EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZERS ON GROWTH AND YIELD OF MUNGBEAN

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CERTIFICATE

This is to certify that the thesis entitled, "**Effect of nitrogen, phosphorus and potassium fertilizers on growth and yield of mungbean**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **Master of Science (M.S.) in Soil Science,** embodies the result of a piece of *bona fide* research work carried out by **Md. Nayemul Islam,** Registration No. **13-05448** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:

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DEDICATED TO

MY

BELOVED PARENTS

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The author

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ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University farm, during April to June, 2019 in Kharif season with a view to evaluating the performance of two mungbean varieties under different NPK fertilizer doses. The experiment was laid out in Randomized Complete Block Design (RCBD) comprising six treatments with three replications each. In the experiment, varieties used were BARI mung-6 and BARI mung-5 and the imposed treatments were T_0 = (control treatment), T_1 (10-40-25 NPK kg ha^{-1}), T_2 (10-60-45 NPK kg ha^{-1}), T_3 (20-50-35 NPK kg ha^{-1}), T_4 (30-40-25 NPK kg ha^{-1}) and T_5 (30-40-45 NPK kg ha^{-1}), respectively. Data on plant height, leaves plant^{-1}, branches plant^{-1}, pods plant^{-1}, pod length, seeds pod^{-1}, 1000- seed weight, seed and straw yield were collected at 30, 45 and 60 DAS (Days after Sowing) respectively. Of the two varieties BARI mung-6 gave the higher seed yield (1.72 t ha^{-1}) along with the higher plant growth and straw yield. In contrast, BARI mung 5 produced the lower seed yield (1.57 t ha^{-1}), plant growth and straw yield. The results showed that, T_3 was the best treatment as regards of plant growth and yield produced. The seed yield produced by treatment T_3 was 74%, 38%, 9%, 7% and 8% higher over the control, T_1, T_2, T_4 and T_5 respectively. As for interaction effect, V_1T_3 showed the best results in all growth and yield contributing characters. Mung bean plants also observed significant increases in N, P and K content at different fertilizer levels. Additionally, mungbean recorded the highest 1.91% N content from treatment T_3, 0.22% P content from treatment T_5 and 1.35% K content from treatment T_3.

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Chapter I

INTRODUCTION

Mungbean (*Vigna radiata L.*) known as green gram or golden gram is one of the most important pulse crop in Bangladesh. It belongs to the family Leguminosae. It is native to the Indian subcontinent and mainly cultivated in India, China, Thailand, Philippines, Indonesia, Mayanmar, Bangladesh, Laos and Cambodia but also in hot and dry regions of Europe and the United States. It is used as a foodstuff in both savory and sweet dishes.

Pulse is a popular crop in the daily diet of the people of Bangladesh. Pulses have been considered as “poor men's meat” since pulses contains more protein than meat and also more economical, they are the best source of protein for the underprivileged people. It is taken mostly in the form of soup which is commonly known as "dal". Generally, there is no complete dish without "dal" in Bangladesh. Green pulse seeds also can be consumed as fried peas or can be used in curry.

In Bangladesh, daily consumption of pulses is only 14.30 g capita^{-1} (BBS, 2010), while The World Health Organization (WHO) suggested 45 g capita^{-1} day^{-1} for a balanced diet. Due to shortage of production 291 thousand ton pulses was imported in Bangladesh in 2006-07 fiscal year (BBS, 2010). Though total pulse production in Bangladesh is 231 thousand metric ton (BBS, 2011), but to provide the abovementioned requirement of 45 g capita^{-1} day^{-1}, the production has to be increased even more than three folds.

Mungbean has good digestibility and flavor. It contains 1-3% fat, 50.4% carbohydrates, 3.5-4.5% fibers and 4.5-5.5% ash, while calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively (Frauque *et al.*, 2000). Hence, on the nutritional point of view, mungbean is perhaps the best of all other pulses (Khan, 1981 and Kaul, 1982), contains almost triple amount of protein as compared to rice. It can also minimize the scarcity of fodder because the whole plant or its by product can be used as good animal feed. Cultivation of pulses also can improve the physical, chemical and biological properties of soil as well as increase soil fertility status through nitrogen fixation. As a whole, mungbean could be considered as an inevitable component of sustainable agriculture.

The major cropping pattern in Bangladesh consists of two major crops of rice (i.e. boro rice-fellow-aman rice). In Bangladesh, more than 75% of the total cropping area is occupied by rice where pulse crop covers only 2.8% of the total cropping area (BBS, 2005). Mungbean is one of the important pulse crops of Bangladesh. It grows well in all over Bangladesh. The majority portion is being produced in southern part of the country. Among the pulse crops the largest area is covered by lentil (40.17%) and mungbean is grown in only 6.34% area (BBS, 2005). The cultivation of mungbean in Bangladesh is tends to increase and it covers 54, 57 and 68 thousand acres respectively in the 2008-09, 2009-10 and 2010-11 fiscal years (BBS, 2011). At present the average yield of mungbean grain in our country is about 279 kg acre^{-1}(BBS, 2010). So mungbean can be a good solution for the increasing need of plant protein.

Among the pulse crops, mungbean has a special importance in intensive crop production system of the country for its short growing period (Ahmed *et al*., 1978). In Bangladesh it can be grown in late winter and summer season. Summer mungbean can tolerate high temperature exceeding 40^{0}C and grown well in the temperature range of 30-35^{0}C (Singh and Yadav, 1978). This crop is reported to be drought tolerant and can also be cultivated in areas of low rainfall, but also grows well in the areas with 750-900 mm rainfall (Kay, 1979). So, cultivation of mungbean in the summer season could be an effective effort to increase pulse production in Bangladesh.

It is recognized that pulses offer the most practical means of solving protein malnutrition in Bangladesh but there is an acute shortage of grain legumes in relation to its requirements, because the yield of legumes in farmer's field is usually less than 1 t ha^{-1} against the potential yield of 2 to 41 ha^{-1} (Ramakrishna *et al.,* 2000). Low yields of grain legumes, including mungbean make the crop less competitive with cereals and high value crops. Therefore, to meet the situation it is necessary to boost up the production through varietal development and proper management practices as well as summer mungbean cultivation. The possibilities of growing mungbean in summer are being experimented and some successes have already been made in Bangladesh. Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Nuclear Agriculture (BINA), Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) developed 17 mungbean varieties with yield potentials in recent years. Very recently, with the introduction of some high yielding varieties like BARIMUNG -6, BARIMUNG -5 increasing attention is being paid to the cultivation of this crop in order to mitigate the alarmingly protein shortage in the diet of our people.

Mungbean is highly responsive to fertilizers and manures. It has a marked response to nitrogen, phosphorus and potassium. These nutrients play a key role in plant physiological process. A balanced supply of essential nutrients is indispensable for optimum plant growth. Continuous use of large amount of N, P and K are expected to influence not only the availability of other nutrients to plants because of possible interaction between them but also the buildup of some of the nutrients creating imbalances in soils and plants leading to decrease fertilizer use efficiency (Nayyar and Chhibbam, 1992).

For legume specially mungbean, nitrogen is more useful. Legumes although fix atmospheric N_2 by symbiotic process but application of nitrogenous fertilizer as starter or initial dose becomes helpful in increasing the growth and yield of legume crops (Ardeshana *et al*., 1993). Nitrogen is most useful for pulse crops because it is a major component of protein (Anon., 2005). Nitrogen deficiency cause reduced early vigor and crop yield will be reduced accordingly (Sohrabi, 1991). Adequate nitrogen is one of the most important management factors that cause increasing in seed yield. Nitrogen deficiency reduces the number of branches per plant, plant height, stem diameter, pod length, number of nodes (Majnoon, 1997). Nitrogen enhances the uptake of other nutrients and increasing nitrogen content in the crop which increases protein content of mungbean (Singh, 1999).

Phosphorus plays a remarkable role in plant physiological processes. It is an essential constituent of majority of enzymes which are of great importance in the transformation of energy in carbohydrate metabolism in different types of plants and is closely related in cell division and grain development. Phosphorus is a key constituent of ATP and it plays a significant role in the energy transformation in plants and also in various physiological processes (Sivasankar *et al.* 1982). It is also essential for energy storage and release in living cells. Phosphorus shortage restricted the plant growth and remains immature (Hossain, 1990). Experimental findings of Arya and Kalra (1988) revealed that application of phosphorus had no effect on the growth of mungbean, while number of grains per pod, weight of 1000-seeds were found to be increased with increasing level of phosphorus from zero to 50 kg P_2O_5 ha^{-1}. Phosphorus deficiency causes yield reduction by limiting plant growth (Poehlman, 1991). It influences nutrient uptake by promoting root growth and nodulation (Singh *et al*., 1999). Phosphorus enhances the uptake of nitrogen in the crop which increase protein content of mungbean (Soni and Gupta, 1999). Phosphorus is essential constituents, nucleoprotein, phospholipids, many enzymes and other plant substances.

Potassium plays a vital role in plant physiological processes. It is an essential constituent of different plant substances. Potassium deficiency causes yield reduction by limiting plant growth. It influences nutrient uptake by promoting root growth and nodulation. Mungbean is highly responsive to fertilizers and has considerable response to potassium. Our soils are not rich in all essential nutrient elements and organic matter content. The farmers of Bangladesh generally grow mungbean with almost no fertilizers. So, there is an ample scope of increasing the yield of mungbean/unit area by using balanced fertilizers including potassium fertilizer. Sangakara (1990) reported that application of 120 kg K_2O ha^{-1} on mungbean increased plant growth and flowers $plant^{-1}$, percent pod set, seeds pod^{-1}, 1000 seed weight and yield $plant^{-1}$ were also increased.

Considering the above facts, the present investigation has been undertaken to study the following objectives

Objectives:

1. To determine the effect of nitrogen, phosphorus and potassium fertilizers on the growth, yield and nutrient uptake of mungbean.
2. To find out the suitable combined dose of N, P and K for maximum yield of mungbean.

Chapter II
REVIEW OF LITERATURE

A huge number of research works on mungbean have been performed extensively in several countries especially in the South East Asian countries for its improvement of yield and quality. In Bangladesh, little attention has so far been given for the improvement of mungbean variety or its cultural management. Currently Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have started extensive research work on varietal development and improvement of this crop. Findings of various experiments related to the present study in home and abroad have been reviewed and discussed in this chapter.

2.1 Effect of nitrogen on growth, yield and yield contributing characters of Mungbean

Azadi *et al.* (2013) observed that different nitrogen levels influenced different growth and yield attributes of mungbean such as plant height, seed yield, stem diameter, number of node and 75 kg N ha^{-1} showed higher values than the other N doses (50, 100 and 150 kg N ha^{-1}).

Achakzai *et al.* (2012) found that different Nitrogen levels influenced most of the growth attributes of the mungbean. Maximum days to flowering, number of branches plant^{-1}, number of leaves plant^{-1}, plant height, number of branches plant^{-1}, leaf area, and grain yield recorded for plants subjected to highest dose of applied N fertilizer at 100 kg ha^{-1}.

Sultana *et al.* (2009) reported that application of 20 kg N ha^{-1} as basal dose and 20 kg N ha^{-1}with one weeding at vegetative stage showed significantly higher values of all growth parameters like leaf area, shoot dry weight, number of branches, pods plant^{-1} and seed yield.

Sultana (2006) noticed that plant height of mungbean showed superiority at 30 kg N ha^{-1} followed by 40 kg N ha^{-1}. Nitrogen fertilizer significantly influenced plant height at all growth stages of mungbean. At 20, 35, 50, 65 DAS and harvest the maximum heights were observed in the plants treated with 30 kg N ha^{-1}.

Ghosh (2004) used different levels of nitrogen and indicated that number of branches $plant^{-1}$ of mungbean was gradually increased with increasing N level at 25 kg N $ha^{-1.}$

Masud (2003) observed that highest plant height of mungbean with the application of 30 kg N ha^{-1} while Ghosh (2004) at 25 kg N ha^{-1}.

Rudreshhappa and Halikatti (2002) explained the effect of N levels (0, 12.5 and 25 kg) on growth, yield and nutrient uptake of green gram in paddy fallows. Application of 12.5 kg N ha^{-1} was recorded to produce significantly higher seed yield. Further increase in N doses (25 kg ha $^{-1}$) did not significantly increase the yield.

Srinivas *et al.* (2002) examined the effects of N (0, 20, 40 and 60 Kg ha^{-1}) and P_20_5, 50 and 75 Kg ha^{-1}) along with seed inoculation with *Rhizobium* culture on the growth, yield and yield components of mungbean. They observed that number of pods $plant^{-1}$, pod length and seeds pod^{-1} were increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} and also observed that 1000 seed weight in greengram.

Tank *et al.* (1992) found that mungbean fertilized with 20 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} produced significantly higher number of pods $plant^{-1}$ over the unfertilized control.

Pathak *et al*. (2001) evaluated the effect of N levels (0, 10, 20 and 30 kg ha^{-1}) on growth and yield of mungbean under rainfed condition during the summer of 1999 and found that application of 20 kg N ha^{-1} yielded poorer than 30 kg N ha^{-1}.

Hamid (1999) revealed the effects of foliar application of nitrogen on mungbean cv. Mubarik. In both pot and field trials he showed 10 kg N ha^{-1} increased the number of pods $plant^{-1}$.

Mandal and Sikdar (1999) laid out a green house pot experiment where mungbean (BARI Mung-5) grown on saline soil and given 0, 50 or 100 kg N ha^{-1} and 0, 75 or 150 kg P ha^{-1}. Growth and yield increased significantly with N application while P significantly increased the setting of pods and seeds. Root growth was significantly improved by both individual and combined application of these two fertilizers.

Mozumder (1998) studied the effect of five N levels (0, 20, 40, 60 and 80 kg N ha^{-1}) and two varieties of summer mungbean, BINA Mung-2 and Kanti, found that N exerted negative effect on the harvest index.

In an experiment with the foliar application of nutrients on the growth and yield of mungbean cv. Kowmy-1, Abd-El-Latif *et al.* (1998) revealed that application of urea increase the number of branches $plant^{-1}$ on mungbean plant.

Provorov *et al*. (1998) observed the effect of seed inoculation of mungbean with strain CIAMI 901 of *Bradyrhizobium* and found that the seed yield was increased by 39.2% and 1000 seed weight 16%. These results were equivalent to applying 120 kg N ha^{-1}. Best results obtained with inoculations + 60 kg N ha^{-1}.

Satyanarayanamma *et al.* (1996) in a field experiment found that spraying of 2% urea at flowering and pod development stage produced the highest seed yield (1.59 t ha^{-1}) over the control.

Kaneria and Patel (1995) reported that the application of 10 kg N ha^{-1} to mungbean significantly increased seed yield attributes.

Quah and Jafar (1994) noted that plant height of mungbean was significantly increased by the application of nitrogen fertilizer with 50 kg ha^{-1} and also noted that 1000 seed weight of mungbean increased significantly by the application of N at 50 kg ha^{-1}.

Gopala *et al.* (1993) found that the response of mungbean cultivars (Pusa Baishakhi, LGG 407, LGG 410 and MS 267) to a uniform dose of 20 kg N ha^{-1} and found that plant height, net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR) were increased at 20 kg N ha^{-1}.

Tank *et al.* (1992) observed that mungbean fertilized with 40 kg N ha^{-1} produced the highest seed yield $plant^{-1}$ while the lowest was observed in control treatment (0 kg N ha^{-1}).

Sarkar and Banik (1991) revealed that application of 10 kg N ha^{-1} to mungbean resulted in appreciable improvement in yield attributes. They found that the stover yield of mungbean increased significantly due to use of N up to 10 kg N ha^{-1}. On an average , the stover yield increased by 24% due to the application 10 kg N ha^{-1} over no N. they also observed that application of 10 kg N ha^{-1} to mungbean resulted in appreciable improvement in number of pods $plant^{-1}$ over no N.

Suhartatik (1991) also reported that NPK fertilizers significantly increased the plant height of mungbean.

Agbenin *et al.* (1991) revealed that application of N significantly increased plant height, seed yield, dry weight, crop growth rate and nutrient uptake of mungbean over control.

Leelavathi *et al.* (1991) reported that different levels of N showed significant difference in seed yield of mungbean up to a certain level.

Samiullah *et al.* (1987) recorded that number of seeds pod^{-1} were the highest with 10 kg N + 75 kg P_2O_5 + 60 kg K_2O in summer mungbean.

Mahmud and Gad (1988) observed that application of N increased the stover yield up to a certain level under different row spacing of mungbean.

Patel and Parmer (1986) observed that increasing N application to rainfed mungbean (*Vigna radiata* cv. Gujrat-1) from 0-45 kg ha^{-1} increase average seed yield from 0.83 to 0.94 t ha^{-1} and also increased protein content, plant height, number of branches $plant^{-1}$, pods $plant^{-1}$, seeds $plant^{-1}$ and 1000 seed weight.

Patel *et al.* (1993) studied that, in summer season on clayey soil application of 0, 10, 20 and 30 kg N ha^{-1} significantly increased the number of pods $plant^{-1}$.

2.2 Effect of potassium on growth, yield and yield contributing characters of Mungbean

Abbas *et al.* (2011) suggested that mineral nutrients plays a significant role in improving plant growth and development. Results showed significant impacts of applied K on plant height, number of grain pod^{-1} and grain yield as compared to control. Among different treatments, T_4 (K_2SO_4 @ 75 kg ha^{-1}) caused more prominent increase in yield and yield contributing parameters. It was found that K helped to improve the growth and yield of mungbean which played an important role in maintaining soil fertility.

Hussain *et al.* (2011) showed that potassium application is directly related to growth, plant biomass and yield in crops. Different Potassium levels significantly affected the seed yield and yield contributing parameters except number of plants per plot. Maximum seed yield (753 Kg ha^{-1}) was obtained with the application of 90 Kg potash per hectare. The interactive effect of Mungbean varieties and Potassium level was found significant in parameter of protein contents (%). Maximum protein contents were observed with application of 90 Kg potash per hectare. It was found that the application of Potash fertilizer gave higher yield of mungbean cultivars under agro-climatic conditions of Faisalabad.

Jahan *et al.* (2009). reported that grain and stover yield of all varieties were increased with the increase of potassium application up to 35 kg ha^{-1}. The highest grain yield (2.16 t ha^{-1}) was found at 35 kg K ha^{-1} and the lowest grain yield (1.61 t ha^{-1}) was exhibited from control potassium level and the highest stover yield (3.89 t ha^{-1}) was also found in 35 kg K ha^{-1} and the lowest (3.32 t ha^{-1}) was found in control potassium level. In case of interaction, the highest seed yield (2.58 t ha^{-1}) was produced by BARImasur-6 with 35 kg K ha^{-1}. Therefore, fertilization of all the varieties with 35 kg K ha^{-1} appeared as the best rate of potassium in respect of grain and stover yield.

Tawfik *et al.* (2008). conducted a pot experiment to study the effect of extension of irrigation interval (2, 5, and 10 days) on growth, yield and metabolic changes in mungbean (*Vigna radiata L.*) var. VC 1000 in addition to potassiomag application. Generally, fresh, dry weights and yield were significantly reduced under water stress condition. Treatment with K biofertilizer to some extent mitigated the effect of drought stress. The greatest vegetative growth was obtained in plants irrigated every two days and treated with potassiomag, while the greatest seed yield was obtained from plant irrigated every five days and treated with potassiomag. Osmoprotectants such as total soluble sugars, proline and glycine betaine increased in plants subjecter To water stress. It could be concluded that to maximize mungbean yield irrigation should be extended through all phenological stages, especially in flowering and pod-filling stages.

Asghar *et al.* (2006) laid out a field experiment to determine the effect of different levels of potassium (0, 25,50,75 and 100 kg ha^{-1}) on growth, yield and quality of two mungbean genotypes (NM-92 and NM-98) was studied in the Department of Agronomy, University of Agriculture, Faisalabad during 2003. Different potassium levels significantly affected the seed yield and Protein contents. Maximum seed yield (1458.46 kg ha^{-1}) with 25.31 percent in contents was obtained with 100 kg K per hectare. Genotype NM-98 produced higher seed yield than NM-92.

Naeem *et al.* (2006). carried out a field experiment to determine the effect of manures and inorganic fertilizers on growth and yield of mungbean (*Vigna radiata L*.). Experiment comprised of two varieties (NM-98 & M-1) and four fertility levels as N P K@ 25 -50 - 50 kg ha^{-1}, poultry manure @ 3.5t ha^{-1}, FYM @ 5t ha^{-1} and Bio-fertilizer @ 8 kg per ton seed. NPK fertilizers and organic manures were applied at the time of seed bed preparation. Wheat grain yield was recorded highest (1104 kg ha^{-1}) with the application of the inorganic fertilizer (N P K @ 25 - 50 - 50 kg ha^{-1}). Among organic nutrient a source, poultry manure @ 3.5 t ha^{-1} was found the best followed by FYM @ 5 t ha^{-1}. Both varieties were equal in grain yield. Numbers of pods, number of seeds per pod, 1000 grain weight were also almost higher in inorganic fertilizer treatment, The economic analysis revealed maximum net benefit from the treatment, where poultry manure was applied.

Oad and Buriro (2005) laid out a field experiment to determine the effect of different NPK levels on the growth and yield of mung bean *cv. AEM 96* and showed that the 10-30-30 kg N-P-K $ha^{-1}$was the best treatment, recording plan height of 56.25 cm, pod length of 5.02 cm, seed weight per plant of 10.53 g and the highest seed yield of 1205.2 kg ha^{-1}.

Ahmad *et al.* (2003) conducted an experiment on mungbean with N P K at 50 : 0: 0 (F_1), 50 : 100 : 0 (F_2) and 50 : 100 : 50 kg ha^{-1}. (F_3) and revealed that no significant differences in the number of pods per plant, number of grains per plant, grain yield and straw yield were observed in plants under F_2 and $F_{3,}$ F: resulted in the highest grain yield value and costs, and lowest net field benefit.

Abraham and Lal (2003) conducted field experiments from 1997 to 1999 to investigate the effects of NPK fertilizer, organic manures (farm compost + vermicompost and farm compost + poultry manure) and biofertilizers on the productivity of black Gram-wheat-Green gram cropping system black gram and green gram and grain yield for wheat were highest with farm grain yield compost + poultry manure, but the highest seed yield was recorded with farm compost + vermicompost in black gram in the first year. The treatment biofertilizer + cow's urine recorded higher values of pod count in the first year and weight and seed yield in the second year in green gram.

