-1}, 1000-seed weight recorded in 27 kg P ha^{-1} with BU mung-4, which was identical to BU mung-4 with 18 kg P ha^{-1}. The highest NPK concentration and protein concentration were also recorded in 27 kg P ha^{-1} with BU mung-4. Among the varieties, BU mung-4 was found superior in respect of RLD, TDM and seed yield followed by BARI mung-6 and BARI mung-2 and the lowest from BINA mung-5.

CONCLUSION

The following conclusion can be made based on the results of the study :

- Variety BU mung-4 was superior to that of other varieties in respect of root length density, dry matter accumulation, nutrient uptake and yield.
- Application of P fertilizer in Gray Terrace Soil at the rate of 18-27 kg ha^{-1} for mungbean increased yield attributes and also favoured greater uptake of different nutrient (NPK).

References

REFERENCES

Abdul Salam , M. and Nair, R.V. (1983). Performance of mungbean (*Vigna radiata* (L.) Wilczek) under graded doses of lime and phosphorus in the acid sandy clay loom soils of Kerala. Madras Agril. J. **70** (2) : 128-129.

Agbenin, J. O., Lombin, G. and Owonubi, J. J. (1991). Direct and interactive effect of boron and nitrogen on selected agronomic parameters and nutrient uptake by mungbean (*Vigna radiata*) under glasshouse condition. *Tropic. Agric.* (Trinidad and Tobago). **68**(4) : 352-362.

Ahmed, I. U., Rahman, S., Begum, N. and Islam, M. S. (1986). Effect of Phosphorus and Zinc application on the growth, yield and P, Zn production of mungbean (*Vigna radiata* (L) Wilezek). *Indian Soil*. **64** (2) : 305-308.

Arihara, J. N. A. E. and Okada, K. (1991). Root development of pigeonpea and chickpea and its significance in different cropping system. Pages 183-195 in phosphorus nutrition of grain legumes in the semi-arid tropic (Johansen, C., K. K. Lee and K. L. Sahrawat, eds.). Patancheru, Andhra Pradesh, ICRISAT, India.

BARI (Bangladesh Agricultural Research Institute). (1999). Annual Report for 1997-98. Lentil, black gram and mungbean development pilot project, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. pp. 8-9.

Bayan, H. C. and Saharia, P. (1996). Effect of weed management and phosphorus on *Kharif* mungbean (*Vigna radiata* (L) Wilczek). *J. Agril. Sci. Soc. North East India*. **9**(2) : 151-154.

BBS (Bangladesh Bureau of Statistics). (2004). Statistical Year Book of Bangladesh. Statistics Division. Ministry of Planning. Government of the Peoples Republic of Bangladesh. Dhaka. pp. 141-142.

BBS (Bangladesh Bureau of Statistics). (2005). Statistical Year Book of Bangladesh. Statistics Division. Ministry of Planning. Government of the Peoples Republic of Bangladesh. Dhaka. p. 140.

Black, C. A. (1965). Methods of Soil Analysis. Part II. Americ. Soc. Agron. Inc. Publisher. Madison Wisconsin, USA.

Borde, B. K., Mohite, A. V., Kadam, J. R. and Patil, N. D. (1983). Effect of phosphorus application through fertilizer and press mud cake on mungbean (*Vigna radiata*). *J. Maharashtra Agril. Univ.* **8**(3) : 290-291.

Chowdhury, M. M. U. (1996). Response of mungbean (*Vigna radiata* (L.) Wilczek) *Rhizobium* inoculum and phosphorus application. M.S. Thesis, Dept. of Soil Sci, IPSA, Salna, Gazipur-1703, Bangladesh. pp. 47-51.

Chowdhury, M. M. U., Ullah, M. H. and Mahmmud, Z. U. (2000). Dry matter production in mungbean (*Vigna radiata* (L.) Wilczek) as influenced by *Bradyrhizobium* inoculum and phosphorus application. *Legume Res.* **23**(1) : 15-20.