Oad *et al.* (2003) conducted a field experiment on the growth and yield performance of mungbean and showed that mungbean varieties were significantly influenced by phosphorus and potassium fertilizers except pod number, seed weight per plant and seed index were non-significant. However, 100 kg P and 100 kg K ha^{-1} showed an increase in the yield of the crop.

Chanda *et al.* (2002) carried out a field experiment on mungbean and showed that seed yield, protein content and net production value increased with increasing rates of K and S. Similarly, the status of N and P in soil decreased with increasing rates of K and S.

Das *et al.* (2002) studied the effects of vermicompost and chemical fertilizer application on the growth and yield of green gram. The dry matter and pod yield of green gram were increased with the application of vermicompost applied in integrated form. The yield was highest with 100% enriched vermicompost compared to sole organic manure. Greater dry matter content, pod yield, nutrient uptake (N, P and K), plant height, leaf area, root volume, number of nodules and fresh weight of nodules were obtained with treatments containing vermicompost. Flowering was earlier by 7 days in vermicompost treated plants compared with the control.

Sangakara *et al.* (2001) carried out a field experiment to determine the benefits of potassium in overcoming water stress in mungbean. They found that potassium increased shoot growth, root growth and as a significant factor in overcoming soil moisture stress in tropical cropping systems.

Prasad *et al.* (2000) conducted a pot experiment to study the effects of potassium on yield, water use efficiency and K-uptake by summer mungbean. They observed that total biomass production, grain yield, the water use efficiency and potassium uptake significantly increased with 20 and 30 kg K as compared to other levels of potassium.

Gobindar and Thirumurugan (2000) conducted an experiment and observed that 1.0% KCI + 1.0% $KN0_3$ gave the highest values for plant height at harvest (48.6 cm), leaf area index at 60 DAS (6.83), number of branches plant^{-1} (2.89), number of pods plant^{-1} (20.6), pod length (8.12cm), number of grains pod^{-1} (10.77), 100-grain weight (4.0 g), gain yield (777 kg ha^{-1}), dry matter production at harvest (2783 kg ha^{-l}) and benefit cost ration (2.53).

Ram and Dixit (2000) conducted a field experiment on summer greengram cv. k-851 and revealed that nodulation, N, P and K uptake and yield increased with increasing P rate.

Chaudhury and Mahmood (1999) laid out a field experiment to study the effect of optimum potassium levels on growth, yield and quality of mungbean and reported that 50 kg K_2O gave the highest seed yield (832 kg ha^{-1}) and also reported that the optimum level of K_2O was between 50 to 100 kg per hectare.

Reddy *et al.* (1998) carried out a field trial during kharif of 1995 at Attibele, Karnataka, India, on peas cv. Selection FC-1 with 0, 50 or l00% of the recommended rates of NPK (37.5: 60 : 50 kg ha^{-1}), and 0, 5 or 10 t farmyard manure and/or vermicompost ha^{-1}. Plant height at harvest, days to initial flowering, number of branches per plant, number of pods per plant, number of seeds per pod and yield were highest with 10 t vermicompost + 100% recommended NPK.

Sushil *et al.* (1997) conducted an experiment to study the effect of sulphur, potassium and phosphorus supply (0, 25, 50 and 100 mM) on seed protein of *Vigna radiata*. They reported that the amount of globulin and albumin were increased with increasing concentrations of K. Tryptophan in all the protein fractions also increased with higher K levels.

Chatterjee and Mandal (1996) carried out a field experiment on integrated fertilizer management with or without application of potassium and organic matter or manure. They observed that maximum crop productivity was achieved using 150% of the recommended doses of N, P and K in rice-potato-sesame, rice-potato-mungbean and rice-potato-groundnut systems and the available K status was improved in 0-15 cm soil depth.

Abd-El-Lateef *et al.* (1995) carried out a field experiment with 0, 15.5 or 31 kg P_2O_5 and 0 or 24 kg K_2O feddan^{-1} and observed that seed yield increased by the application of K and the lower rates of P (1 feddan = 0.42ha).

Singh *et al.* (1993) found significant increase of nitrogen concentration in mungbean due to the application of increasing level of K fertilizer.

Sangakkara, U. R. (1990) observed in an experiment that K application increased plant growth rate, flowers/plant, percentage pod set, seeds/pod, 100-seed wt and yield/plant. In the short maturing cv. MI 5, seed yield and quality increased with a basal application of up to 80 kg K ha^{-1} and a split application of up to 60 kg K ha^{-1}. In the long maturing cv. Type 61, seed yield and quality increased with a basal application of up to 100 kg K ha^{-1} or a split application of up to 80 kg K ha^{-1}.

Maiti *et al*. (1988) reported that 60 or 100 kg ha^{-1} each of P_2O_5 and K_2O increased seed yield in *Vigna radiata* and lentils.

Sardana and Verma (1987) made a field trial in Delhi, India with combined application of aldicarb (for the control of various insect pests) with nitrogen, phosphorus and potassium fertilizers and reported that plant height, leaf surface area, number and length of pods, 100-grain weight and yield of green gram were significantly increased.

2.3 Effect of phosphorus on growth, yield and yield contributing characters of mungbean

Nigamananda and Elamathi (2007) conducted an experiment during 2005-06 to evaluate the effect of N application time as basal and as DAP (diammonium phosphate) or urea spray and plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram. Results showed that 2% foliar spray as DAP and NAA, applied at 35 DAS resulted in the highest values for number of pods plant^{-1} (38.3), seeds pod^{-1}, test weight, flower number, fertility coefficient, grain yield (9.66 q ha^{-1}).

Malik *et al.* (2006) conducted a field experiment in Faisalabad, Pakistan in 2000 and 2001 to evaluate the interactive effects of irrigation and phosphorus on green gram *(Vigna radiata,* cv. NM-54). Five phosphorus doses (0, 20, 40, 60 and 80 kg *P* ha^{-1}) were arranged in a split plot design with four replications. Phosphorus application at 40 kg P_2O5 ha^{-1} affected the crop positively, while below and above this rate resulted in no significant effects. Interactive effects of two irrigations and 40 kg P_2O_5 ha^{-1} were the most effective. The rest of the combinations remained statistically non-significant to each other. It may be concluded that green gram can be successfully grown with phosphorus at 40 kg $P2O_5$ ha^{-1}.

Tickoo *et al.* (2006) carried out an experiment on mungbean and cultivars Pusa 105 and Pusa Vishal which were sown at 22.5 and 30.0 m spacing and was supplied with 36-46 and 58-46 kg of N and P ha^{-1} in a field experiment conducted in New Delhi. India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 t ha^{-1}) respectively compared to *cv.* Pusa 105. Nitrogen and phosphorus rates had no significant effects on both the biological and grain yield of the crop. Row spacing at 22.5 cm resulted in higher grain yields in both the cultivars.

A field experiment was conducted by Raman and Venkataramana (2006) during February to May 2002 in Annamalainagar. Tamil Nadu. India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram *(V. radiata).* There were 10 foliar spray treatments, consisting of water spray. 2% diammonium phosphate (DAP) at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA, DAP + NAA, DAP + Penshibao, DAP + Zn chelate, DAP + Penshibao + NAA, and DAP + NAA + Zn chelate. Crop nutrient uptake, yield and its attributes (number of pods plant^{-1} and number of seeds pod^{-1}) of greengram augmented significantly due to foliar nutrition. The foliar application of DAP + NAA + Penshibao was significantly superior to other treatments in increasing the values of N. P and K uptakes, yield attributes and yield. The highest grain yield of 1529 kg/ha was recorded with this treatment.

Bhat *et al.* (2005) conducted a study during the summer of 2004 in Uttar Pradesh, India to examine the effects of phosphorus levels on greengram. Four phosphorus rates (0. 30, 60 and 90 kg ha^{-1}) were used. All the phosphorus rates increased the seed yield significantly over the control. The highest seed yield was observed with 90 kg P ha^{-1}, which was at a with 60 kg P ha^{-1}. and both were significantly superior to 30 kg P ha^{-1}. Likewise, 60 kg P ha^{-1} significantly improved the yield attributes except test weight compared to control. For the phosphorus rates, the stover yield followed the trend observed in seed yield.

A field experiment was conducted by Vikrant (2005) on a sandy loam soil in Hisar, Haryana India during khatif 2000-01 and 2001-02 to study the effects of P (0. 20. 40 and 60 kg P_2O_5 ha^{-1}) applications to green gram *cv.* Asha. Application of 60 kg P, being at par with 40 kg P, was significantly superior to 0 and 20 kg P ha^{-1} in respect of grain, stover and protein yields of green gram.

Manpreet *et al.* (2005) conducted a field experiment to assess the response of different mungbean genotypes in terms of nutrient uptake and quality to incremental levels of phosphorus application. Genotypes showed significant differences for straw and grain N content and grain P content while straw P content, N and P uptake differed non-significantly. Phosphorus application resulted in significant increase in N and P content and their uptake.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mungbean *cv.* AEM 96 in Tandojam, Pakistan, during the spring season of 2004. The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.3. germination of 90.5%. satisfactory plant population of 162.0. prolonged days taken to maturity of 55.5. long pods of 5.02 cm, seed weight of 10.5 g, seed index of 3.5 g and the highest seed yield of 1205.2 kg ha^{-1}. There was no significant change in the crop parameters beyond this level.

A field experiment was conducted by Edwin *et al.* (2005) during 1995 and 1996 pre-kharif seasons in Imphal. Manipur, India to study the effect of sources (Single superphosphate (SSP), diammonium phosphate (DAP). Mussoorie rock phosphate (MRP). phosphate solubilizing organism (PSO) and farmyard manure) and levels (10, 15, 30 and 60 kg P_2O_5 ha^{-1}) of P on the growth and yield of green gram *cv.* AAU-34. The highest number of branches plant^{-1} (3.23) was obtained with 30 kg MRP + 30 kg SSP ha^{-1}. Single super phosphate at 60 kg ha^{-1} gave the highest number of clusters plant^{-1} (4.36). Pod length (7.34 cm), seeds pod^{-1} (10.5). 1000-seed weight (34.9 g) and seed yield (15.1 q ha^{-1}). Maximum plant height (31.2 cm), dry matter plant^{-1} (36.1 g) and number of pods plant^{-1} (l 7.4) was obtained with 60 kg DAP ha^{-1}.

Khan *et al.* (2004) conducted a study to determine the effect of different levels of phosphorus on the yield components of mungbean *cv.* NM-98 in D.I. Khan. Pakistan in 2000. Treatments comprised: 0, 20, 40, 60, 80, and 100 kg P ha^{-1}. The increase in phosphorus levels decreased the days to flowering and increased the branches plant^{-1}, number of pods plant^{-1}, 1000-grain weight and grain yield. The highest yield of 1022 kg ha^{-1} was obtained at the phosphorus level of 100 kg ha^{-1} compared to a 774 kg ha^{-1} yield in the control. However, the most economical phosphorus level was 40 kg ha^{-1}, because it produced a grain yield statistically comparable to 100 kg P ha^{-1}.

A field experiment was conducted by Manpreet *et al.* (2004) in Ludhiana. Punjab. India during summer 2000 to investigate the response of mungbean genotypes (SML 1 34. SML 357 and SML 668) to P application (0. 20. 40 and 60 kg P_2O_5 ha^{-1}) under irrigated conditions. Yield attributes such as number of branches $plant^{-1}$ and pods $plant^{-1}$ were significantly higher in SML 357 and SML 134. whereas pod length and 100-seed weight were higher in SML 668. which accounted for higher grain yield in this cultivar compared to SML 134 but was at par with SML 357. The straw yield showed the reverse trend with significantly higher value for SML 134, thus lowering the harvest index significantly compared to SML 668 and SML 357. Phosphorus application showed a non-significant effect on number of branches/plant, number of seeds pod^{-1}, pod length and 100-seed weight. However, the increase in P level showed significant increase in the number of pods $plant^{-1}$, which accounted for significantly higher grain and straw yields at higher levels (40 and 60 kg ha^{-1}) compared to lower levels (0 and 20 kg ha^{-1}). Harvest index remained unaffected with P application. The economic optimum P level for all the 3 summer mungbean genotypes was found to be 46. 1 kg P_2O_5 ha^{-1}.

Nadeem *et al.* (2004) studied the response of mungbean *cv.* NM-98 to seed inoculation and different levels of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N- P_2O_5 ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied along with 60 kg P_2O_5 ha^{-1}.

Asif *et al* (2003) conducted a field trial to find out the influence of phosphorus fertilizer on growth and yield of mungbean in India. They found that various levels of phosphorus significantly affected the number of leaves $plant^{-1}$, number of pods $plant^{-1}$, plant height, number of grain pod^{-1} and 1000 grain weight. Phosphorus level of 35 kg ha^{-1} produced the maximum grain yield.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean *cv.* NM-98 in 2001. They observed that number of flowers/plant was found to be significantly higher by 25 kg N ha^{-1}. Number of seeds/pod was significantly affected by varying levels of nitrogen and phosphorus. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted with maximum seed yield (1.1 ton ha^{-1}).

Satish *et al.* (2003) conducted an experiment in Haryana, India in 1999 and 2000 to investigate the response of mungbean cultivars Asha, MH 97-2, MH 85-111 and K 851 to different P levels (0, 20, 40 and 60 kg P_2O_5 ha^{-1}). Results revealed that the highest dry matter content in the leaves, stems and pods was obtained in Asha and MH 97-2. The total above-ground dry matter as well as the dry matter accumulation in leaves, stems and pods increased with increasing P level up to 60 kg P ha^{-1}. MH 97-2 and Asha produced significantly more number of pods and branches plant^{-1} compared to MH 85-111 and K 851. Phosphorus at 40 and 60 kg ha^{-1} increased the number of pods plant^{-1} grain yield and grains pod^{-1} over the control and P at 20 kg ha^{-1}. The number of branches plant^{-1} increased with increasing P rates.

Rajender *et* al. (2002) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield. The number of branches, number of pods plant^{-1}, numbers of seeds pod^{-1}. 1000-seed weight and straw yield increased with increasing rates P. whereas grain yield increased with increasing rates up to 40 kg P ha^{-1} only.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on mungbean at the Agronomic Research Station, Farooqabad in Pakistan. They revealed that various yield components like 1000-grain weight was affected significantly with 50-50-0 kg N, P and K ha^{-1} application. Again they revealed that seed inoculation with 50-50-0 kg N, P and K ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Nita *et al.* (2002) carried out a field experiment on mungbean and showed that seed yield, protein content and net production value increased with increasing rates of K and S. Similarly, the status of N and P in soil decreased with increasing rates of K and S.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at different levels of nitrogen and phosphorus. Different rates of N (0, 25 and 60 kg ha^{-1}) and P (0, 25, 50 and 60 kg ha^{-1}) were tested. They observed that the number of pods/plant was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N. They also observed that 1000-seed weight was increased with increasing rates of N up to 40 kg ha^{-1} along with increasing rates of P which was then followed by a decrease with further increase in N.

Yadav and Rathore (2002) carried out a field trial to find out the effect of phosphorus and iron fertilizer on yield, protein content and nutrient uptake in mungbean on loamy sandy soil in India. The results indicated that the seed and stover yield increased with the increasing phosphorus levels but significantly increased up to 60 kg P_2O_5 ha^{-1}. These results were confirmative to earlier reports of Singh *et al.* (1993).

Umar *et al.* (2001) observed that plant height and numbers of branches per plant were significantly increased by phosphorus application. Number of pods per plant, number of seeds per pod, 1000-seed weight and grain yields were also increased significantly by application of phosphorus along with nitrogen.

Teotia *et al.* (2001) conducted a greenhouse experiment to study the effect of P and S interaction on yield and nutrient composition of mungbean cv. *Pant Moong-2* and revealed that P and S applied individually or in combination increased the N and K content of the grain and straw and the yield of the plant.

Two field experiments were conducted in Kalubia Governorate. Egypt, in 1999 and 2000 summer seasons by El-Metwally and Ahmed (2001) to investigate the effects of P levels (0, 15. 30 and 45 kg ha^{-1}) on the growth, yield and yield components as well as chemical composition of mungbean *cv.* Kawmy-1. Growth, yield and yield components of mungbean were markedly improved with the addition of 45 kg P ha^{-1}. Addition of 45 kg P ha^{-1} markedly increased total carbohydrates and protein percentages compared with other treatments. Application of 45 kg P ha^{-1} markedly increased the number of pods $plant^{-1}$. Addition of 30 kg P ha^{-1} was the recommended treatments to obtain the best results for growth, yield and yield components as well as chemical composition of mungbean.

Prasad *et al.* (2000) conducted a pot experiment to study the effect of potassium on yield K-uptake by summer mungbean (cv. T-44) and showed that the grain yield increased potassium application but result was statistically non-significant. Increasing potassium levels significantly increased potassium uptake. Available K in soil after K harvest of crop increased with increasing levels of K.

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat. Assam. India. Mungbean was grown using farmers practices (no fertilizer) or using a combinations of fertilizer application (30 kg N + 35 kg P_2O_5 ha^{-1}). Seed yield was 0.40 ton $ha^{-1}$with farmers practices, while the highest yield was obtained by the fertilizer application (0.77 ton ha^{-1}).

Mastan *et al.* (1999) stated that the number of pods $plants^{-1}$ of summer mungbean cv. LOG 127 increased with increasing P rates.

Mitra *et al.* (1999) reported that mungbean grown in acid soils of Tripura, the maximum number of pods/plants were recorded with application of 50 kg P_2O_5 ha^{-1}.

Raundal *et al.* (1999) also reported that application of phosphorus 60 kg ha^{-1} to mungbean grown in *Kharif* season significantly increase the dry matter yield.

Karle and Pawar (1998) examined the effect of varying levels of N and P fertilizers on summer mungbean. They reported that mungbean produced higher seed yield with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Singh and Ahlawat (1998) reported that application of phosphorus to mungbean *cv.* PS 16 increased the number of branches plant^{-1} up to 12.9 kg ha^{-1} 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.

Ramamoorthy and Raj (1997) obtained 517 kg ha^{-1} seed yield of rainfed green gram without applied phosphorus and the highest (1044 kg) with 25kg P_2O_5 ha^{-1}.

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^{-1}) on the growth and yield of mungbean. Results of their study revealed that application of phosphorus at 30 kg ha^{-1} enhanced the plant height significantly.

Thakur *et al.* (1996) conducted an experiment with greengram *(Vigna radiata)* grown in kharif [monsoon] 1995 at Akola, Maharashtra, India which was given 0. 25. 50 or 75 kg P_2O_5 ha^{-1} as single superphosphate or di-ammonium phosphate. Seed and straw yields were not significantly affected by P source, and seed yield averaged 0.91, 1.00, 1.24 and 1.13 ha^{-1} at the 4 P rates, respectively. Phosphorus uptake was also highest with 50.

Shukla and Dixit (1996) conducted a field trial to study the response of mungbean to different levels of phosphorus. They also reported that application of phosphorus up to 50 kg P_2O_5 ha^{-1} significantly increased the vigour of the plants resulted in more dry matter production.

Bayan and Saharia (1996) carried out an experiment to study the effect of phosphorus on mungbean during the *kharif* seasons of 1994-95 in Bishanath Chariali Assam, India. The results indicated that plant height was unaffected by phosphorus application.

Rajkhowa *et al.* (1992) reported that application of phosphorus at 0- 60 kg P_2O_5 ha^{-1} increased seed yield of mungbean. However, the increase was significant up to 20 kg P_2O_5 ha^{-1} application.

Satter and Ahmed (1992) reported that phosphorus application up to 60 kg $P2O_5$ ha^{-1} on mungbean progressively and significantly increased nodulation, shoot length and weight, grain yield and total protein content.

Singh and Chaudhary (1992) conducted a field experiment with green gram and observed that phosphorus had beneficial effect on branches per plant, yield attributes and yield. Application of 30 kg P_2O_5 ha^{-1} recorded significantly higher values of these attributes than the control.

Sarkar and Banik (1991) conducted a field experiment and stated that increase in P_2O_5 up to 60 kg ha^{-1} progressively increased the number of nodules/plants of mungbean.

Solaiman *et al*, (1991) found that higher dose of phosphorus decrease the grain and other parameters. Phosphorus application at the rate of 60 kg P_2O_5 ha^{-1} significantly increased nodule number, dry weight of plant tops and mungbean yield

Patel and Patel (1991) observed that plant height of mungbean showed superiority at 60 kg P_2O_5 ha^{-1} followed by 40 kg P_2O_5 ha^{-1} application rate, growth on the soil which was sandy in texture, low in total N (0.04%), higher in available Phosphorus (77.33kg ha^{-1}) and rich in available potassium (388.15 kg ha^{-1}) with the pH 7.5. Thus plant height was found to be increased with increasing levels of phosphorus from 0 to 60 kg ha^{-1}.

Reddy *et al.* (1990) set up an experiment with three cultivars of mungbean in 1987, applying 0 or 50 kg P_2O_5 ha^{-1} as a basal dressing or 50 kg P_2O_5 ha^{-1} in two equal split dressing at the sowing and flowering stages. They found that application of phosphorus increased the dry matter accumulation in mungbean.

Thakuria and Saharia (1990) observed that phosphorus levels significantly influenced the grain yield of green gram. The highest plant height, pods $plant^{-1}$ and the grain yield were recorded with 20kg P_2O_5 ha^{-1}, which was of equal value with 40 and 60 kg P_2O_5 ha^{-1}.

Kalita (1989) conducted an experiment with applying 30 kg P_2O_5 ha^{-1} to mungbean and observed that application of phosphorus increased the number of pods $plants^{-1}$. In another trial, Reddy *et al.* (1990) found similar result.

Arya and Kalra (1988) found that application of phosphorus had no effect on the growth of summer mung, while number of grains per pod, weight of 1000-seeds and grain yield were found to be increased with increasing level of phosphorus from zero to 50 kg P_2O_5 ha^{-1}. Phosphorus content was also found to be affected by application of phosphorus.

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^{-1} progressively and significantly enhanced the plant height. They also stated that phosphorus application significantly increased plant height, number of pods per plant, grain and straw yields and protein content of mungbean.

Samiullah *et al.* (1986) conducted a field experiment on summer rnung to study the effect of four levels of phosphorus (0, 30, 45, 60 P_2O_5 ha^{-1}). They noted that 60 kg P_2O_5 ha^{-1} proved optimum for yield parameters such as length, 1000 seed weight, pod number, seed number and seed yield.

Patel *et al.* (1984) studied the effect of 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1} on growth and seed yield of summer mungbean. They reported that 40 kg P_2O_5 ha^{-1} significantly increased the seed yield, number of pods per plant and 1000-seed weight.