Das, K. L. (1993). Effect of phosphorus on growth, nodulation and enzymatic activities of mungbean. M.S. Thesis. Dept. of Soil Sci., IPSA, Salna, Gazipur, Bangladesh.

Douglas, L. A. and Weaven, R. W. (1986). Partitioning of nitrogen labeled biologically fixed nitrogen and nitrogen labeled nitrate in cowpea during pod development. *Agron. J.* **78**: 499-502.

Evans, L. T. (1975). The physiological basis of crop yield *In*: Crop Physiol. Cambridge Univ. Press Cambridge. pp. 327-355.

FAO, (1988). The Year Book of Production, FAO, Rome, Italy.

Fernandez, G.C.J. and Sanmugasundaram, S. (1988). The AVRDC mungbean improvement programme. The Past, present and future. In mungbean S Shanmugasundaram (Ed.). proceedings of the 2nd International Symposium, Bankok (16-19 Nov. 1987). pp. 58-70.

Gill, M. A., Maimat, A. and Nayer, M. M. (1985). Relative effect of phosphorus combined with potash and *Rhizobium phaseoli* on the yield of mungbean (*Vigna radiata* (L.) Wilczek). *J. Agril. Res.* (*Pakistan*). **23**(4) : 297-282.

Gomez, A. A. and Gomez, K. A. (1983). Multiple cropping in the humid tropics of Asia. Internaitonal Development Research Centre. Ottawa, Canada. pp. 37-37.

Gopala Rao, P., Shrajee, A. M., Roma Rao, K. and Reddy. T. R. K. (1993). Response of mungbean (*Vigna radiata*) cultivars to levels of phosphorus. *Indian J. Agron.* **38** (2) : 317-318.

Griffith, W. K. (1978). Effects of phosphorus and potassium on nitrogen fixation. In: Phosphorus for Agriculture a Situation Analysis. Potash or Phosphate Institute, Atlanta, G.A. pp. 80-90.

Gupta, A. K. and Rai, R. K. (1989). Influence of dates of planting, moisture levels and rate of P application on root development and phosphorus uptake in summer greengram (*Vigna radiata*). *Fert. News*. **34** : 43-45.

Hunt, R. (1978). The fitted curve in plant growth studies. Math and Plant Physiology (Edn. Rose, D.A. and Edwards, D.A.C.). Aca. Press, London, pp. 283-298.

Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi. P. 498.

Jain, R. C., Nema, D. P., Khandwe, and Thakur, R. (1990). Effect of phosphorus and potassium on yield, nutrients uptake and oil contents of groundnut (*Arachis hypogaea* L.), *Indian J. Agric. Sci.* **60** : 559-566.

Kalita, M. M. (1989). Effect of phosphate of phosphate and growth regulator on mungbean (*Vigna radiata* (L.) Wilczek). *Indian J. Agron.* **34**(2) : 236-237.

Katiya, R. P. (1980). Development changes in LAI and growth parameters in chickpea. *Indian. J. Agric. Sci.* **50** : 684-691.

Khan, M. A. A. (1981). The effect of CO_2 environment on the pattern of growth and development in rice and mustard. Ph.D Dissertation. Royal Vet. and Agril. Univ. Copenhagen. p. 104.

Kumari, T. S. and Singh, B. G. (1990). Analysis of dry matter production and yield potential in groundnut genotypes. *J Maharashtra Agric. Univ.* **15** : 310-313.

Masthan, S. C., Reddy, S. N., Reddy, T. M. M. Shaik, M. and Mohammad, S. (1999). Productivity potential of rice-sunflower-mungbean cropping system as influenced by rational use of phosphorus. *Indian J. Agron.* **44**(2) : 232-236.

Mishra, S. N. and Singh, A. P. (1989). Studies on sulphur and phosphorus availability and uptake by groundnut. *Legume Res.* **12** : 160-164.

Mitra, S., Bhattacharya, S. K., Datta, M. and Banik, S. (1999). Effect of variety, rock phosphate and phosphate solubilizing bacteria on growth and yield of mungbean (*Vigna radiata* (L.) Wilczek) in acid soils of Tripura. *Environ. Ecol.* **17**(4) : 926-930.

Morrison, F. B. (1956). Feeds and Feeding, 2nd Edn. The Morrison Publishing Co. Ithaca, New York, USA. p. 77.

Murakami, T., Siripin, S., Wadisirisuk, P., Boonderd, N., Yoneyama, T., Yokoyama, T. and Imai, H. (1990). The nitrogen fixing ability of mungbean *Vigna radiata*. The mungbean meeting. 90, Thailand. pp. 187-197.

Nelson, E. (1980). Phosphorus nutrition of cotton, peanuts, rice, sugarcane and tobacco. pp. 693-736. In The Role of Phosphorus in Agriculture. F.E. Khasawneh, E.C. Sample and E.J. Kamprath, eds. Am. Soc. Agron. Madison, Wisconsin, USA.

Nerson, H. M., Edelstein and Pinthus, M. J. (1990). Effects of N and P nutrition on spike development in spring wheat. *Plant and Soil*. **124** : 33-37.

Olsen, S.R., Cale, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. U.S. Dept. Agr. Rices. P.929.

Page, A. L., Miller, R. H. and Keeney, D. R. (1982). Methods of soil analysis. Part 2.2nd ed. Amer. Soc. Agron. Inc. Madi, USA.

Pal, G. and Lal, B. (1993). Nodulation and rooting pattern of summer greengram (*Phaseolus radiatus*) as influenced by irrigation variables. *Indian J. Agric. Sci.* **38**(1): 129-131.

Patel, F. M. and Patel, L. R. (1991). Response of mungbean (*Vigna radiata*) varieties to phosphorus and *Rhizobium* inoculation. *Indian J. Agron.* **36**(2) : 295-297.

Patel, R. R., Patel, J. R., Sonani, V. V. and Sasani, G. V. (1988). Effect of inoculation N and P fertilization on yield and yield attributes of mungbean var. Gajarat-I (*Vigna radiata* (L.) Wilczek). *Gujarat Agril. Univ. Res. J.* **14**(1) : 17-22.

Pereira, P. A. A. and Blish, F. A. (1987). Nitrogen fixation and plant growth of common bean (*Phaseolus vulgaris*) at different levels of phosphorus availability. *Plant and Soil*. **104**: 79-84.

Piper, C. S. (1950). Soil and Plant Analysis. Adelaide Univ. Press. Australia.

Poehlman, J. M. (1991). The mungbean. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India.

Radford, P. J. (1967). Growth analysis formulae, their use and abuse. *Crop Sci.* 7 : 171-175.

Rahman, M. M. (1994). Varietal development in pulses. In: proceedings of workshop on Transfer of Technology of CDP crops under Research – Extension Linkage programme. 22-27 October, 1994. BARI, Gazpur.

Ram, S. N. and Dixit, R. S. (2000). Effect of dates of sowing and phosphorus on nodulation, uptake of nutrients and yield of summer mungbean (*Vigna radiata* (L.) Wilczek). *Crop Res. Hisar*. **19**(3) : 414-417.

Rani, B. P. and Kodandaramaiah, D. (1997). Response of soybean (*Glycine max*) to inoculation with varying nitrogen levels. *Indian J. Agron.* **42**(1): 135-137.

Rao, V. U. and Rao, A. S. (1993). Dual inoculation of VAM and *Rhizobium* in black gram and mungbean (*Vigna radiata*). *Legume Res*. **16**(3-4) : 119-126.