Rajput and Verma (1982) found the beneficial effect of phosphorus on grain yield, number of pods per plant and seeds per pod of mungbean. The highest response was recorded with 50 kg P_2O_5 ha^{-1} in most of the characters.

Anwar *et al.* (1981) reported beneficial effect of P application on greengram in respect to number of pods $plant^{-1}$, number of seed $plant^{-1}$, weight of 1000 seeds at low doses of P but higher doses of P showed depressing effect. The maximum grain yield of 1446.6 kg ha^{-1} was recorded at 60kg P_2O_5 ha^{-1} compared to only 886.6 kg ha^{-1} in control.

Sharma and Yadav (1976) conducted field experiment using 4 doses of phosphorus (0, 40, 80 and 120 kg P_2O_5 ha^{-1}). They reported that phosphorus application had a significant effect on grain yield of gram. They observed that yield increased up to a dose of 50 kg P_2O_5 ha^{-1}, but declined slightly when the doses were further increased. Straw yield was not significantly affected by phosphorus levels.

Chapter III
MATERIALS AND METHODS

This chapter includes a brief description of the experimental site, experimental period, climatic condition, crop or planting materials, land preparation, experimental design and layout, crop growing procedure, treatments, intercultural operations, data collection, preparation and chemical analysis of soil and plant samples along with statistical analysis.

3.1 Location

The field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka- 1207 during the period from April to June 2019 (Kharif season).

3.2 Soil

The soil of the experimental field belongs to the Tejgaon series under the Agro ecological Zone, Madhupur Tract (AEZ- 28) and the General Soil Type is Deep Red Brown Terrace Soils in Table 3.1.

Table 1. Salient features of the experimental field

Morphological Features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of inundation	Above flood level
Drainage condition	Well drained
Land type	High land

Table 2. Initial physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), 2019, Farmgate, Dhaka.

Characteristics	Value
Partical size analysis	
% Sand	33
%Silt	41
% Clay	26
Textural class	Silty-clay
pH	6.2
Organic matter (%)	1.09
Total N (%)	0.05
Available P (ppm)	21.54
Exchangeable K (me/100 g soil)	0.15

3.3 Climate

The experimental area has sub-tropical climate characterized by high temperature, heavy rainfall during May to September and scanty rainfall during rest of the year. The annual precipitation of the site is 2052 mm and potential evapotranspiration is 1286mm, the average maximum temperature is 30.35^0C, average minimum temperature is 21.14^0C and the average mean temperature is 25.12^0C (BBS, 2018). The experiment was carried out during kharif season (April-May), 2019.

3.4 Plant materials

3.4.1 BARI mung-5

BARI Mung-5, a high yielding variety of mungbean was released by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 1997. It is photo insensitive, short lifespan 55 to 60 days and bold seeded crop. The special characteristic of this variety is its synchronized maturity. It was developed from the NM-92 line introduced by

AVRDC in 1992. Its yield potentiality is about 1.5 to1.7 ton ha^{-1}. This variety is resistant to yellow mosaic virus diseases, insects and pest attack (BARI, 2008).

3.4.2 BARI mung-6

BARI Mung-6, also a high yielding variety of mungbean was released by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2003. It was developed from the NM-94 line introduced by AVRDC in 1992. This variety is resistant to yellow mosaic virus diseases, insects and pest attack. It is also photo insensitive, mature synchronously, short lifespan 55 to 60 days and bold seeded crop, seed yield about 1.6 to 1.8 ton ha^{-1} (BARI, 2008).

3.5 Treatments and treatment combinations of experiment

I. Factor A: Varieties

1. BARI mung 6 (V_1)
2. BARI mung 5 (V_2)

II. Factor B: Fertilizer doses

There were six (6) fertilizer dose combinations. The treatment combinations are as follows:

1. T_0 =Control (without N, P and K application)
2. T_1 = 10 kg N + 40 kg P +25 kg K ha^{-1}
3. T_2 = 10 kg N + 60 kg P + 45 kg K ha^{-1}
4. T_3 = 20 kg N + 50 kg P + 35 kg K ha^{-1}
5. T_4 = 30 kg N + 40 kg P + 25 kg K ha^{-1}
6. T_5 = 30 kg N + 40 kg P + 45 kg K ha^{-1}

3.6 Design and layout of experiment

The two factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of the individual plot was 3.0m x 1.0 m and total numbers of plots were 36. There are 6 treatment combinations. Each block was divided into 12 unit plots and the treatments were assigned in the unit plots at random. Lay out of the experiment was done on 25th March, 2019 with inter plot spacing of 0.75m and inter block spacing 1.0 m.

3.7 Land preparation

The plot selected for the experiment was opened by power tiller driven rotovator on the 10th April 2019; afterwards the land was ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section

3.8 Fertilizers application

The sources of N, P, K were urea, triple superphosphate (TSP), muriate of potash (MoP), were applied, respectively. Whole amount of urea, the entire amounts of TSP, MoP were applied during the final land preparation respectively as per treatment. The fertilizers were then mixed well with the soil by spading and individual unit plots were leveled.

3.9 Seed collection and sowing

Seeds of BARI Mung 6 and BARI Mung 5 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Seeds were sown in the main field on the 12th April, 2019 having line to line distance of 30 cm and plant to plant distance of 10 cm.

3.10 Cultural and management practices

Various intercultural operations such as thinning of plants, weeding and spraying of insecticides were accomplished whenever required to keep the plants healthy and the field weed free. At the very early growth stage (after l5 days of emergence of seedlings) the plants were attacked by Cutworm, which was removed by applying Malathion. Special care was taken to protect the crop from birds especially after sowing and germination stages. The field was irrigated twice- one at 15 days and the other one at 30 days after sowing.

3.11 Harvesting

The crop was harvested at maturity on 17th June 2019. The harvested crop of each plot was bundled separately. Grain and straw yields were recorded plot wise and the yields were expressed in t ha^{-1}.

3.12 Collection of samples

3.12.1 Soil Sample

The initial soil samples were collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. Post harvest soil samples were collected from each plot at 0-15 cm depth. The samples were air -dried, grounded and sieved through a 2 mm (10 meshes) sieve and preserved separately for analysis.

3.12.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at maturity stage of the crop. The samples were collected by avoiding the border effect of the plots. The plant samples were dried in the electric oven at 70^0 C for 48 hours. After that the samples were grounded in an electric grinding machine and stored for chemical analysis.

3.13 Collection of experimental data

Ten (10) plants from each plot were selected as random and were tagged for the data collection. Data were collected at 30, 45 and 60 DAS. The sample plants were cut down to ground level prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

1. Plant height (cm)
2. Number of Leaves per plant
3. Number of branches per plant
4. Number of flowers per plant
5. Number of pod per plant
6. Pod length (cm)
7. Seed per pod
8. 1000 seed weight
9. Seed yield (t/ha)
10. Stover yield (t/ha)
11. Shoot dry weight (g)
12. Root dry weight (g)
13. Nitrogen content in initial and post harvest soil
14. Phosphorus content in initial and post harvest soil
15. Potassium content in initial and post harvest soil

16. Nitrogen uptake by straw
17. Phosphorus uptake by straw
18. Potassium uptake by straw
19. Nitrogen content in seed
20. Phosphorus content in seed
21. Potassium content in seed

3.13.1 Plant height

The plant height was measured from the ground level to the top of the canopy of 10 randomly selected plants from each plot and averaged. It was done at the maturity stage of the crop.

3.13.2 Number of leaves plant^{-1}

No. of leaves were counted from 10 randomly selected plants at 30, 45 and 60 different days after sowing (DAS) from each plot and averaged.

3.13.3 Number of branches plant^{-1}

No. of branches were counted from 10 randomly selected plants at different days after sowing (DAS) from each plot and averaged.

3.13.4 Number of flowers plant^{-1}

Flowers of 10 randomly selected plants were counted at 45 days after sowing (DAS) from each plot and averaged.

3.13.5 Number of pods plant^{-1}

Pods of 10 randomly selected plants were counted at 45 and 60 days after sowing (DAS) from each plot and averaged.

3.13.6 Pod length

Pod length (cm) of 10 randomly selected plants were measured at 45 and 60 days after sowing (DAS) from each plot and averaged.

3.13.7 Seeds pod^{-1}

Seeds in pods of 10 randomly selected plants were counted at maturity stage from each plot and averaged.

3.13.8 1000-seed weight

1000-seed from each plot were collected after harvest and weighed.

3.13.8 Grain yield

Grains obtained from 1 m^2 area from the center of each individual plot was dried, weighed carefully and then converted into t ha^{-1} as yield.

3.13.9 Stover yield

Stover obtained from 1 m^2 area from the center of each individual plot was dried, weighed carefully and expressed in t ha^{-1}.

3.13.10 Root dry weight

Roots of 10 randomly selected plants were collected from each plot after harvest, dried then weighed and averaged.

3.13.11 Shoot dry weight

Shoots of 10 randomly selected plants were collected from each plot after harvest, dried then weighed and averaged.

3.14 Chemical analysis of the plant and soil samples

3.14.1 Plant sample analysis

The grounded plant samples were digested with conc. HNO_3 and $HCIO_4$ mixture for the determination of P, K and S.

3.14.1.1 Nitrogen

Plant samples were digested with 30% H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4 : $CuSO_4.5H_2O$: Selenium powder in the ratio 100 : 10 : 1, respectively) for the determination of total nitrogen by Micro-Kjeldal method. Nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson, 1973).

3.14.1. 2 Phosphorous

Phosphorous in the digest was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer.

3.14.1.3 Potassium

The exchangeable potassium content in plant samples were determined by flame photometer (Black, 1965).

3.14.2 Soil sample analysis

3.14.2.1 Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_2O_2 conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$. 5 H_2O : Selenium powder in the ratio 100 : 10 : 1 respectively). Nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson, 1973).

3.14.2.2 Available Phosphorous

Available phosphorous was extracted from the soil by Bray-1 method (Bray and Kurtz, 1945). Phosphorous in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer.

3.14.2.3 Available Potassium

Available potassium was extracted from soil by 1N ammonium acetate. The exchangeable potassium content in plant samples were determined by flame photometer (Black, 1965).

3.14.3 Statistical analysis

The data were analyzed using MSTAT-C to find out the significance of the difference among the treatments, the mean values of all the characters were evaluated and analysis of variance was performed by using Duncan's Multiple Range Test (DMRT).

Chapter IV

RESULTS AND DISCUSSION

4.1 Plant height

4.1.1 Effect of variety on plant height

There was significant effect of variety on plant height throughout the growing season (Fig. 1). Variety V_1 (BARI mung-6) was recorded with higher plant height (33.76, 50.5 and 62.18 cm at 30, 45 and 60 DAS) while variety V_2 (BARI mung-5) was observed with lower plant height (32.35, 49.21 and 61.32 cm at 30, 45 and 60 DAS).

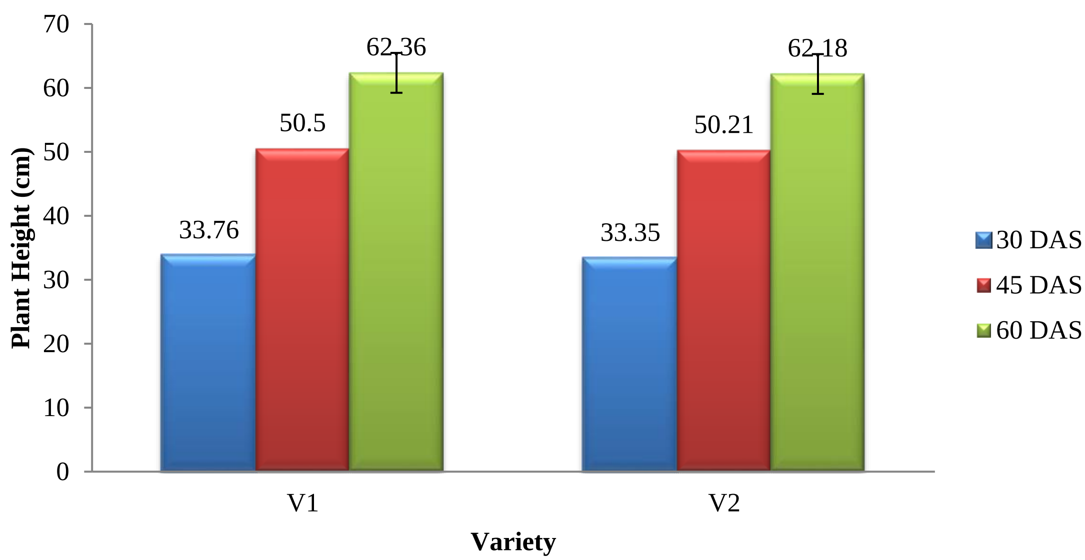

Figure 1. Effect of variety on plant height of mungbean at different days after sowing (DAS)

4.1.2 Effect of fertilizer doses on plant height

Significant variation was observed in plant height due to fertilizer doses (Fig. 2). Throughout the growing period, T_3 treatment (20 kg N + 50 kg P + 35 kg K) scored the highest plant height (36.3, 54.02 and 64.2 cm at 30, 45 and DAS) which was statistically similar to the treatments T_2 (10 kg N + 60 kg P + 45 kg K), T_4 (30 kg N + 40 kg P +

25 kg K), T_5 (30 kg N + 60 kg P + 45 kg K) and control treatment (T_0) attained the lowest (28.81, 41.75 and 58.7 cm at 30, 45 and 60 DAS) plant height. The results were in agreement with the findings of Gopala *et al.* (1993) who stated that highest plant height of mungbean was found at the rate of 20 kg N ha^{-1}. Agbenin *et al.* (1991) revealed that application of N significantly increased plant height of mungbean over control. Similar results observed by Oad and Buriro (2005), they observed that highest plant height attained with application of 30 kg P ha^{-1}. Asif *et al* (2003) found that various levels of phosphorus significantly affect plant height. Abbas *et al.* (2011) observed that increasing application of K helped to improve the plant height of mungbean. Sangakara *et al.* (2001) stated that increasing level of potassium increased plant height of mungbean. Suhartatik (1991) also reported that NPK fertilizers significantly increased the plant height of mungbean.

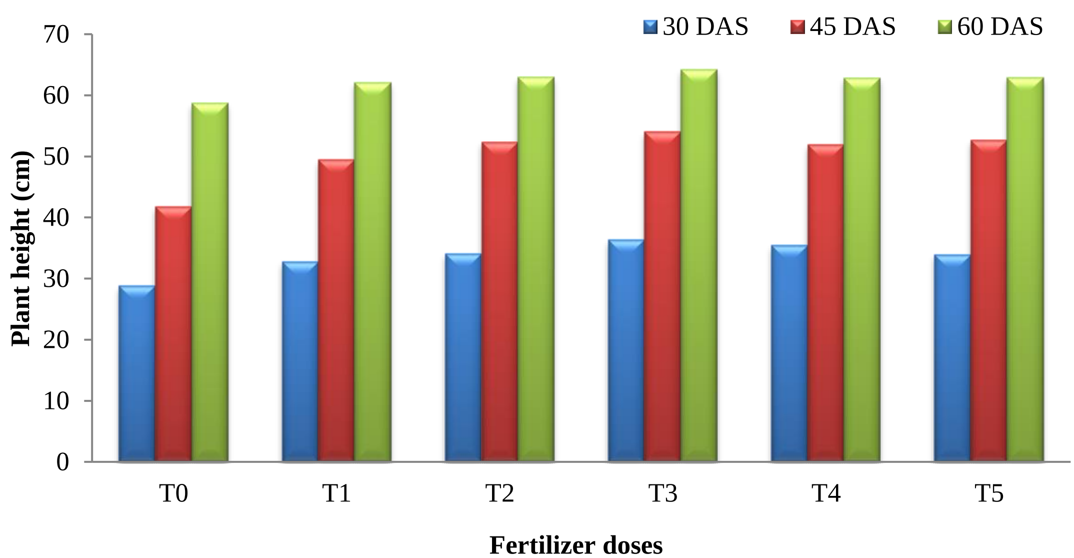

Figure 2. Effect of different fertilizer doses on plant height of mungbean at different days after sowing (DAS)

4.1.3 Interaction effect of fertilizer doses and variety on plant height

Plant height was significantly affected by the interaction of variety and treatment (Table 3). Highest plant height was observed from the combination V_1T_3 (36.79, 54.0 and

64.8 cm at 30, 45 and 60 DAS) which was statistically similar to V_1T_4, V_1T_5, V_2T_3, V_2T_4 and V_2T_5. The lowest plant height was found from the combination of V_1T_0 (28.56, 41.67 and 57.7 cm at 30, 45 and 60 DAS) which was statistically similar to the combination 0f V_2T_0.

Table 3. Interaction effect of fertilizer doses and varieties on plant height of mungbean at different days after sowing

Treatment combination	Plant height		
	Days after sowing (DAS)		
	30 (DAS)	**45 (DAS)**	**60 (DAS)**
V_1T_0	28.56 d	41.67 c	57.70 c
V_1T_1	32.37 bc	50.17 ab	62.03 b
V_1T_2	33.83 ab	52.80 a	63.23 ab
V_1T_3	36.79 a	54.00 a	64.80 a
V_1T_4	36.25 ab	51.82 ab	62.42 ab
V_1T_5	34.81 ab	52.60 a	62.93 ab
V_2 T_0	29.05 cd	41.83 c	59.70 c
V_2 T_1	33.19 ab	48.70 b	62.13 b
V_2 T_2	34.36 ab	51.97 ab	62.67 ab
V_2 T_3	35.82 ab	54.03 a	63.60 ab
V_2 T_4	34.73 ab	52.03 ab	63.20 ab
V_2 T_5	33.00 ab	52.73 a	62.87 ab
SE	1.16	1.16	0.75
CV (%)	5.96	3.97	2.08

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

4.2 Number of leaves

4.2.1 Effect of variety on number of leaves

There was significant effect of variety on number of leaves $plant^{-1}$ throughout the growing season (Fig. 3). Variety V_1 (BARI mung-6) was recorded with higher number of leaves $plant^{-1}$ (5.78, 8.75 and 13.81 at 30, 45 and 60 DAS) while variety V_2 (BARI mung-5) was observed with number of leaves $plant^{-1}$ (3.98, 7.58 and 12.51 at 30, 45 and 60 DAS).

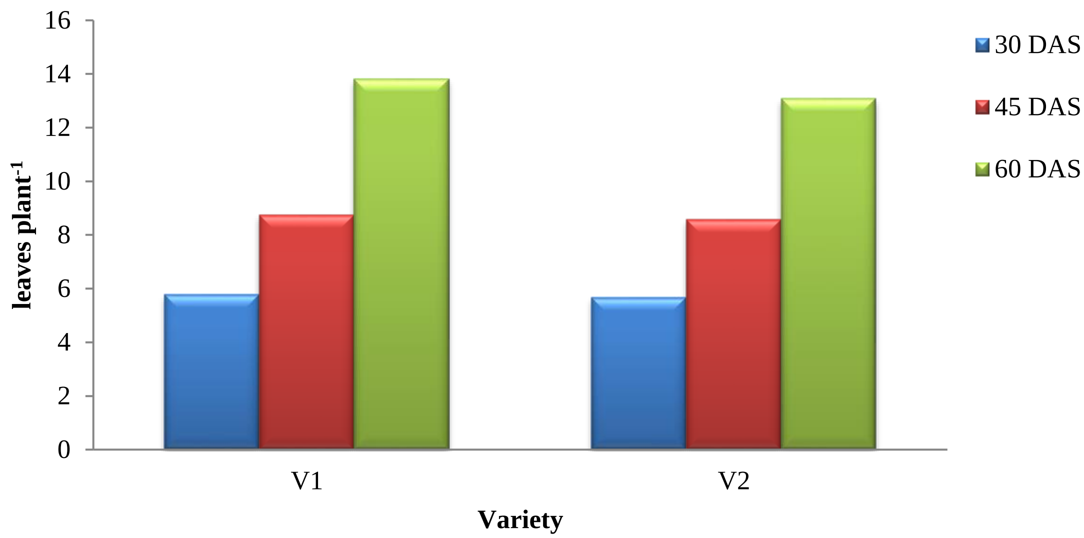

Figure 3. Effect of variety on number of leaves per plant of mungbean at different days after sowing (DAS)

4.2.2 Effect of fertilizer doses on number of leaves per plant

Significant variation was observed in number of leaves plant^{-1} due to different fertilizer levels (Fig. 4). Throughout the growing period, T_3 treatment (20 kg N + 50 kg P + 35 kg K) produced the highest number of leaves plant^{-1} (6.3, 9.31 and 15.3 at 30, 45 and DAS) which was statistically similar to the treatments of T_2 (10 kg N + 60 kg P + 45 kg K), T_4 (30 kg N + 40 kg P + 25 kg K), T_5 (30 kg N + 60 kg P + 45 kg K) and control treatment (T_1) attained the lowest (4.75, 7.56 and 10.83 at 30, 45 and 60 DAS respectively). The results were in agreement with the findings of Asif *et al* (2003) who found that various levels of phosphorus significantly affected the number of leaves plant^{-1}.

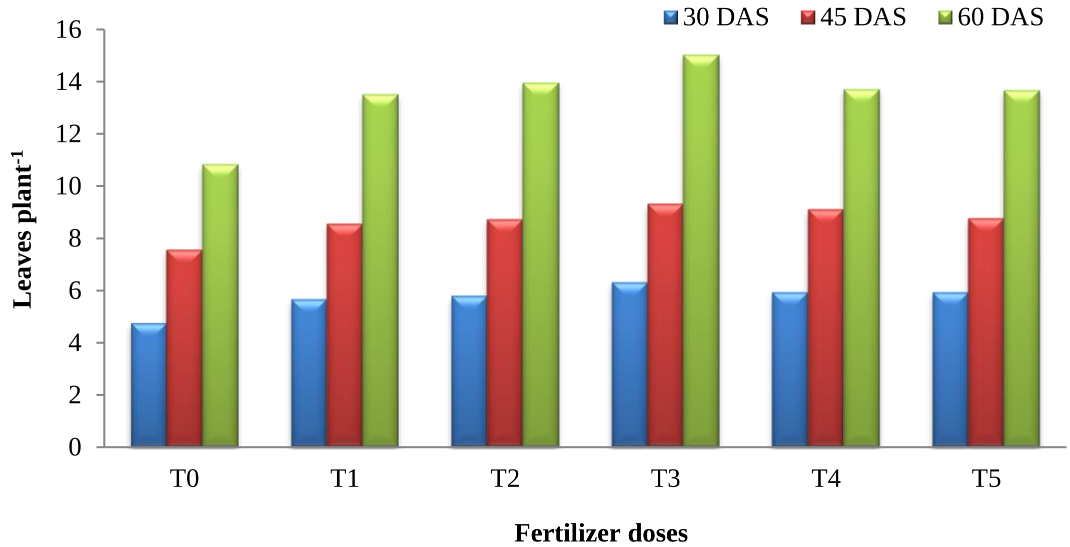

Figure 4. Effect of different fertilizer doses on number of leaves per plant of mungbean at different days after sowing (DAS)

4.2.3 Interaction effect of fertilizer doses and variety on number of leaves

Number of leaves plant^{-1} was significantly affected by the interaction of variety and treatment (Table 4). Highest number of leaves plant^{-1} was observed from the combination V_1T_3 (6.4, 9.4 and 15.53 at 30, 45 and 60 DAS) which is statistically similar to V_1T_2, V_1T_4, V_2T_3, V_2T_4 and V_2T_5. The lowest number of leaves plant^{-1} was found from the combination V_2T_0 (4.7, 7.5 and 10.8 at 30, 45 and 60 DAS) which was statistically similar to the combination V_1T_0.