Rathee, O. P. and Chahal, R. S. (1977). Effect of P and S application on the yield and composition of groundnut in Ambala soils. *HAV. J. Res.* **7** : 173-177.

Raundal, P. U., Sabale, R. N. and Dalvi, N. D. (1999). Effect of phospho-manures on crop yield in mungbean-wheat cropping system. *J. Maharashtra Agril. Univ.* **24**(2) : 151-154.

Raychaudhuri, M., Kumar, K. and Raychaudhuri, S. (1997). Effect of *Rhizobium japonicum* and phosphorus on nutrient uptake and yield of soybean (*Glycine max* L.) in an Ultisol of Manipur Hills. *Indian J. Agric. Sco*. **67** : 459-62.

Reddy, S. C. S. and Patil, S. V. (1980). Effects of Ca and S and certain minor elements on the growth, yield and quality of groundnut. *Oleagineu*. **35** : 507-510.

Reddy, S. N., Singh, B. G. and Rao, I. V. S. (1990). An analysis of dry matter production, growth and yield in mungbean and black gram with phosphate fertilization. *J. Maharashtra Agril. Univ.* **15**(2) : 189-191.

Samanta, M. P. and Sigh, R. (1997). Effect of P and S on green gram (Phaseolus radiatus). *Ind. J. Agron*. **42**(4) : 650-652.

Samanta, S. C., Rashid, M. H., Biswas, P. and Hasan, M. A. (1999). Performance of five cultivars of mungbean under different dates of sowing. *Bangladesh J. Agril. Res.* **24**(3): 521-527.

Sana, M., Ali, A., Malik, M. A., Saleem, M. F. and Rafiq, M. (2003). Comparative yield potential and oil contents of different canola cultivars *(brassica napus L.). Pak. J. Agron.* **2**(1): 1-7.

Sankar, A. S., Reddy, P. R. and Rao, I. V. S. (1984). Nodulation and nitrogen fixation in groundnut as affected by seed and phosphorus. *Legume Res.* **7** : 1-5.

Santhi, R. and Kothandaraman, G. V. (1995). Effect of rhizobial inoculation and phosphorus sources on the phosphorus recovery, nutrient uptake and growth of mungbean. *Indian J. Agril. Res.* **26**(4) : 209-214.

Sardana, H. R. and Verma, S. (1987). Combined effect of insecticide and fertilizers on the growth and yield of mungbean (*Vigna radiata* (L.) Wilczek). *Indian J. Entom.* **49**(1) |: 64-68.

Sarkar, R. K. and Banik, P. (1991). Response of mungbean (*Vigna radiata*) to nitrogen, phosphorus and molybdenum. *Indian J. Agron.* **36**(1) : 91-94.

Savani, V. N., Vaishnav, M. R., Vaishnav, P. R. and Darji, V. B. (1995). Statistical estimation of relative changes in P content with different levels of applied phosphorus in groundnut. *Gujarat Agril. Univ. J.* **21** : 119-123.

Schenk, M. K. and Barber, S. A. (1979). Root characteristics of corn genotypes as related to P uptake. *Agron. J.* **71** : 921-924.

Schollenberger, C. J. (1980). analytical methods of nutrients in soil. Japanese Soc. Soil Sci. and Plant Nutr. Yokendo Co. Tokyo. pp. 34-41.

Sharma, B. M. and Yadav, J. S. P. (1976). Effect of P and S on green gram (*Phaseolus radiatus*). *Indian J. Agron.* **42**(4) : 650-652.

Sharma, B.M. and Yadav, J. S. P. (1976). Availability of phosphorus to grain as influenced by phosphatic fertilization and irrigation regimes. *Indian J. Agric. Sci.* **46** : 205-210.

Sharma, M. P. and Singh, R. (1997). Effect of phosphorus and sulphur on mungbean (*Vigna radiata*). *Indian J. Agron.* **42**(4) : 650-652.