Table 4. Interaction effect of fertilizer doses and varieties on number of leaves plant^{-1} of mungbean at different days after sowing

Treatment combination	Number of leaves Plant^{-1}		
	Days after sowing (DAS)		
	30 (DAS)	**45 (DAS)**	**60 (DAS)**
V_1T_0	4.80 c	7.63 f	10.87 e
V_1T_1	5.73 b	8.80 b-d	13.87 b-d
V_1T_2	5.86 ab	8.90 b-d	14.50 a-c
V_1T_3	6.40 a	9.40 a	15.53 a
V_1T_4	6.00 ab	9.10 a-c	14.10 b-d
V_1T_5	5.90 ab	8.66 c-e	14.00 b-d
V_2 T_0	4.70 c	7.50 f	10.80 e
V_2 T_1	5.60 b	8.30 e	13.13 d
V_2 T_2	5.70 b	8.53 de	13.40 b-d
V_2 T_3	6.20 ab	9.23 ab	14.53 ab
V_2 T_4	5.86 ab	9.13 a-c	13.30 d
V_2 T_5	5.96 ab	8.83 b-d	13.33 cd
SE	0.18	0.15	0.36
CV(%)	5.43	3.06	4.57

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

4.3 Number of branches

4.3.1 Effect of variety on number of branches per plant

There was a significant difference among the two mungbean varieties in number of leaves plant^{-1} throughout the growing season (Fig. 5). Variety V_1 (BARI mung-6) showed higher number of branches plant^{-1} (1.53 and 1.84 at 45 and 60 DAS) while variety V_2 (BARI mung-5) was observed with number of branches plant^{-1} (1.12 and 1.44 at 45 and 60 DAS).

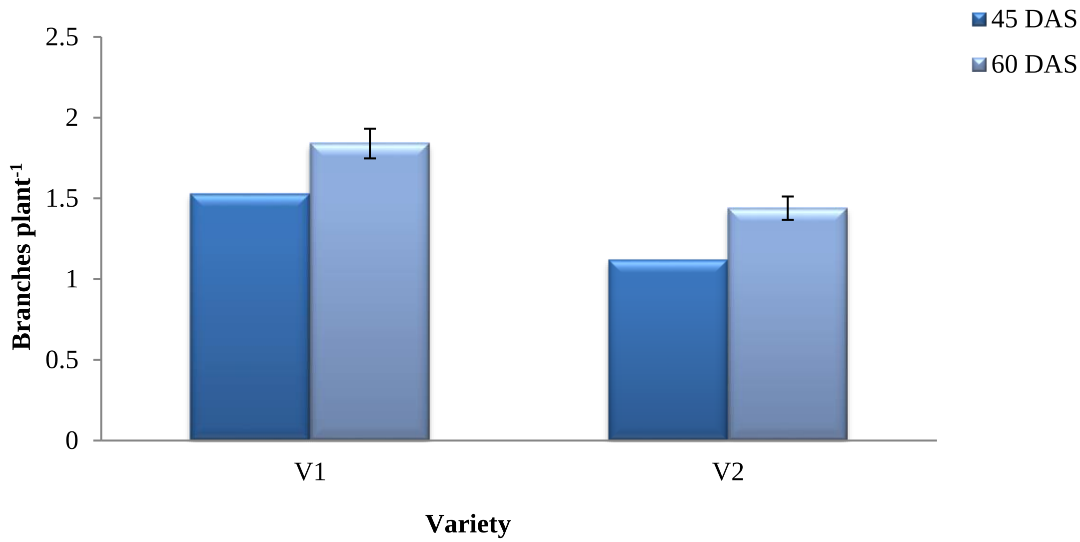

Figure 5. Effect of variety on number of branches per plant of mungbean at different days after sowing (DAS)

4.3.2 Effect of fertilizer dose on number of branches per plant

Significant variation was observed in number of branches plant^{-1} due to different fertilizer doses (Fig. 6). Throughout the growing period, T_3 treatment (20 kg N + 50 kg P+ 35 kg K) produced the highest number of branches plant^{-1} (2.06 and 2.23 at 45 and 60 DAS) which was statistically similar to the treatments T_2 (10 kg N + 60 kg P + 45 kg K), T_4 (30 kg N + 40 kg P + 25 kg K), T_5 (30 kg N + 60 kg P + 45 kg K) and control treatment (T_0) attained the lowest results. The results were in agreement with the findings of Sultana *et al.* (2009) who observed that application of 20 kg N ha^{-1} as basal dose showed significantly higher values of all growth parameters like number of branches plant^{-1}. Similar results showed by Ghosh (2004) that number of branches plant^{-1} of mungbean was gradually increased with increasing N level at 25 kg N ha^{-1}. Rajender *et* a/. (2002) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean and they observed that number of branches plant^{-1} increased with increasing rates of N and P. Umar *et al.* (2001) also observed that numbers of branches per plant were significantly increased by phosphorus application.

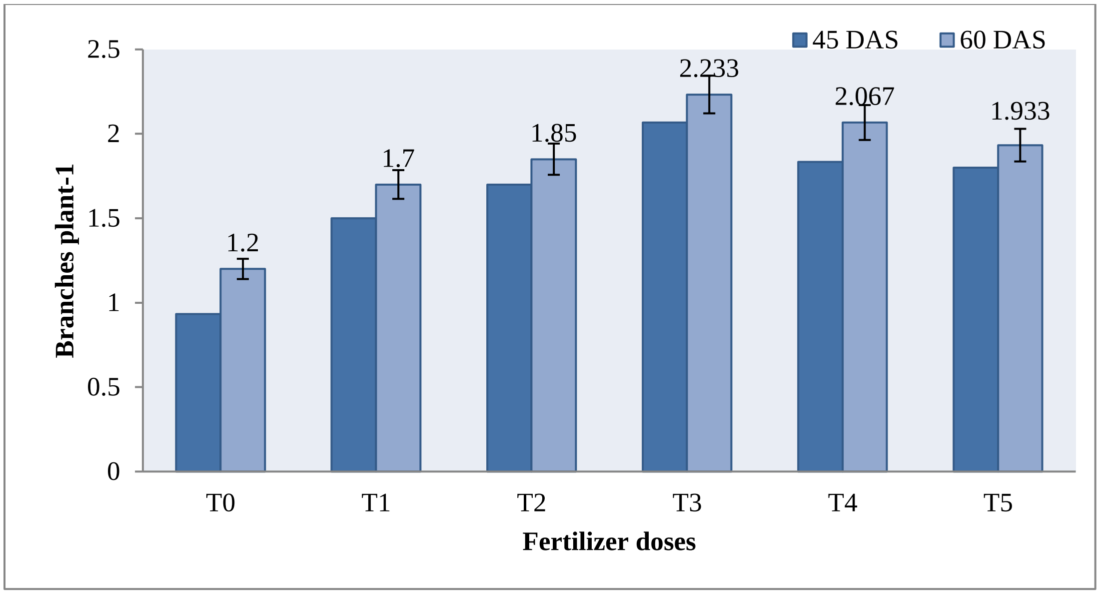

Figure 6. Effect of fertilizer doses on number of branches per plant of mungbean at different days after sowing (DAS)

4.3.3 Interaction effect of fertilizer doses and varieties on number of branches

The combined effect of different fertilizer doses and varieties on the number of branches plant^{-1} of mungbean was statistically significant (Table 5). Highest number of branches plant^{-1} was observed from the combination V_1T_3 and V_2T_3 (2.06 and 2.26 at 45 and 60 DAS) which was statistically similar to V_1T_4, V_2T_4 and V_2T_5 respectively. The lowest number of branches plant^{-1} was found from the combination V_2T_0 (0.86 and 1.13 at 45 and 60 DAS) which were statistically similar to the combination V_2T_0.

Table 5. Interaction effect of fertilizer doses and varieties on number of branches plant^{-1} of mungbean at different days after sowing (DAS)

Treatment combination	Number of branches Plant^{-1}	
	Days after sowing (DAS)	
	45 (DAS)	**60 (DAS)**
V_1T_0	1.0 d	1.26 de
V_1T_1	1.40 c	1.53 cd
V_1T_2	1.73 a-c	1.90 a-c
V_1T_3	2.06 a	2.26 a
V_1T_4	1.86 ab	2.13 ab
V_1T_5	1.73 a-c	1.86 a-c
V_2 T_0	0.86 d	1.13 e
V_2 T_1	1.60 bc	1.86 a-c
V_2 T_2	1.66 a-c	1.80 bc
V_2 T_3	2.06 a	2.20 ab
V_2 T_4	1.80 a-c	2.00 ab
V_2 T_5	1.86 ab	2.00 ab
SE	0.13	0.13
CV(%)	14.04	11.93

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

4.4 Root dry weight

4.4.1 Effect of variety on root dry weight per plant

There was significant differences between two mungbean varieties in root dry weight plant^{-1} (Fig. 7). Variety V_1 (BARI mung-6) showed higher root dry weight plant^{-1} (1.69 g) while variety V_2 (BARI mung-5) was observed with lower root dry weight plant^{-1} (1.59 g).

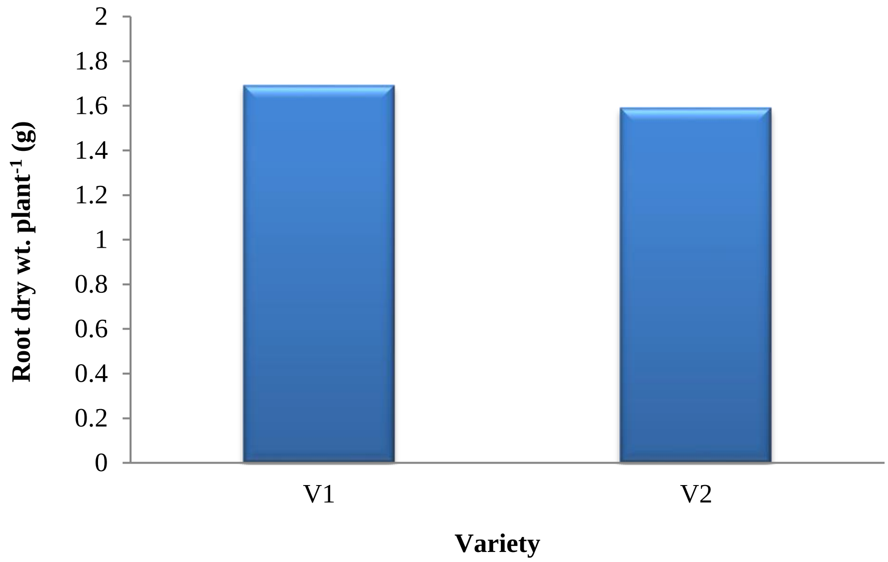

Figure 7. Effect of variety on root dry weight per plant of mungbean

4.4.2 Effect of fertilizer doses on root dry weight per plant

Root dry weight plant^{-1} deferred significantly due to different fertilizer levels (Fig. 8). Treatment T_3 (20 kg N + 50 kg P+ 35 kg K) resulted the highest root dry weight plant^{-1} (1.907 g) which was statistically similar to the treatments T_2 (10 kg N + 60 kg P + 45 kg K), T_4 (30 kg N + 40 kg P + 25 kg K), T_5 (30 kg N + 60 kg P + 45 kg K) and control treatment (T_0) attained the lowest (1.037 g). The results were in agreement with the findings of Agbenin *et al.* (1991), they observed that application of N significantly increased plant root dry weight of mungbean over control. This highest root wt. dry plant^{-1} from the treatment T_3 might be due to the availability of optimal doses of N, P and K at initial stages. Nitrogen enhances rapid cell division and cell enlargement, phosphorus promoting root growth and nodulation (Singh *et al.*, 1999) and potassium also promotes root growth and nodulation.

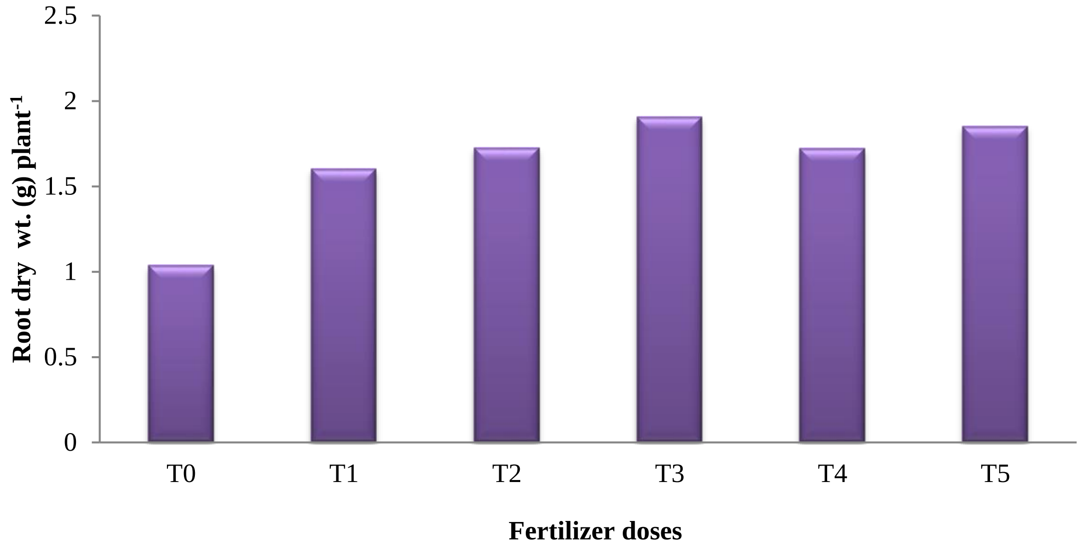

Figure 8. Effect of fertilizer doses on root dry weight (g) per plant of mungbean

4.4.3 Interaction effect of fertilizer dose and varieties on root dry weight per plant

The combined effect of different fertilizer doses and varieties on root dry weight plant^{-1} of mungbean was statistically significant (Table 6). Highest weight of dry root plant^{-1} was observed from the combination V_1T_3 (1.98 g) which was statistically similar to V_1T_1, V_1T_4, V_1T_5, V_2T_2, V_2T_3 and V_2T_5 respectively. The lowest root dry weight plant^{-1} was found from the combination V_2T_0 (1.01 gm) which was statistically similar to the combination V_2T_0.

4.5 Shoot dry weight

4.5.1 Effect of variety on shoot dry weight per plant

There was significant differences between two mungbean varieties in case of shoot dry weight plant^{-1} (Fig. 9). Variety V_1 (BARI mung-6) showed higher shoot dry weight plant^{-1} (29.77 g) while variety V_2 (BARI mung-5) was observed with lower shoot dry weight plant^{-1} (26.65 g).

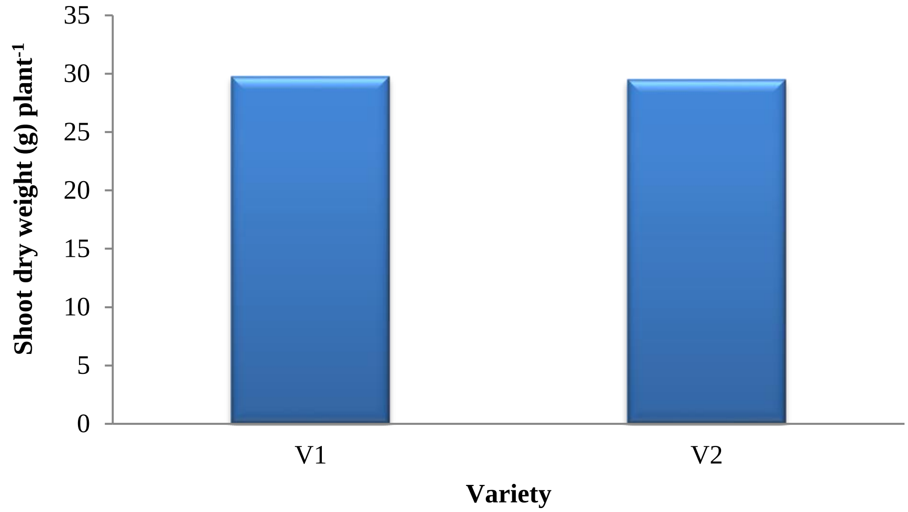

Figure 9. Effect of variety on shoot dry weight (g) per plant of mungbean

4.5.2 Effect of fertilizer dose on shoot dry weight per plant

Shoot dry weight plant^{-1} deferred significantly due to different fertilizer levels (Fig. 10). Treatment T_3 (20 kg N + 50 kg P+ 45 kg K) resulted the highest shoot dry weight plant^{-1} (31.74 g) which was statistically similar to the treatments T_2 (10 kg N + 60 kg P + 35 kg K), T_4 (30 kg N + 40 kg P + 25 kg K), T_5 (30 kg N + 60 kg P + 45 kg K) and control treatment (T_0) attained the lowest (24.53 g). The results were in agreement with the findings of Sultana *et al.* (2009) observed that application of 20 kg N ha^{-1} as basal dose showed significantly higher values of shoot dry weight. Similarly, Shukla and Dixit (1996) reported that application of phosphorus up to 50 kg P_2O_5 ha^{-1} significantly increased the vigour of the plants resulted in more dry matter production. Agbenin *et al.* (1991) also revealed that application of N significantly increased plant shoot dry weight of mungbean over control.

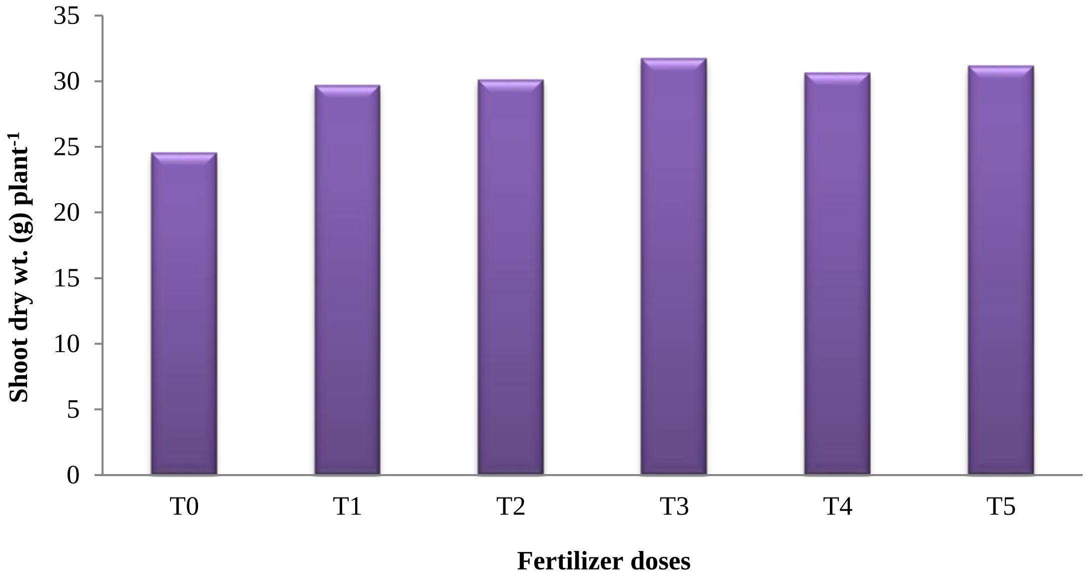

Figure 10: Effect of fertilizer dose on shoot dry weight (g) per plant of mungbean

4.5.3 Interaction effect of fertilizer dose and variety on shoot dry weight per plant

The combined effect of different fertilizer doses and varieties on shoot dry weight plant^{-1} of mungbean was statistically significant (Table 6). Highest shoot dry weight plant^{-1} was observed from the combination V_1T_3 (31.96 g) which was statistically similar to V_1T_1, V_1T_4, V_1T_5, V_2T_2, V_2T_3 and V_2T_5 respectively. The lowest shoot dry weight plant^{-1} was found from the combination V_1T_0 (24.39 g) which were statistically similar to the combination V_2T_0.

Table 6. Interaction effect of fertilizer doses and varieties on root dry weight (g) plant^{-1} and shoot dry weight (g) plant^{-1}

Treatment combination	Root dry weight (g) plant^{-1}	Shoot dry weight (g) plant^{-1}
V_1T_0	1.06 c	24.39 d
V_1T_1	1.62 ab	29.75 c
V_1T_2	1.71 ab	30.25 bc
V_1T_3	1.98 a	31.96 a
V_1T_4	1.83 ab	30.70 a-c
V_1T_5	1.91 ab	31.61 ab
V_2 T_0	1.01 c	24.66 d
V_2 T_1	1.57 b	29.61 c
V_2 T_2	1.73 ab	29.97 c
V_2 T_3	1.82 ab	31.53 ab
V_2 T_4	1.61 b	30.58 a-c
V_2 T_5	1.79 ab	30.68 a-c
SE	0.11	0.45
CV (%)	11.80	2.61

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

4.6 Number of flowers

4.6.1 Effect of variety on number of flowers per plant

There was significant difference between two mungbean varieties in number of flowers plant^{-1} (Fig. 11). Variety V_1 (BARI mung-6) showed higher number of flowers plant^{-1} (5.12) while variety V_2 (BARI mung-5) was observed with number of flowers plant^{-1} (4.54).

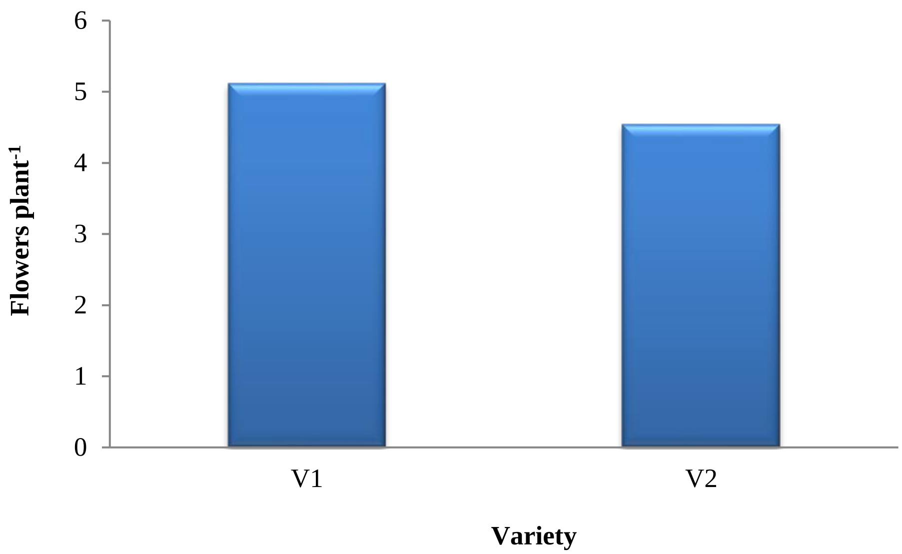

Figure 11. Effect of variety on number of flowers per plant of mungbean

4.6.2 Effect of fertilizer dose on number of flowers per plant

Significant variation was observed in number of flowers plant^{-1} at 45 DAS due to different fertilizer doses (Fig. 12). Treatment T_3 (20 kg N + 50 kg P+ 35 kg K) produced the highest number of flowers plant^{-1} (6.53) which is about 63% higher than the control (T_0) and it is statistically similar to the treatment T_4 (30 kg N + 40 kg P + 25 kg K). The results were in agreement with the findings of Malik *et al.* (2003) who observed that number of flowers plant^{-1} was higher by the application of 25 kg N ha^{-1}.

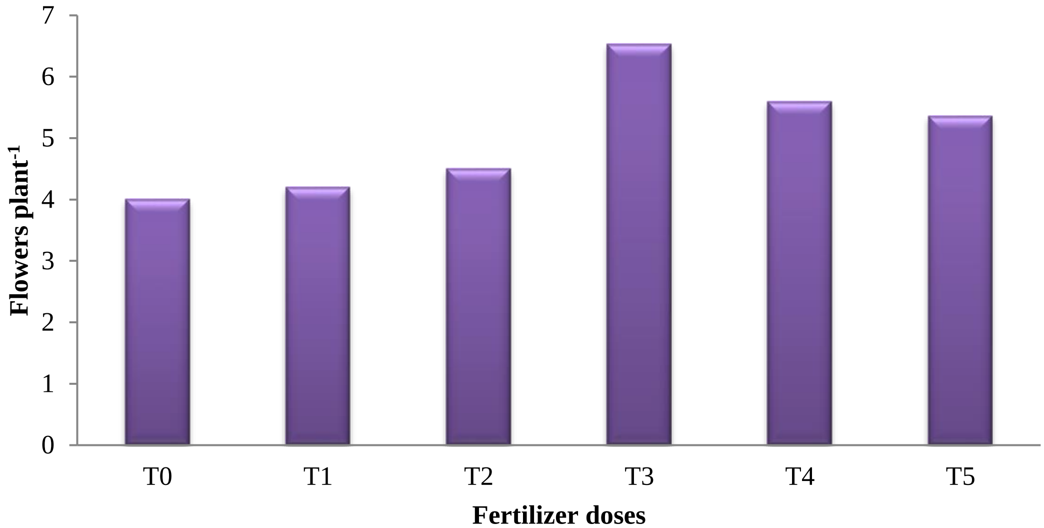

Figure 12. Effect of fertilizer dose on number of flowers per plant of mungbean at 45 days after sowing (DAS)

4.6.3 Interaction effect of fertilizer doses and varieties on number of flowers per plant

The combined effect of different fertilizer doses and varieties on the number of flowers plant^{-1} of mungbean was statistically significant (Table 7). Highest number of flowers plant^{-1} was observed from the combination V_1T_3 (6.73) which was statistically similar to V_2T_3 (6.33). The second highest number of flowers plant^{-1} was found from the combination V_1T_4, V_1T_5 and V_2T_4 (5.60). The lowest number of flowers plant^{-1} was found from the combination V_1T_0 (3.86) which were statistically similar to the combination V_2T_0 (4.0).

4.7 Number of pods

4.7.1 Effect of variety on number of pods

The effects of varieties on the in number of pods plant^{-1} were statistically significant (Fig. 13). Variety V_1 (BARI mung-6) showed higher number of pods plant^{-1} (2.7 and 21.48 at 45 and 60 DAS) while variety V_2 (BARI mung-5) showed lower number of pods plant^{-1} (2.66 and 21.32 at 45 and 60 DAS). The results were in agreement with the findings of Uddin *et al.* (2009) who stated that BARI mung 6 obtained highest number of pods plant^{-1} than the other mungbean varieties.

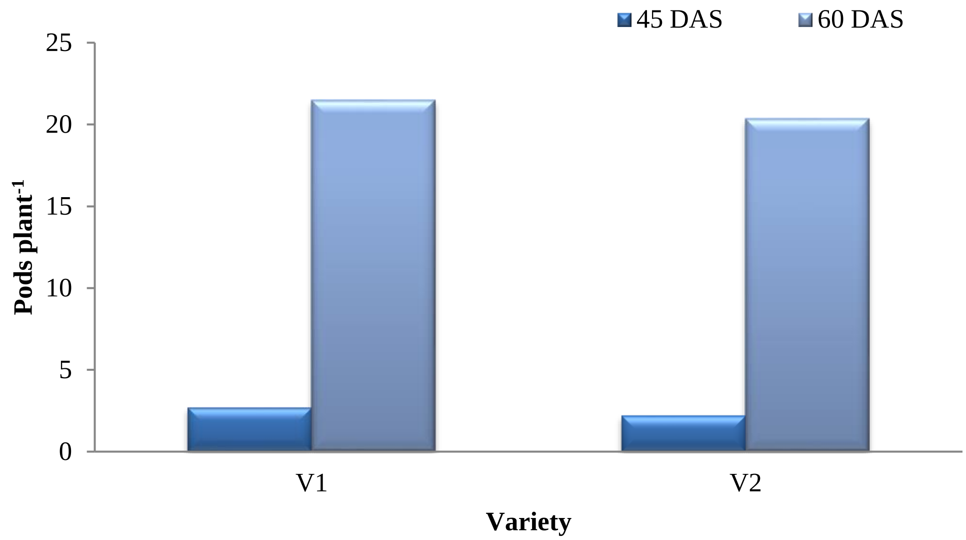

Figure 13. Effect of variety on number of pods per plant of mungbean at different days after sowing (DAS)

4.7.2 Effect of fertilizer dose on number of pods

Significant variations were observed for number of pods plant^{-1} due to different fertilizer levels (Fig. 14). Throughout the growing period, T_3 treatment (20 kg N + 50 kg P + 35 kg K) produced the highest number of pods plant^{-1} (3.36 and 23.36 at 45 and 60 DAS) which were about 181% and 34% higher than the control, T_0 (1.53 and 17.48 at 45 and 60). Treatments T_2 (10 kg N + 60 kg P + 45 kg K), T_4 (30 kg N + 40 kg P + 25 kg K) and T_5 (30 kg N + 60 kg P + 45 kg K) also statistically similar to the treatment T_3. The results were in agreement with the findings of Sultana *et al.* (2009) who observed that application of 20 kg N ha^{-1} as basal dose produced highest number of pods plant^{-1}. Similar results also found by Rajender *et al*. (2002) and Tank *et al.* (1992). Again Asif *et al* (2003), Satish *et al.* (2003), Srinivas *et al.* (2002) and Umar *et al.* (2001) found that number of pods plant^{-1} increased significantly by the application of phosphorus along with nitrogen.

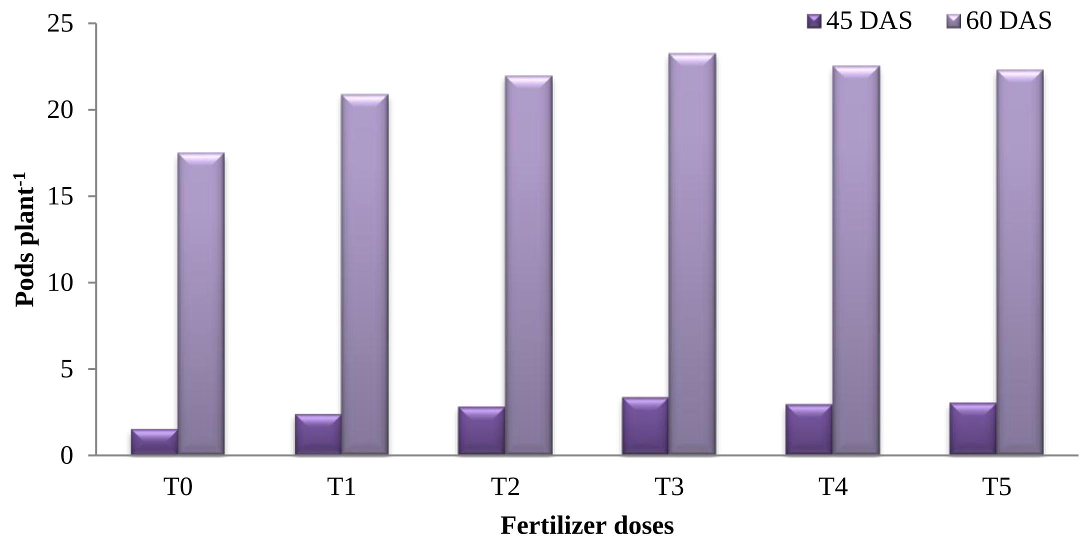

Figure 14. Effect of fertilizer dose on number of pods per plant of mungbean at different days after sowing (DAS)

4.7.3 Interaction effect of fertilizer doses and varieties on number of pods

The combined effect of different fertilizer doses and varieties on the number of pods plant^{-1} of mungbean was statistically significant (Table 7). Highest number of pods plant^{-1} was observed from the combination V_1T_3 (3.46 and 23.47 at 45 and 60 DAS) which were statistically similar to V_1T_2, V_1T_4, V_1T_5, V_2T_3, V_2T_4 and V_2T_5 respectively. The lowest number of pods plant^{-1} was found from the combination V_1T_0 (1.46 and 17.33 at 45 and 60 DAS) which were statistically similar to the combination V_2T_0.

4.8 Pod length

4.8.1 Effect of variety on pod length

There was significant effect of variety on pod length throughout the growing season (Fig. 15). Variety V_2 (BARI mung-5) was recorded with higher pod length (7.75 and 8.62 cm at 45 and 60 DAS) while variety V_1 (BARI mung-6) was observed with pod length (7.53 and 8.57 cm at 45 and 60 DAS).

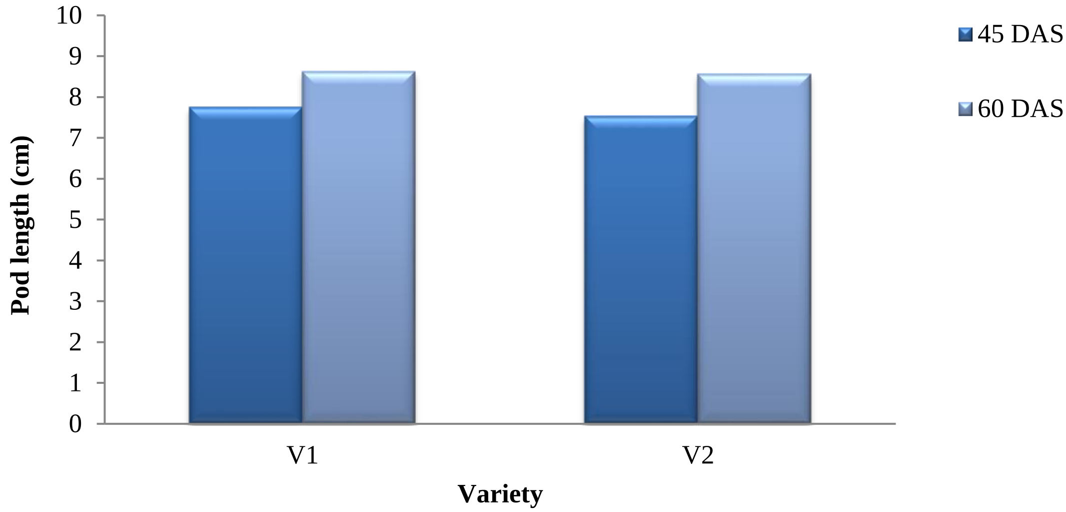

Figure 15. Effect of variety on pod length of mungbean at different days after sowing (DAS)

4.8.2 Effect of fertilizer dose on pod length

There was significant variation observed for pod length due to different fertilizer levels (Fig. 16). Throughout the growing period, T_3 treatment (20 kg N + 50 kg P+ 45 kg K) scored the highest pod length (36.3, 8.31 and 9.36 cm at 45 and DAS) which was statistically similar to the treatments T_2 (10 kg N + 60 kg P + 35 kg K), T_4 (30 kg N + 40 kg P + 25 kg K) and T_5 (30 kg N + 60 kg P + 45 kg K) and control treatment (T_0) attained the lowest (5.6 and 6.58 cm at 45 and 60 DAS) pod length. The results were in agreement with the findings of Srinivas *et al.* (2002) who observed that pod length was increased with increasing rates of P and with increasing rates of N. Surdana and Verma (1987) reported that application of N, P and K fertilizers resulted in significant increase in pod length of mungbean. Oad and Buriro (2005) also showed that 30 kg K ha^{-1} was the best treatment to attain highest pod length of mungbean.

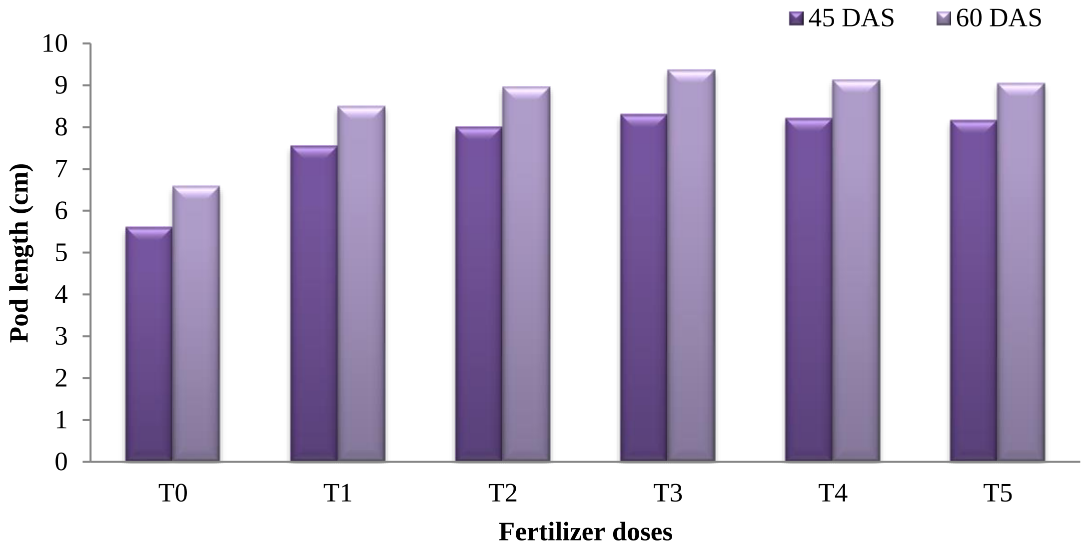

Figure 16. Effect of fertilizer dose on pod length of mungbean at different days after sowing (DAS)

4.8.3 Interaction effect of fertilizer doses and varieties on pod length

Pod length was significantly affected by the interaction of variety and treatment (Table 7). Highest pod length was observed from the combination V_2T_3 (8.50 and 9.26 cm at 45 and 60 DAS) which were statistically similar to V_1T_2, V_1T_3, V_1T_4, V_1T_5, V_2T_2 and V_2T_5 respectively. The lowest pod length was found from the combination V_2T_0 (5.46 and 6.30 cm and 45 and 60 DAS) which were statistically similar to the combination V_1T_0.

4.9 Seeds per pod

4.9.1 Effect of variety on seeds per pod

There was significant effect of variety on seeds pod^{-1} (Fig. 17). Variety V_1 (BARI mung-6) was recorded higher seeds pod^{-1} (10.8) while Variety V_2 (BARI mung-5) produced lower seeds pod^{-1} (9.7). The results were in agreement with the findings of Uddin *et al*. (2009), they observed that BARI mung 6 obtained highest number of seeds plant^{-1} than the other mungbean varities.

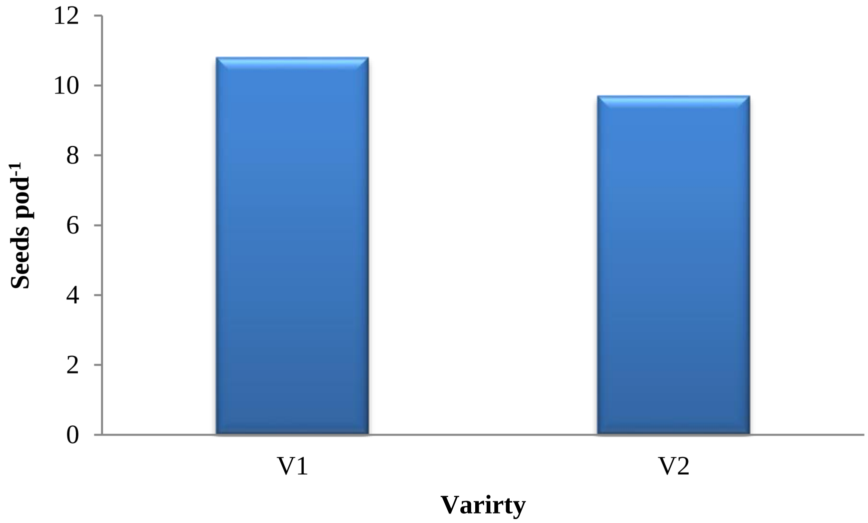

Figure 17. Effect of variety on seeds per pod of mungbean

4.9.2 Effect of fertilizer dose on seeds per pod

Significant variation was observed in seeds pod^{-1} due to different fertilizer levels (Fig. 18). T_3 treatment (20 kg N + 50 kg P + 35 kg K) produced the highest seeds pod^{-1} (11.57 seeds pod^{-1}) which was 32.22% more than the control, T_0 (8.75 seeds pod^{-1}). The results were in agreement with the findings of Asif *et al* (2003), Satish *et al.* (2003) and Srinivas *et al.* (2002), they observed that seeds pod^{-1} of mungbean were increased with the increasing rates of P. Umar *et al.* (2001) also observed that number of seeds per pod significantly increased by application of phosphorus along with nitrogen.

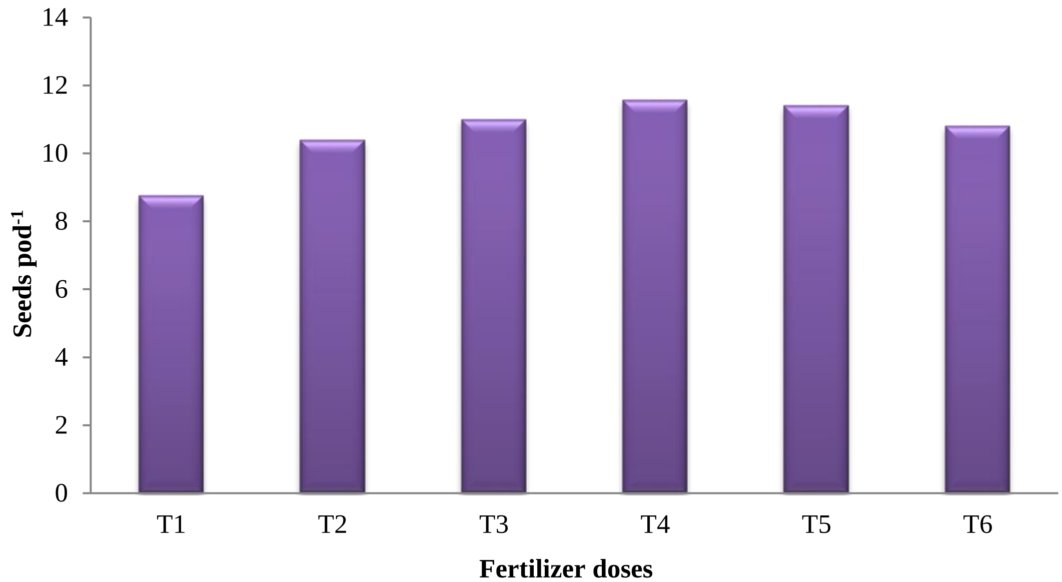

Figure 18: Effect of fertilizer dose on seeds per pod of mungbean

4.9.3 Interaction effect of fertilizer doses and varieties on seeds per pod

Seed pod^{-1} was significantly affected by the interaction of variety and treatment (Table 7). Highest seeds pod^{-1} was observed from the combination V_2T_4 (11.70) which were statistically similar to V_1T_5, V_1T_6 and V_2T_4 respectively. The lowest seeds pod^{-1} was found from the combination V_2T_1 (8.70) which was statistically similar to the combination V_1T_1.

4.10 1000-seed weight

4.10.1 Effect of variety on 1000-seed weight

There was significant effect of variety on 1000-seed weight (Fig. 19) Variety V_1 (BARI mung-6) was recorded the 1000-seed weight (42.77 gm) while variety V_2 (BARI mung-5) was observed with 1000-seed weight (37.78 gm). The results were in agreement with the findings of Uddin *et al.* (2009), who observed that BARI mung 6 yielded highest 1000-seed weight.