Sharma, Y. M., Dikshit, P. R., Turkar, O. R. and Sharma, A. M. (1993). Effect of *Rhizobium* culture with different starter doses of nitrogen and phosphorus on yield, nutrition and nodulation of summer mungbean (*Vigna radiata*). *Bharatia Akrishi Pattrika*, **8**(2) : 106-114.

Shukla, S. K. and Dixit, R. S. (1996). Effect of *Rhizobium* inoculation, plant population and phosphorus on growth and yield of summer mungbean (*Vigna radiata*). *Indian J. Agron.* **41**(4) : 611-615.

Singh, A. V. and Ahlawat, I. P. S. (1998). Studies on N-economy in rainy season maize as affect by P-fertilizer and stover management in preceding summer mungbean (*Vigna radiata* (L.) Wilczek). *Crop Res. Hisar*. **16**(2) : 171-179.

Singh, A.L. and Chaudhary, V. (1996). Interaction of sulphur with phosphorus and potassium in groundnut nutrition in calcareous soil. *Indian J. Plant Physiol*. **1** : 21-27.

Singh, B.G., Rao, V.J.M., Suguna, C.A. and Rao, L.M. (1985). Verietal differences in growth and yield mungbean (*Vigna radiata*) during summer and kharif seasons. *J. Plant Physiol*. 32 : 207-214.

Singh, K.P. and Ahuja, K. N. (1985). Dry matter production, oil content and nutrient uptake in groundnut as affected by fertilizers and plant density. *Indian. J. Agron*. **30** : 40-45.

Singh, O. P., Tripathi, P. N., Room Singh and Singh, R. (1999). Effect of phosphorus and sulphur nutrition on summer mungbean (*Vigna radiata*). *Indian J. Agril. Sci*. **59**(11) : 798-799.

Singh, V. K. and Bajpai, R. P. (1990). Effect of phosphorus and potash on the growth and yield of rainfed soybean. *Indian J. Agron*. **35** : 310-31.

Sivasankar, A., Reddy, P. R. and Singh, B. G. (1982). Nitrogen nutrition in groundnut. 2. Effect of phosphorus on N_2-fixation and dry matter partitioning. *Legume Res*. **7** : 105, 1984.

Suhartatik, E. (1991). Residual effect of lime and organic fertilizer on mungbean (*Vigna radiata* (L.) Wilczek) on red yellow podzolic soil: Proceedings of the seminar of Food Crops Research Balittan Bogor (Indonesia). 2 : 267-1275.

Vasimalai, M. P. and Subramanian, S. (1980). Response o mungbean (*Vigna radiata* (L.) Wilczek) to irrigation and phosphorus. *Madras Agril. J*. **67**(8) : 506-509.

Walkley, A. C. and Black, T. A. (1935). Estimation of soil organic carbon by chromic acid titration method. *Soil Sci.* **47**: 29-38.

Yamakawa, T. (1992). Laboratory Methods for soil science and plant nutrition IPSA-JICA project publication No. 2. IPSA, Gazipur, Bangladesh. pp. 4-11.

Yein, B. R. (1982). Effect of carbofuran and fertilizers on the incidence of insect pests and on the growth and yield of mungbean (*Vigna radiata* (L.) Wilczek). *J. Res.* (Assam Agril. Univ.). **3**(2) : 197-203.

Yein, B. R. Harcharan, S., Cheema, S. S. and Singh, H. (1981). Effect of combined application of pesticides and fertilizers on the growth and yield of mungbean (*Vigna radiata* (L.) Wilczek). *Indian J. Ecol.* **8**(2) : 180-188.