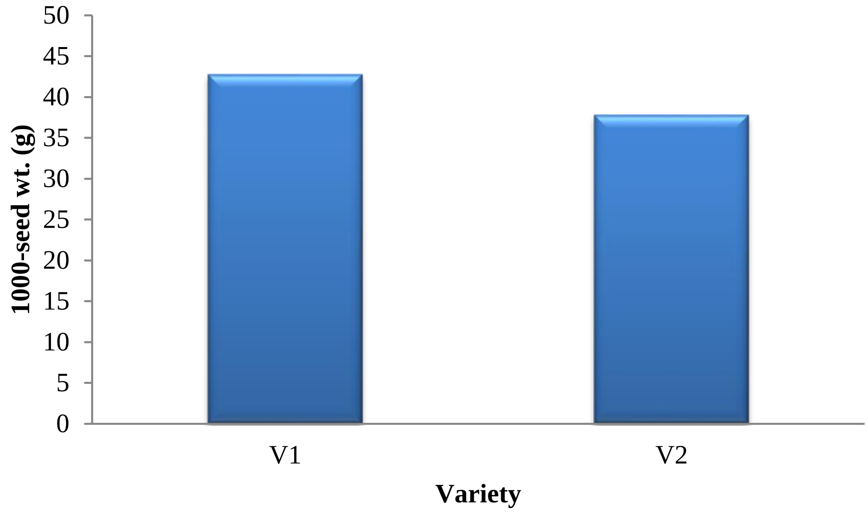

Figure 19. Effect of variety on 1000-seed weight of mungbean

4.10.2 Effect of fertilizer dose on 1000-seed weight

There was significant variation observed for 1000-seed weight due to different fertilizer doses (Fig. 20). Treatment T_3 (20 kg N + 50 kg P+ 35 kg K) produced the highest 1000-seed weight (41.22 gm) and control treatment (T_0) attained the lowest (38.34 gm) 1000-seed weight. The results were in agreement with the findings of Srinivas *et al.* (2002) and Umar *et al.* (2001) observed that 1000-seed weight increased significantly by application of phosphorus along with nitrogen. Asif *et al.* (2003) also found that various levels of phosphorus significantly affected the 1000 grain weight. Mahboob and Asghar (2002) revealed that like 1000-grain weight was affected significantly by 50 kg P ha^{-1}. Patel and Parmer (1986) also observed that increasing N application to rainfed mungbean increased 1000-seed weight.

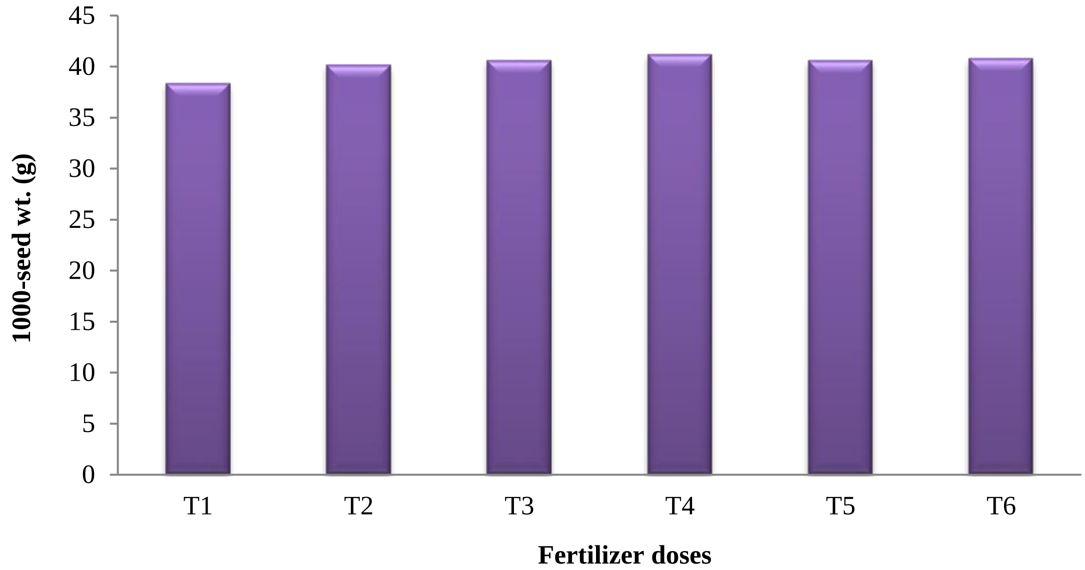

Figure 20. Effect of fertilizer dose on 1000-seed weight of mungbean

4.10.3 Interaction effect of fertilizer doses and varieties on 1000-seed weight

1000-seed weight was significantly affected by the interaction of variety and treatment (Table 7). Highest 1000-seed weight was observed from the combination V_2T_3 (43.63 g) which were statistically similar to V_1T_1, V_1T_2, V_1T_4 and V_1T_5. The lowest 1000-seed weight was found from the combination V_2T_0 (35.98 g).

Table 7. Interaction effect of varieties and fertilizer doses in case of yield contributing characters of mungbean

Treatment Interaction	Flowers plant^{-1}	Yield contributing characters					
		Pods plant^{-1}		Pod length		Seeds pod^{-1}	1000-seed weight (g)
		45 DAS	60 DAS	45 DAS	60 DAS		
V_1T_0	3.86 e	1.46 e	17.33 e	5.73 d	6.86 d	8.80 e	40.70 b
V_1T_1	4.40 de	2.33 d	20.40 d	7.26 c	8.33 c	10.27 cd	42.82 a
V_1T_2	4.53 de	2.86 a-d	22.03 bc	7.96 ab	8.93 a-c	11.17 a-d	43.08 a
V_1T_3	6.73 a	3.46 a	23.47 a	8.13 ab	9.46 a	11.70 a	43.63 a
V_1T_4	5.60 bc	3.06 a-c	22.73 a-c	8.10 ab	9.10 ab	11.57 a	43.10 a
V_1T_5	5.60 bc	3.00 a-d	22.93 ab	8.00 ab	8.96 a-c	11.47 ab	43.33 a
V_2 T_0	4.13 e	1.60 e	17.63 e	5.46 d	6.30 d	8.70 e	35.98 e
V_2 T_1	4.00 e	2.46 cd	21.40 cd	7.83 b	8.66 bc	10.50 b-d	37.50 d
V_2 T_2	4.46 de	2.73 b-d	21.87 bc	8.03 ab	9.00 a-c	10.83 a-d	38.16 cd
V_2 T_3	6.33 ab	3.26 ab	23.07 ab	8.50 a	9.26 ab	11.43 ab	38.81 c
V_2 T_4	5.60 bc	2.86 a-d	22.30 a-c	8.33 ab	9.16 ab	11.23 a-c	38.04 cd
V_2 T_5	5.13 cd	3.06 a-c	21.67 b-d	8.33 ab	9.13 ab	10.13 d	38.21 cd
SE	0.29	0.22	0.43	0.19	0.21	0.32	0.27
CV (%)	9.79	14.03	3.48	4.34	4.25	5.20	1.18

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

4.11 Seed yield

4.11.1 Effect of variety on seed yield

There was significant effect of variety on seed yield (Fig. 21). Variety V_1 (BARI mung-6) was recorded the seed yield (1.72 t/ha) while variety V_2 (BARI mung-5) was observed with seed yield (1.57 t/ha). The results were in agreement with the findings of Jahan *et al.* (2009) and Uddin *et al* (2009) who reported that BARI mung 6 produced the highest seed yield of all mungbean varieties.

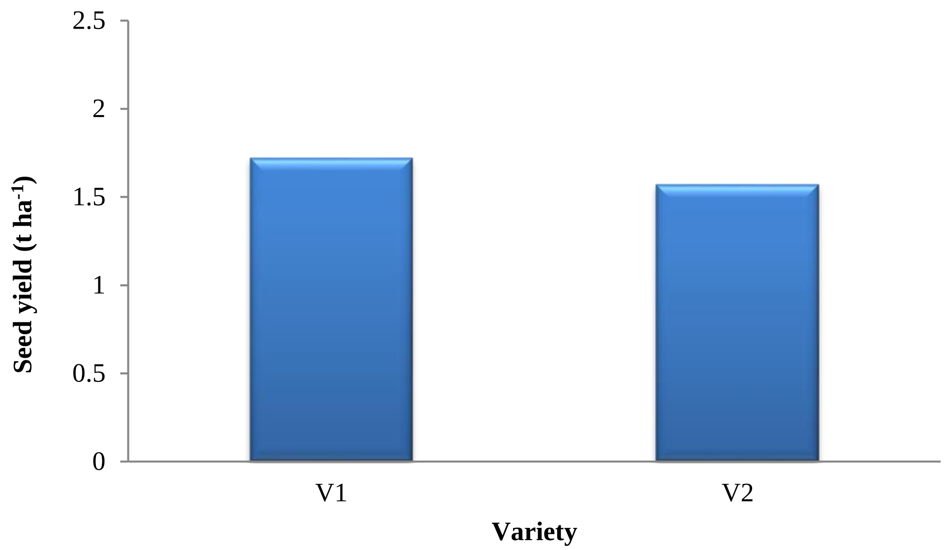

Figure 21. Effect of variety on seed yield of mungbean

4.11.2 Effect of fertilizer doses on seed yield

There was significant variation observed for seed yield due to different treatment levels. T_3 treatment (20 kg N + 50 kg P+ 35 kg K) produced the highest seed yield (1.69 t ha^{-1}) which is about 73% higher than the control treatment, T_0 (0.98 t ha^{-1}). The second highest seed yield was produced by the treatment T_4 (30 kg N + 40 kg P_2O_5 + 25 kg K_2O). The seed yields come from treatment combinations T_2, T_3, T_4 and T_5 were statistically similar. The results were in agreement with the findings of Umar *et al.* (2001) who observed that seed yield of mungbean increased significantly by application of phosphorus along with nitrogen. Sultana *et al.* (2009) observed that application of 20 kg N ha^{-1} as basal dose produced the highest seed yield of mungbean. Agbenin *et al.* (1991) revealed that application of N significantly increased seed yield of mungbean over control. Abbas *et al.*(2011) also observed that K helped to improve the yield of mungbean. Jahan *et al.* (2009). reported that grain yield of all varieties were increased with the increase of potassium application up to 35 kg ha^{-1}. Oad and Buriro (2005) showed that 30 kg K ha^{-1} was the best treatment, recording the highest seed yield of 1205.2 kg ha^{-1}.

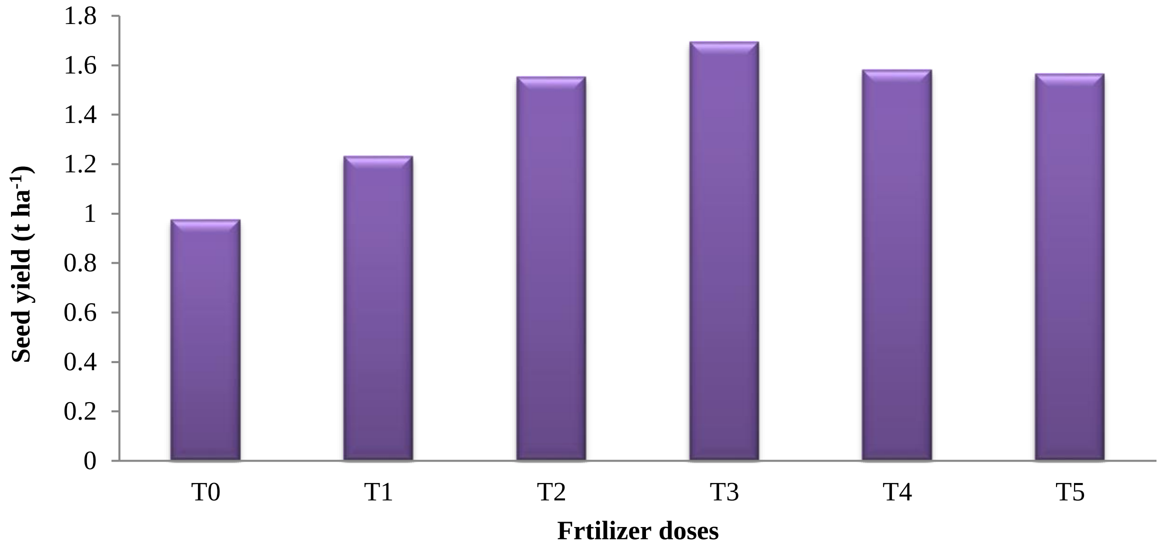

Figure 22. Effect of fertilizer doses on seed yield of mungbean

4.11.3 Interaction effect of fertilizer dose and variety on seed yield

Seed yield was significantly affected by the interaction of variety and treatment (Table 8). Highest seed yield was observed from the combination V_1T_3 (1.78 t ha^{-1}) which were statistically similar to V_1T_2, V_1T_4, and V_1T_5. The lowest seed yield was found from the combination V_2T_0 (1.16 t ha^{-1}).

4.12 Stover yield

4.12.1 Effect of variety on stover yield

There was significant effect of variety on stover yield (Fig. 23). Variety V_1 (BARI mung-6) was recorded the stover yield (2.59 t ha^{-1}) while variety V_2 (BARI mung-5) was observed with stover yield (2.2 t ha^{-1}). The results were in agreement with the findings of Jahan *et al.* (2009) who reported that BARI mung 6 produced the highest stover yield of all mungbean varieties.

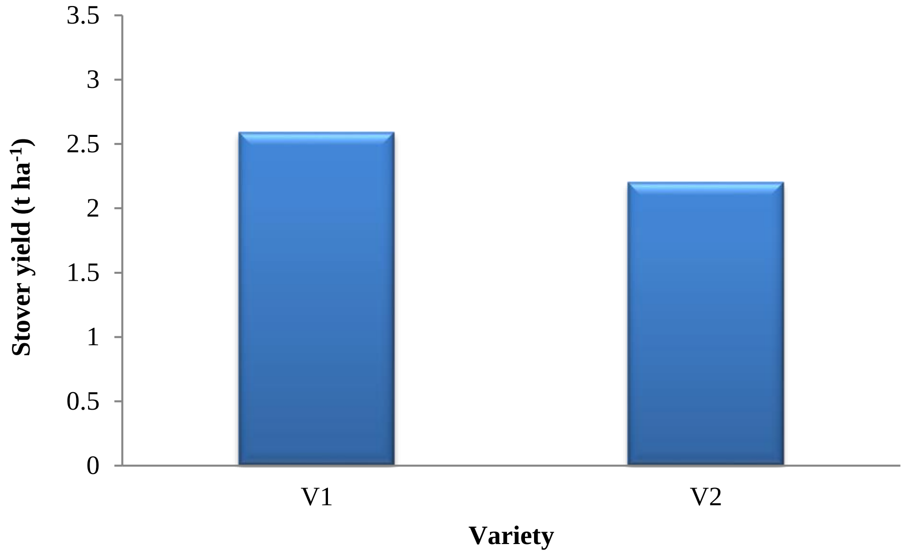

Figure 23. Effect of variety on stover yield of mungbean

4.12.2 Effect of fertilizer dose on stover yield

There was significant variation observed for stover yield due to different fertilizer levels (Fig. 19). T_3 treatment (20 kg N + 50 kg P + 35 kg K) produced the highest stover yield (2.42 t ha^{-1}) which was 27.4% higher than the control treatment, T_0 (1.9 t ha^{-1}). The results were in agreement with the findings of Jahan *et al.* (2009) who reported that stover yield of mungbean of all varieties were increased with the increase of potassium application up to 35 kg ha^{-1}. Rajender *et al.* (2002) also reported that stover yield of mungbean increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

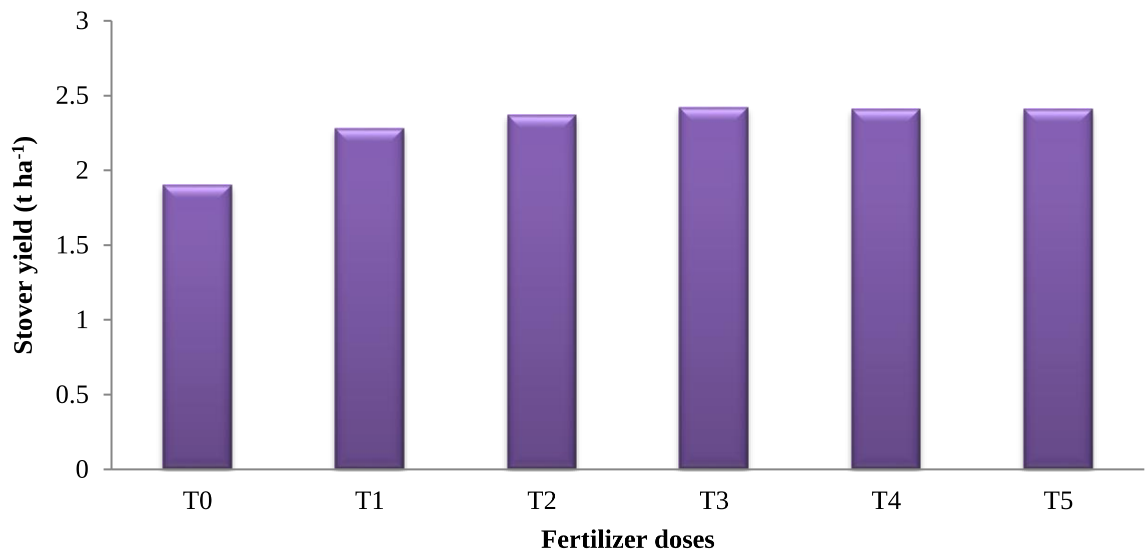

Figure 24. Effect of fertilizer doses on stover yield of mungbean

4.12.3 Interaction effect of fertilizer doses and varieties on stover yield

Stover yield was significantly affected by the interaction of variety and treatment (Table 8). Highest stover yield was observed from the combination V_1T_3 (2.54 t ha^{-1}) which were statistically similar to V_1T_4 and V_1T_5. The lowest stover yield was found from the combination V_1T_0 (1.89 t ha^{-1}).

Table 8. Interaction effect of varieties and fertilizer doses on seed yield and stover yield of mungbean

Treatment combination	Seed yield (t/ha)	Straw yield (t/ha)
V_1T_0	1.19 f	1.89 f
V_1T_1	1.56 b-d	2.41 bc
V_1T_2	1.58 a-c	2.47 ab
V_1T_3	1.78 b	2.54 a
V_1T_4	1.61 ab	2.53 a
V_1T_5	1.59 a-c	2.52 ab
V_2 T_0	1.16 f	1.91 f
V_2 T_1	1.49 e	2.15 e
V_2 T_2	1.52 de	2.27 d
V_2 T_3	1.6 b-d	2.31 cd
V_2 T_4	1.54 c-e	2.30 d
V_2 T_5	1.53 c-e	2.29 d
SE	0.01	0.04
CV (%)	1.70	2.66

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

4.13 Nitrogen content of seed

4.13.1 Effect of variety on nitrogen content of seed

There was significant effect of variety on nitrogen content of mungbean seed (Fig. 25). Variety V_1 (BARI mung-6) showed higher N content in seed (4.05%) and variety V_2 (BARI mung-5) resulted seed N content (3.96).

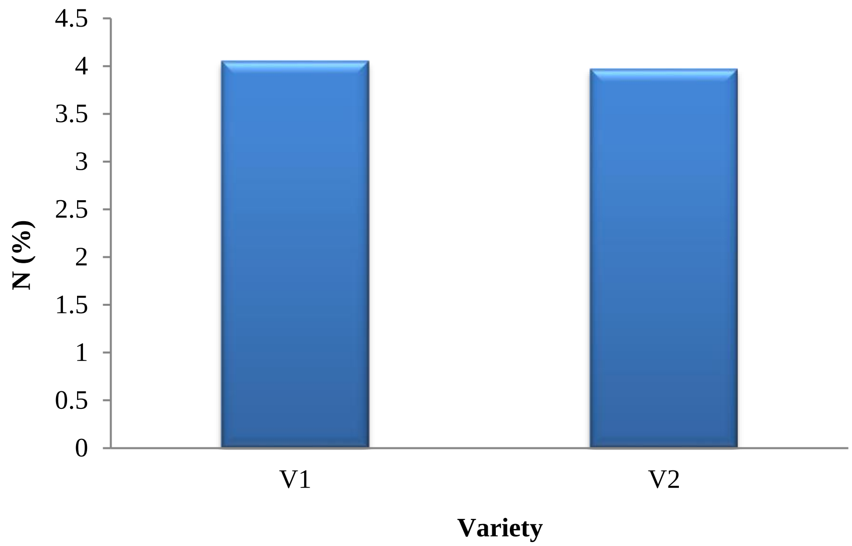

Figure 25. Effect of variety on the nitrogen content of mungbean seed

4.13.2 Effect of fertilizer dose on nitrogen content of seed

Different fertilizer doses showed significant variation in the nitrogen concentration in mungbean seed (Fig. 26). The N concentration in mungbean seed increased with increasing level of NPK fertilizers. The highest nitrogen concentration in seed (4.45%) was recorded in treatment T_5 (30 kg N + 40 kg P + 45 kg K). On the other hand, the lowest nitrogen concentration in seed (2.93%) was recorded in the control treatment (T_0).

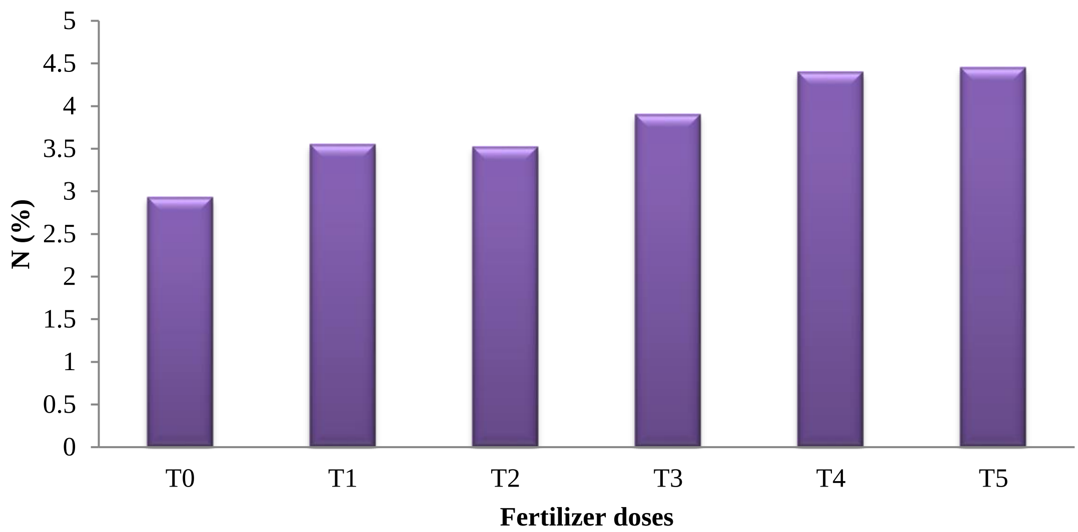

Figure 26. Effect of fertilizer doses on the nitrogen content of mungbean seed.

4.13.3 Interaction effect of fertilizer doses and varieties on nitrogen content of seed

Nitrogen content in mungbean seed was significantly affected by the interaction of variety and treatment (Table 9). Highest N content was observed from the combination V_1T_5 (4.45%) which are statistically similar to V_2T_5 respectively. The lowest N content was found from the combination V_2T_0 (2.89%) which is statistically similar to the combination V_1T_0.

4.14 Phosphorus content of seed

4.14.1 Effect of variety on phosphorus content of seed

There was significant effect of variety on phosphorus content of mungbean seed (Fig. 27). Variety V_1 (BARI mung-6) showed the highest P content in seed (0.25%) and variety V_2 (BARI mung-5) resulted lowest seed P content (0.23%).

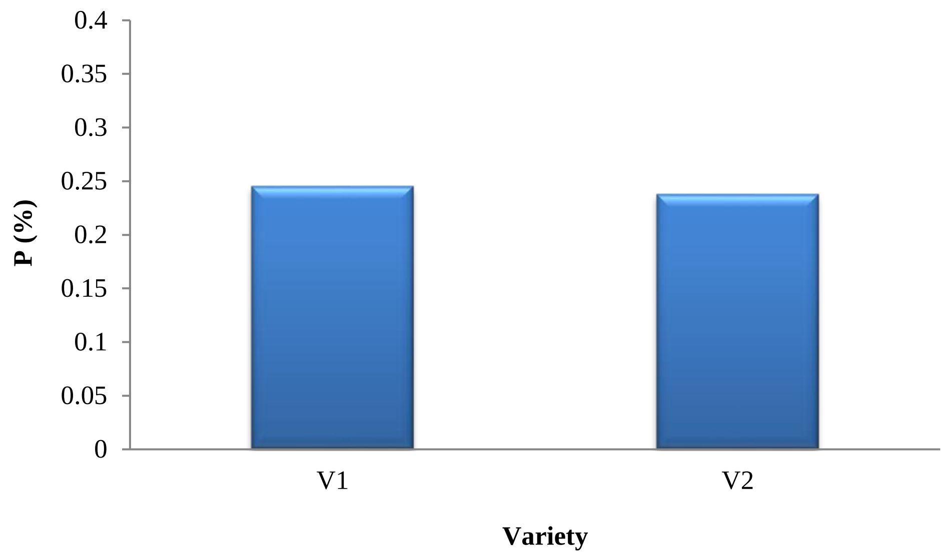

Figure 27. Effect of variety on the phosphorus content of mungbean seed

4.14.2 Effect of fertilizer doses on phosphorus content of seed

Different fertilizer doses showed significant variation in the phosphorus concentration in mungbean seed (Fig. 28). The P concentration in mungbean seed increased with increasing level of NPK fertilizers. The highest phosphorus concentration in seed (0.3%) was recorded in treatment T_3 (10 kg N + 60 kg P + 45 kg K). On the other hand, the lowest phosphorus concentration in seed (0.15%) was recorded in the control treatment (T_0).

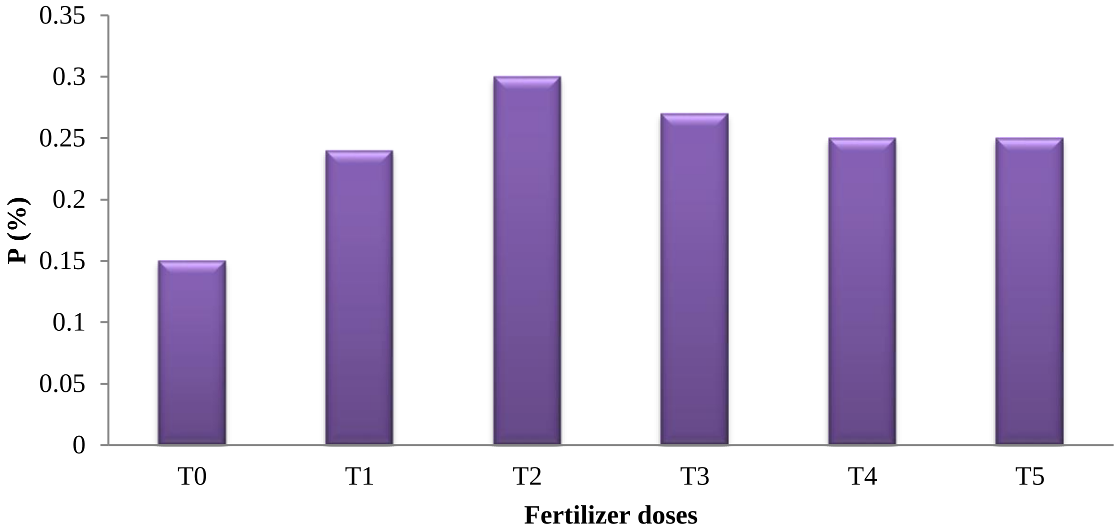

Figure 28. Effect of fertilizer doses on the phosphorus content of mungbean seed.

4.14.3 Interaction effect of variety and fertilizer doses on phosphorus content of seed

Phosphorus content in mungbean seed was significantly affected by the interaction of variety and treatment (Table 9). Highest P content was observed from the combination V_2T_3 (0.31%) which was statistically similar to V_1T_2, V_1T_4, V_2T_3 and V_2T_4 respectively. The lowest P content was found from the combination V_2T_0 (0.14%) which was statistically similar to the combination V_1T_0.

4.15 Potassium content of seed

4.15.1 Effect of variety on potassium content of seed

There was significant effect of variety on potassium content of mungbean seed (Fig. 29). Variety V_1 (BARI mung-6) showed higher K content in seed (1.31%) and variety V_2 (BARI mung-5) resulted seed K content (1.29%).

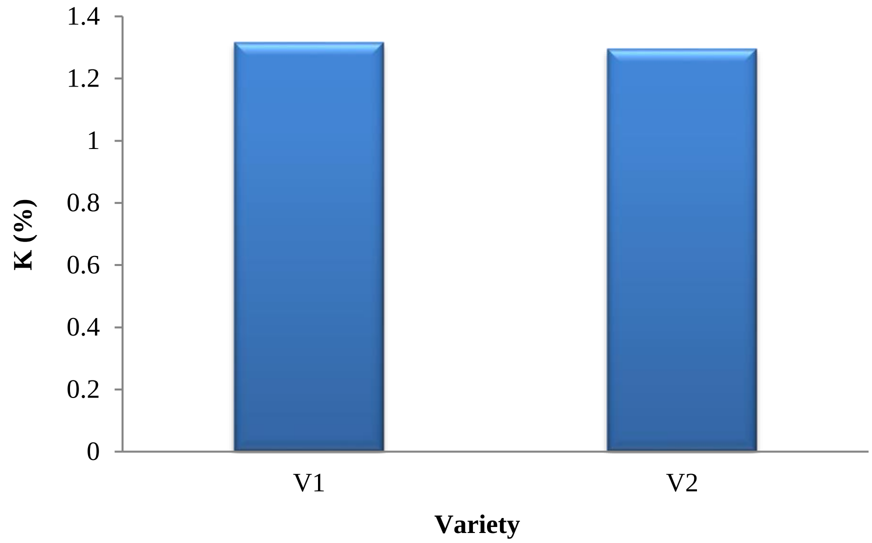

Figure 29. Effect of variety on the potassium content of mungbean seed

4.15.2 Effect of fertilizer dose on potassium content of seed

Different fertilizer doses showed significant variation in the potassium concentration in mungbean seed (Fig. 30). The K concentration in mungbean seed increased with increasing level of NPK fertilizers. The highest potassium concentration in seed (1.44%) was recorded in treatment T_5 (30 kg N + 40 kg P + 45 kg K). On the other hand, the lowest potassium concentration in seed (0.98%) was recorded in the control treatment (T_0).

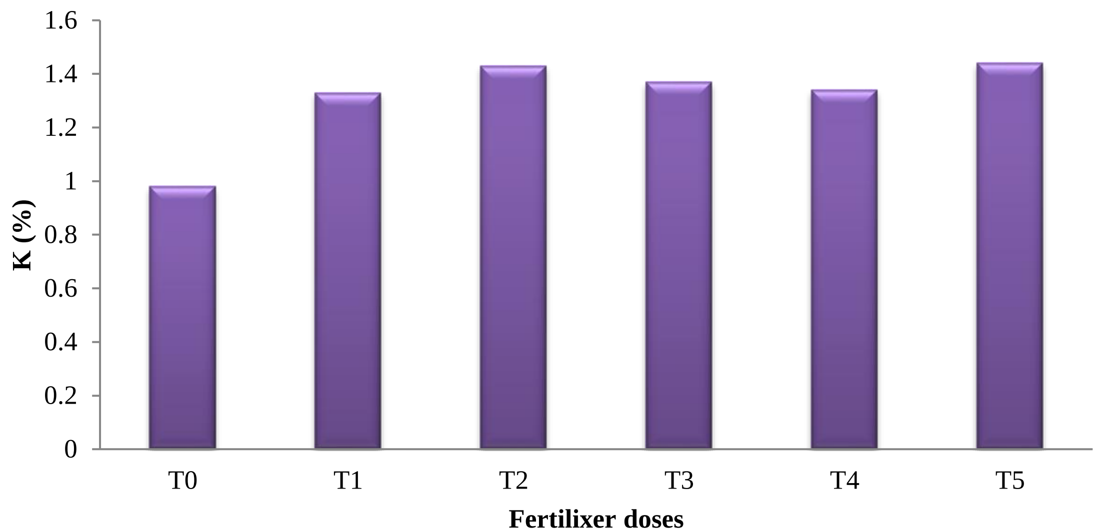

Figure 30. Effect of fertilizer doses on the potassium content of mungbean seed

4.15.3 Interaction effect of variety and fertilizer doses on potassium content of seed

Potassium content in mungbean seed was significantly affected by the interaction of variety and treatment (Table 9). Highest K content was observed from the combination V_1T_3 and V_2T_3 (1.43%) which were statistically similar to V_1T_2, V_1T_5, V_1T_6, V_2T_4 and V_2T_5 respectively. The lowest K content was found from the combination V_1T_0 (1.06%).

Table 9. Interaction effect of varieties and fertilizer doses on the nutrient content of mungbean seed

Treatment combination	Seed of mungbean		
	Total N %	Available P %	Available K %
V_1T_0	2.89 e	0.17 de	1.06 c
V_1T_1	3.59 cd	0.22 cd	1.30 b
V_1T_2	3.72 bc	0.25 a-c	1.37 ab
V_1T_3	3.90 b	0.31 a	1.43 a
V_1T_4	4.40 ab	0.26 a-c	1.37 ab
V_1T_5	4.45 a	0.24 bc	1.35 ab
V_2T_0	2.90 e	0.14 e	0.96 d
V_2T_1	3.60 cd	0.21 cd	1.30 b
V_2T_2	3.69 c	0.25 bc	1.36 ab
V_2T_3	3.76 ab	0.30 ab	1.43 a
V_2T_4	4.40 ab	0.26 a-c	1.36 ab
V_2T_5	4.40ab	0.25 bc	1.34 b
SE	0.05	0.02	0.03
CV (%)	2.19	7.83	3.70

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

4.16 Nitrogen content of stover

4.16.1 Effect of variety on nitrogen content of stover

There was significant effect of variety on nitrogen content of mungbean stover (Fig. 31). Variety V_1 (BARI mung-6) showed higher N content in stover (1.67%) and variety V_2 (BARI mung-5) resulted stover N content (1.52%).

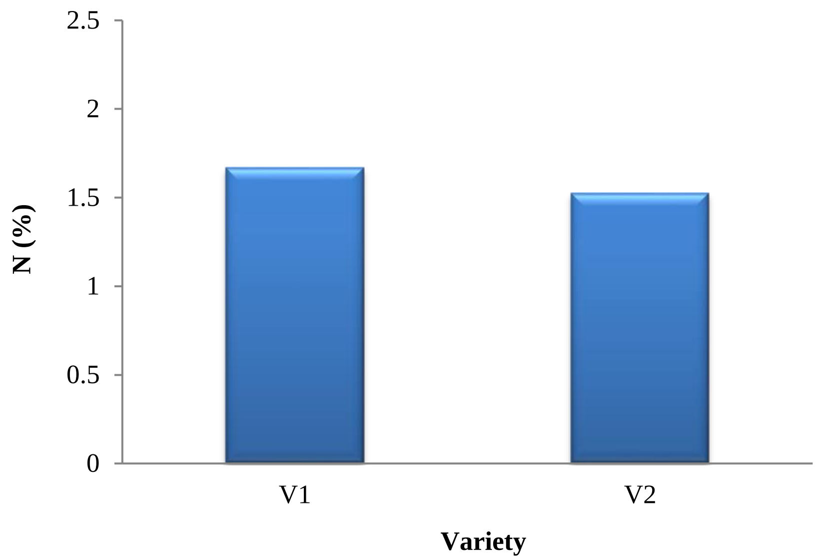

Figure 31. Effect of variety on the nitrogen content of mungbean stover

4.16.2 Effect of fertilizer doses on nitrogen content of stover

Different fertilizer doses showed significant variation in the nitrogen concentration in mungbean stover (Fig. 32)).The N concentration in mungbean stover increased with increasing level of NPK fertilizers. The highest nitrogen concentration in stover (1.91%) was recorded in treatment T_4 (30 kg N + 40 kg P + 25 kg K). On the other hand, the lowest nitrogen concentration in nitrogen (1.22%) was recorded in the control treatment (T_0).

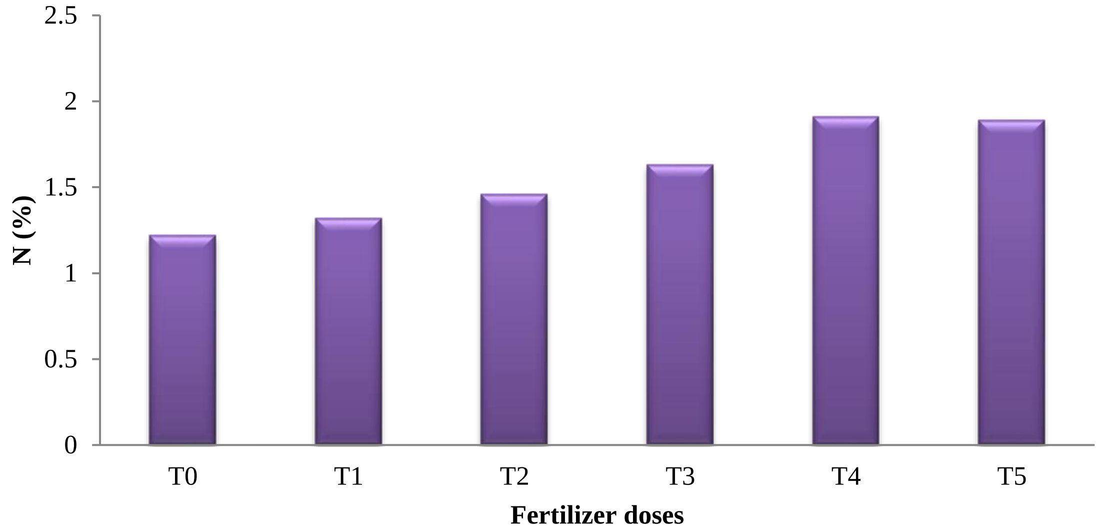

Figure 32. Effect of fertilizer doses on the nitrogen content of mungbean stover

4.16.3 Interaction effect of fertilizer doses and varieties on nitrogen content of stover

Nitrogen content in mungbean stover was significantly affected by the interaction of variety and treatment (Table 10). Highest N content was observed from the combination V_1T_3 (1.92%) which was statistically similar to V_1T_2, V_1T_4, V_2T_2 and V_2T_4. The lowest N content was found from the combination V_1T_0 (1.31%) which was statistically similar to the treatments V_1T_1, V_1T_5, V_2T_0, V_2T_1 and V_2T_5.

4.17 Phosphorus content of stover

4.17.1 Effect of variety on phosphorus content of stover

There was significant effect of variety on phosphorus content of mungbean seed (Fig. 33). Variety V_1 (BARI mung-6) showed higher P content in seed (0.18%) and variety V_2 (BARI mung-5) resulted seed P content (0.17%).

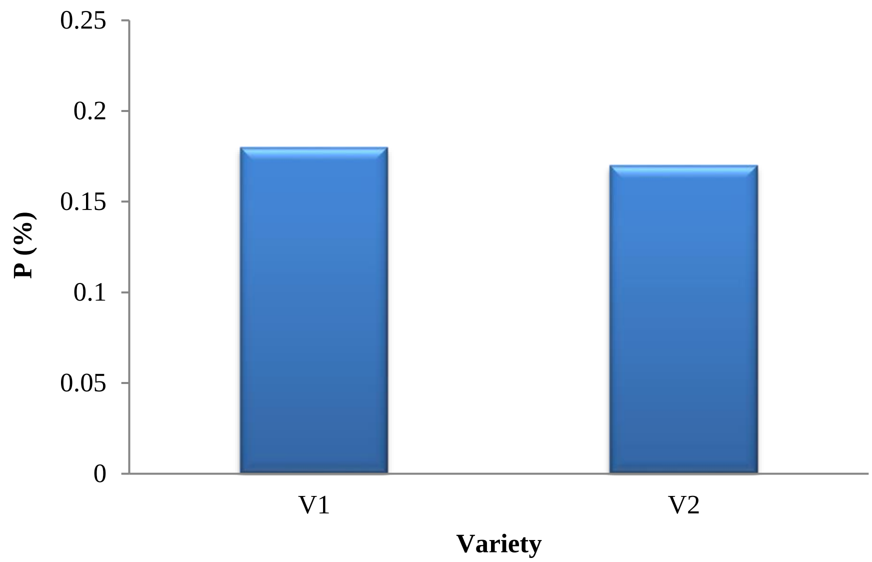

Figure 33. Effect of variety on the phosphorus content of mungbean stover

4.17.2 Effect of fertilizer dose on phosphorus content of stover

Significant variation was observed in phosphorus concentration in stover of mungbean with different doses of NPK (Fig. 34). Considering the different doses of NPK the highest phosphorus concentration in stover (0.22%) was recorded in T_2 (10 kg N + 60 kg P + 45 kg K). The lowest phosphorus concentration in stover (0.11%) was recorded in the control treatment (T_0).

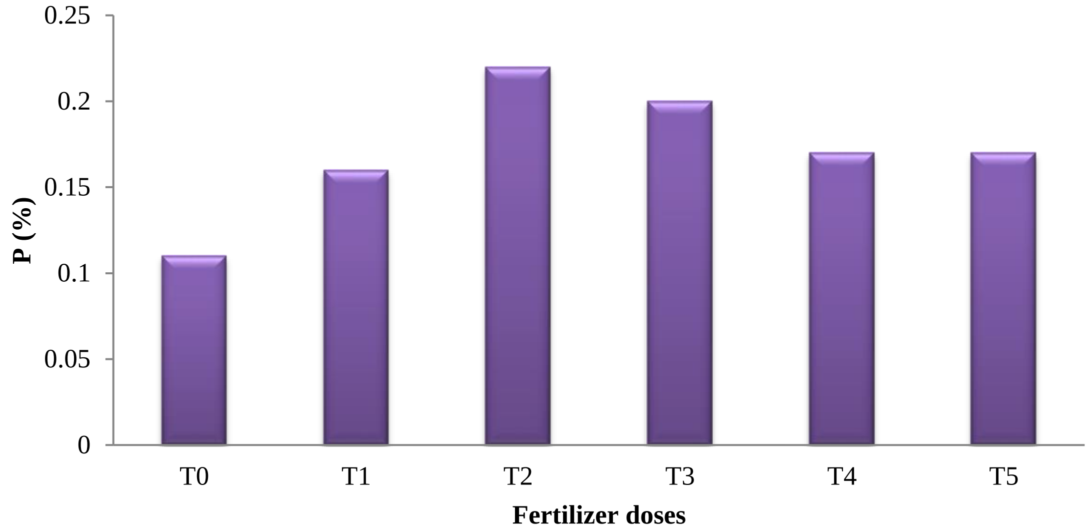

Figure 34. Effect of fertilizer doses on the phosphorus content of mungbean stover.

4.17.3 Interaction effect of varieties and fertilizer doses on phosphorus content of stover

The interaction effect of variety and treatment in case of phosphorus content of mungbean stover was statistically insignificant (Table 10). Highest P content was observed from the combination V_1T_5 (0.23%) and the lowest P content was found from the combination V_2T_0 (0.05%).

4.18 Potassium content of stover

4.18.1 Effect of variety on potassium content of stover

There was significant effect of variety on potassium content of mungbean stover (Fig. 35). Variety V_1 (BARI mung-6) showed the higher K content in stover (1.43%) and variety V_2 (BARI mung-5) resulted seed K content (1.12%).

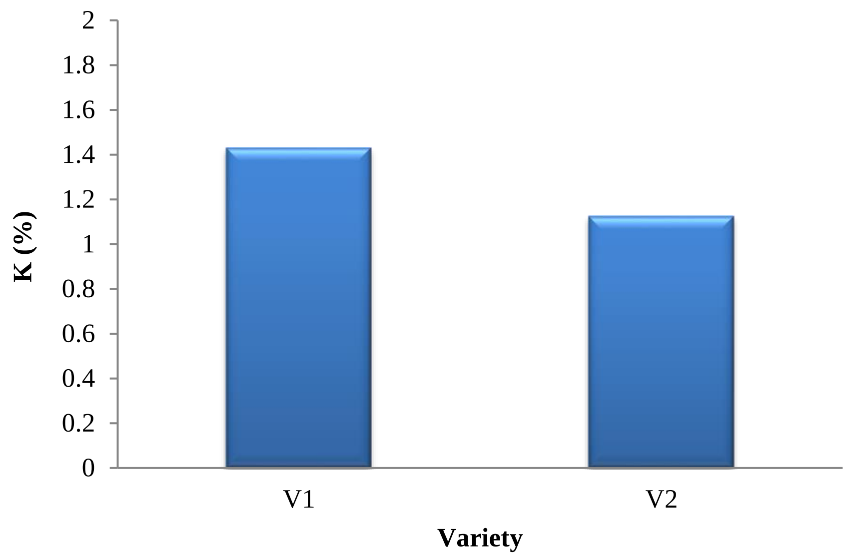

Figure 35. Effect of variety on the potassium content of mungbean stover

4.18.2 Effect of fertilizer dose on potassium content of stover

Different fertilizer doses showed significant variation in the potassium concentration in mungbean stover (Fig. 36)).The K concentration in mungbean stover increased with increasing level of NPK fertilizers. The highest potassium concentration in stover (1.35%) was recorded in treatment T_2 (10 kg N + 60 kg P + 45 kg K). On the other hand, the lowest potassium concentration in stover (0.88%) was recorded in the control treatment (T_0).