Appendices

APPENDICES

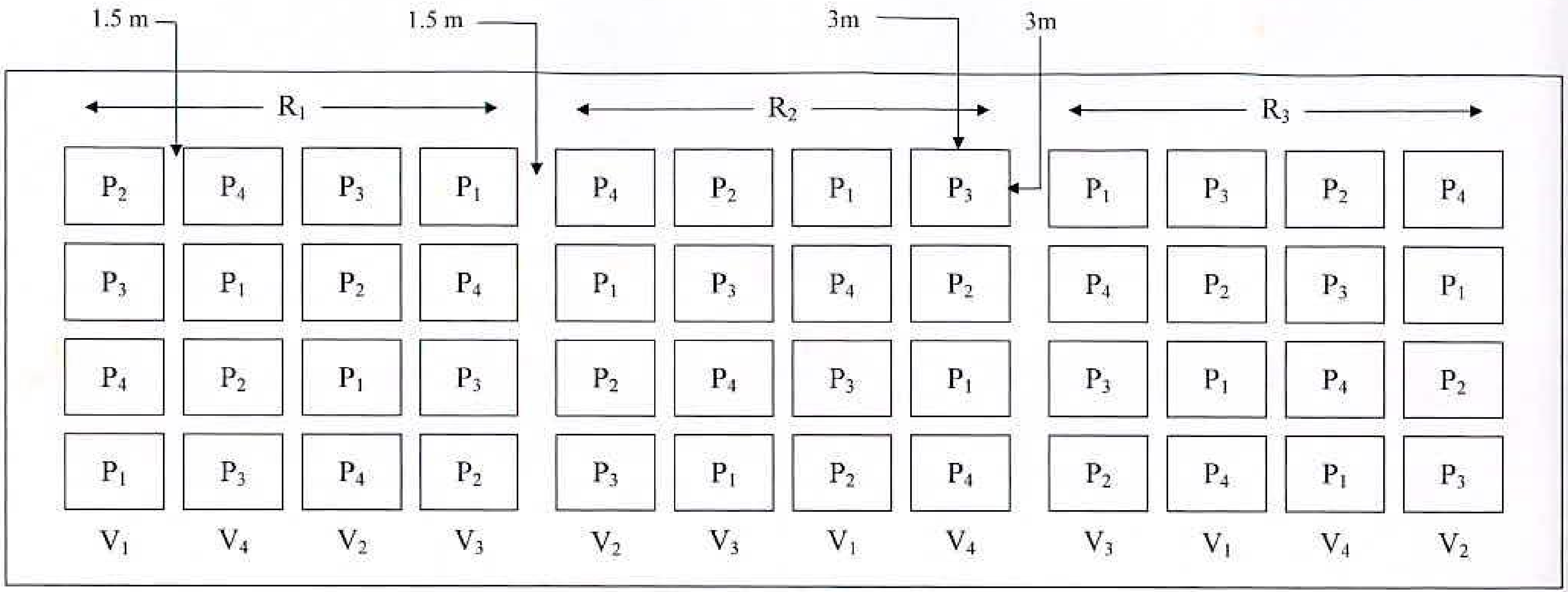
Appendix 1. Physical characteristics of the initial soil

Constituent	Value
Particle size distribution	
Sand (%)	38
Silt (%)	35
Clay (%)	27
Textural Class	Clay loam
Particle density (g/cc)	2.70
Bulk density (g/cc)	1.40
Porosity (%)	48.14

Appendix 2. Chemical characteristics of the initial soil

Constituent	Value	Critical
pH (Soil: Water= 1:2.5)	5.53	-
Organic matter (%)	0.82	-
Total N (%)	0.043	-
Available P (ppm)	18.60	14.0
Available S (ppm)	11.00	14.0
Available B (ppm)	0.18	0.2
Exchangeable K (meq/100g soil)	0.11	0.2
CEC (meq/100g soil)	8.35	-

Appendix 3. Layout of the experiment



P_1 = 0 kg P/ha, P_2 = 9 kg P/ha, P_3 = 18 kg P/ha and P_4 = 27 kg P/ha and
V_1 = BARI mung-2, V_2 = BARI mung-6, V_3 = BU mung-4 and V_4 = BINA mung-5