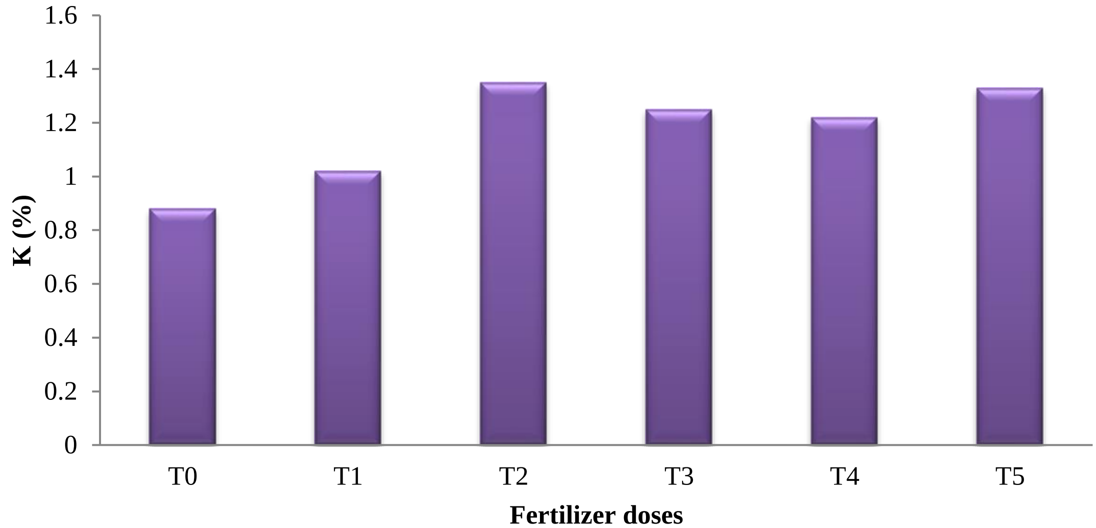

Figure 36. Effect of fertilizer doses on the potassium content of mungbean stover.

4.18.3 Interaction effect of varieties and fertilizer doses on potassium content of stover

Potassium content in mungbean stover was significantly affected by the interaction of variety and treatment (Table 10). Highest K content was observed from the combination V_1T_3 (1.35%) which was statistically similar to V_1T_2 and V_2T_3 respectively. The lowest K content was found from the combination V_2T_0 (0.88%).

Table 10. Interaction effect of varieties and fertilizer doses on nutrient content of mungbean stover

Treatment combination	Mungbean stover		
	N %	P %	K %
V_1T_0	1.31 b	0.08 d	0.89 f
V_1T_1	1.34 b	0.14 b	1.02 de
V_1T_2	1.68 ab	0.19 a-c	1.26 ab
V_1T_3	1.92 a	0.20 ab	1.35 a
V_1T_4	1.65 ab	0.21 ab	1.12 cd
V_1T_5	1.51 b	0.23 a	1.13 c
V_2T_0	1.33 b	0.05 e	0.88 f
V_2T_1	1.31 b	0.12 c	1.02 e
V_2T_2	1.60 ab	0.20 ab	1.25 b
V_2T_3	1.90 a	0.20 ab	1.35 ab
V_2T_4	1.60 ab	0.21 ab	1.12 cd
V_2T_5	1.40 b	0.21 ab	1.13 cd
SE	0.12	0.02	0.03
CV (%)	13.16	22.93	4.76

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

4.19 N content of post harvest soil

4.19.1 Effect of variety on N content of post harvest soil

There was significant effect of variety on total nitrogen content of mungbean post harvest soil (Fig. 37). Variety V_1 (BARI mung-6) showed the higher total N content in post harvest soil (0.07%) and variety V_2 (BARI mung-5) resulted post harvest total soil N content (0.065%).

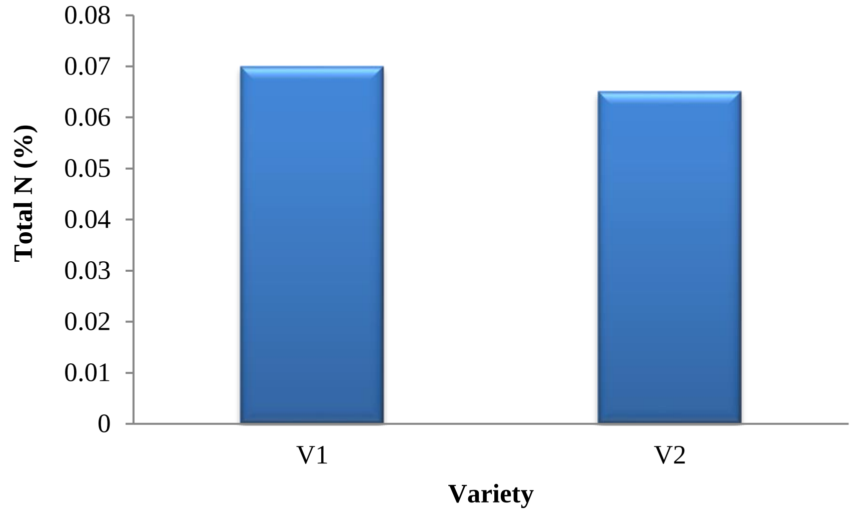

Figure 37. Effect of variety on the total nitrogen content of post harvest soil

4.19.2 Effect of fertilizer dose on N content of post harvest soil

Significant variation was observed in total nitrogen concentration in post harvest soil of mungbean field with different doses of NPK (Fig. 38). Considering the different doses of NPK the highest total nitrogen concentration in post harvest soil (0.07 %) was recorded in treatment T_5 (30 kg N + 40 kg P + 25 kg K) and T_6 (30 kg N + 40 kg P + 45 kg K). The lowest available nitrogen concentration in post harvest soil (0.03%) was recorded in the control.

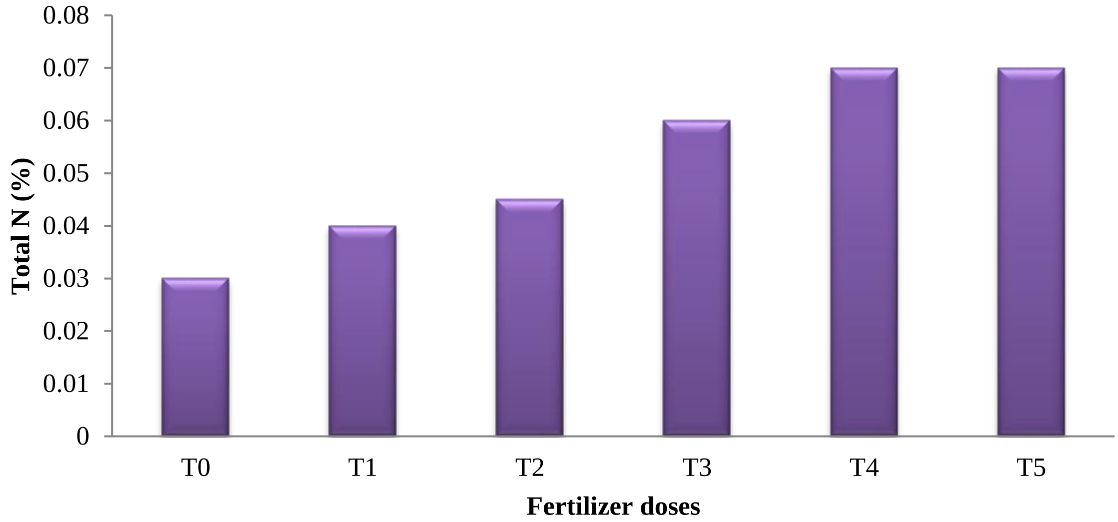

Figure 38. Effect of fertilizer dose on the total nitrogen content of post harvest soil of mungbean

4.19.3 Interaction effect of variety and fertilizer doses on N content of post harvest soil

Total nitrogen content in mungbean post harvest soil was significantly affected by the interaction of variety and treatment (Table 11). Highest total N content was observed from the combination V_1T_4, V_1T_5, V_2T_4 and V_2T_5 (0.07%). The lowest total N content was found from the combination V_2T_0 (0.03%).

4.20 P content of post harvest soil

4.20.1 Effect of variety on P content of post harvest soil

There was significant effect of variety on available phosphorus content of mungbean post harvest soil (Fig. 39). Variety V_2 (BARI mung-5) showed higher available P content in post harvest soil (22.97 ppm) and variety V_1 (BARI mung-6) resulted post harvest soil P content (22.33 ppm).

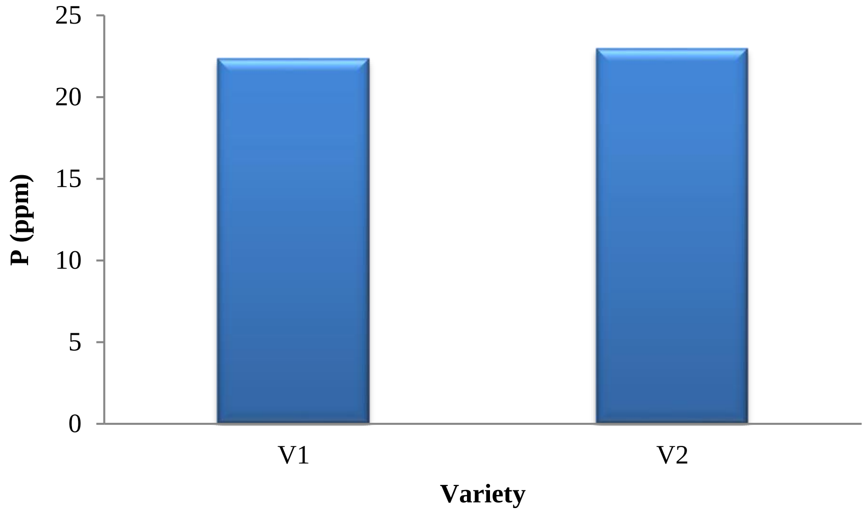

Figure39. Effect of variety on the phosphorus content of post harvest soil

4.20.2 Effect of fertilizer dose on P content of post harvest soil

Different fertilizer doses showed significant variation in the available phosphorus concentration in mungbean post harvest soil (Fig. 40).The available P concentration in mungbean post harvest soil increased with increasing level of NPK fertilizers. The highest available phosphorus concentration in post harvest soil (22.9 ppm) was recorded in treatment T_2 (10 kg N + 60 kg P + 45 kg K). On the other hand, the lowest available phosphorus concentration in post harvest soil (20.65 ppm) was recorded in the control treatment (T_0).

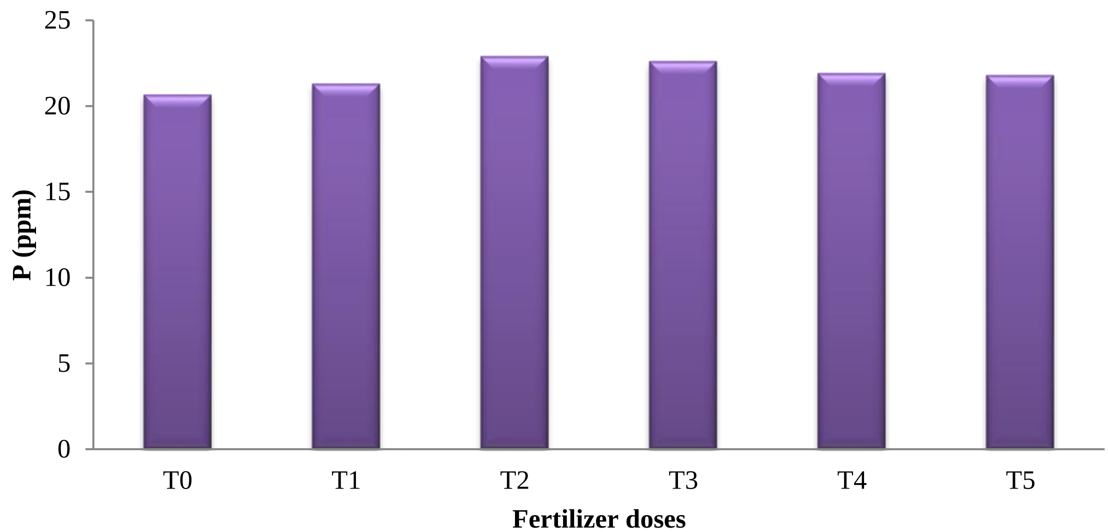

Figure 40. Effect of fertilizer dose on available phosphorus content of post harvest soil of mungbean

4.20.3 Interaction effect of varieties and fertilizer doses on P content of post harvest soil

Available phosphorus content in mungbean post harvest soil was significantly affected by the interaction of variety and treatment (Table 11). Highest available P content was observed from the combination V_1T_2 (23.0 ppm) which was statistically similar to V_2T_3 respectively. The lowest available P content was found from the combination V_2T_0 (19.68 ppm).

4.21 K content of post harvest soil

4.21.1 Effect of variety on K content of post harvest soil

There was significant effect of variety on available potassium content of post harvest soil (Fig. 41). Variety V_1 (BARI mung-6) showed the highest available K content in post harvest soil (0.19 meq/100gm) and variety V_2 (BARI mung-5) resulted available post harvest soil K content (0.18 meq/100gm).

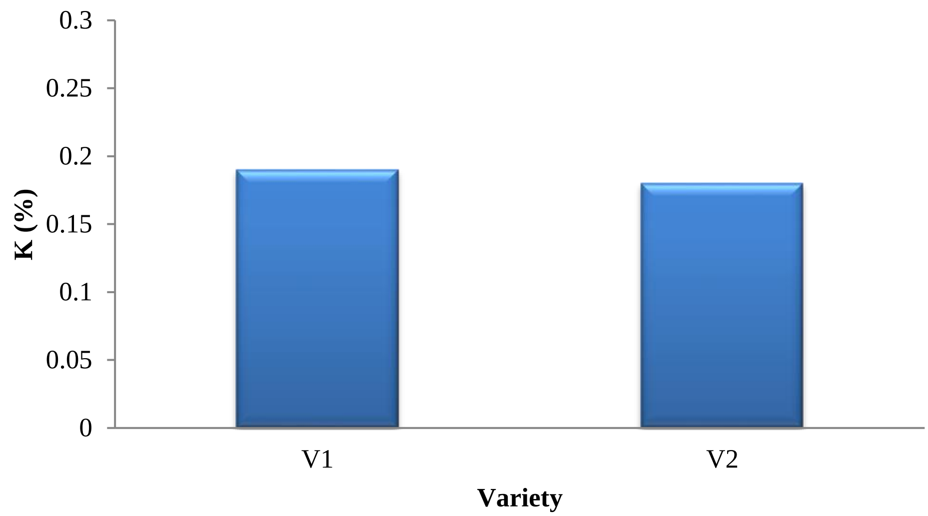

Figure 41. Effect of variety on the available potassium content of post harvest soil

4.21.2 Effect of fertilizer doses on K content of post harvest soil

Different fertilizer doses showed significant variation in the potassium concentration in post harvest soil (Fig. 42). The available K concentration in post harvest soil increased with increasing level of NPK fertilizers. The highest available potassium concentration in post harvest soil (0.27 meq/100g) was recorded in treatment T_5 (30 kg N + 40 kg P + 45 kg K). On the other hand, the lowest available potassium concentration in post harvest soil (0.11 meq/100g) was recorded in the control treatment (T_0). These results were in agreements with the findings of Prasad *et al.* (2000) who found that available K in soil after harvesting of crop increased with increasing levels of K.

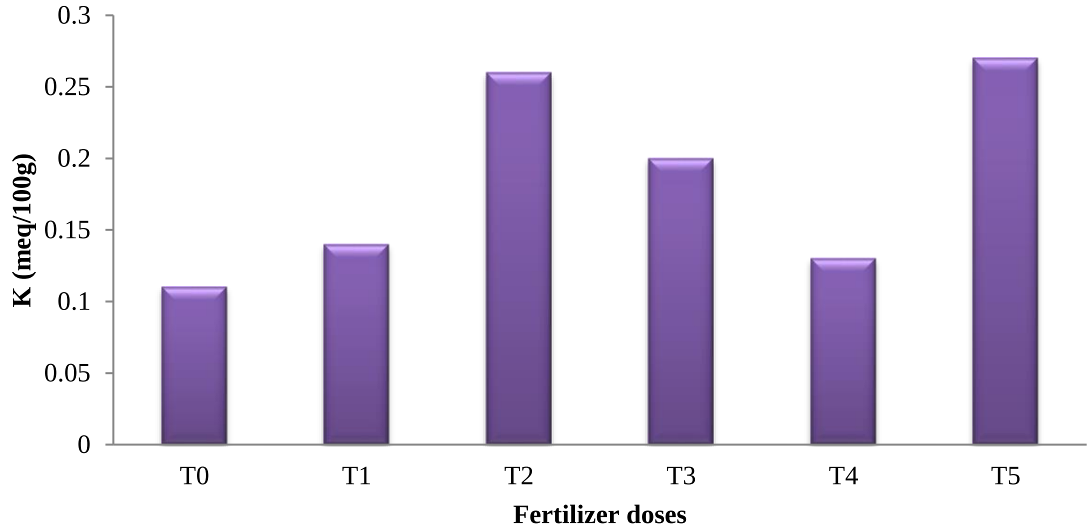

Figure 42. Effect of fertilizer doses on the available potassium content of post harvest soil of mungbean

4.21.3 Interaction effect of varieties and fertilizer doses on K content of post harvest soil

Available potassium content in post harvest soil was significantly affected by the interaction of variety and treatment (Table 11). Highest K content was observed from the combination V_1T_5 (0.27 meq/100g) which was statistically similar to treatment combination V_2T_5. The lowest K content was found from the combination V_2T_0 (0.09 meq/100g).

Table 11. Interaction effect of varieties and fertilizer doses on nutrient content of post harvest soil of mungbean

Treatment combination	Post harvest soil		
	Total N (%)	Available P (ppm)	Available K (meq/100g)
V_1T_0	0.04 e	20.23 d	0.11 f
V_1T_1	0.04 d	21.32 c	0.12 d-f
V_1T_2	0.05 c	23.0 a	0.25 ab
V_1T_3	0.06 b	22.70 b	0.20 c
V_1T_4	0.07 a	21.93 bc	0.13 d-f
V_1T_5	0.07 a	21.59 bc	0.27 a
V_2 T_0	0.03 f	19.68e	0.09 f
V_2 T_1	0.04 d	21.33 b	0.14 cd
V_2 T_2	0.05 c	22.96 a	0.26 b
V_2 T_3	0.05 c	22.67 b	0.19 bc
V_2 T_4	0.07 a	21.92 bc	0.11 cd
V_2 T_5	0.07 a	21.10 c	0.26 ab
SE	0.02	1.34	0.02
CV(%)	16.94	10.27	6.44

V_1 = BARI mung-6, V_2 = BARI mung-5, T_0 = control treatment, T_1 = 10kg N + 40kg P + 25kg K ha^{-1}, T_2 =10kg N + 60kg P + 45kg K ha^{-1}, T_3 = 20kg N + 50kg P + 35kg K ha^{-1}, T_4 = 30kg N + 40kg P + 25kg K ha^{-1}, T_5 = 30kg N + 40kg P + 45kg K ha^{-1}

Chapter V

SUMMARY AND CONCLUSION

The present piece of work was done at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from April to June, 2019 to find out the combined effect of nitrogen, phosphorus and potassium fertilizers on the growth, yield and nutrient uptake of mungbean.

The experiment was laid out in a randomized complete block design with three replications. The size of the individual plot was 3.0 m x 1.0 m and total numbers of plots were 36. There were 6 treatment combinations, T_0 = (control treatment), T_1 (10-40-25 NPK kg ha^{-1}), T_2 (10-60-45 NPK kg ha^{-1}), T_3 (20-50-35 NPK kg ha^{-1}), T_4 (30-40-25 NPK kg ha^{-1}) and T_5 (30-40-45 NPK kg ha^{-1}), respectively. The whole amounts of TSP, MOP and Urea fertilizer were applied as basal dose during final land preparation. Fertilizers were applied as per treatment combination after field layout of the experiment and were mixed properly through hand spading.

Mungbean seeds were sown on 12th April 2019 and the crop was harvested on 17th June 2019. The agronomic data were collected at 30, 45 and 60 days after sowing (DAS). The data were collected plot wise for plant height (cm), number of leaves plant^{-1}, number of branches plant^{-1}, number of flowers plant^{-1}, number of pods plant^{-1}, pod length (cm), number of seeds pod^{-1}, weight of 1000-seed (g), grain yield (t ha^{-1}) , stover yield (t ha^{-1}), root dry weight (g) and shoot dry weight (g).

The plot wise post harvest soil samples from 0-15 cm depth were collected and analyzed for N, P, K contents. Seed and stover samples were also chemically analyzed for total N, P, K contents. All the data were statistically analyzed following F-test and the mean comparison was made by DMRT. The results of the experiment are stated below.

Plant height was significantly affected by both variety and fertilizer doses. Plant height increased with increasing levels of N, P and K. The variety V_1 (BARI mung 6) produced the tallest plant (31.35, 53.5 and 65.32 cm at 30, 45 and 60 DAS). The fertilizer dose T_3 (20 kg N + 50 kg P + 45 kg K) produced the highest plant height (36.3, 54.02 and 64.2cm at 30, 45 and 60 DAS). The tallest plant (36.79, 54.0 and 64.8 cm at 30, 45 and 60 DAS) was found in V_1T_3 treatment combination which was higher than control treatment. The application of N, P and K showed positive effect on the number of leaves per plant, number of branches per plant, number of pod per plant, pod length, number of seeds per pod, weight of 1000-seed, grain yield, stover yield, root dry weight and shoot dry weight. All the plant characters increased with increasing levels of N, P and K up to certain level (20 kg N + 50 kg P + 45 kg K ha^{-1}).

Like all other plant characters, seed yield of mungbean was influenced significantly by variety and fertilizer doses. Variety V_1 (BARI mung 6) produced higher grain yield of 1.72 t $ha^{-1}$and variety V_2 (BARI mung 5) produced seed yield of 1.57 t ha^{-1}. The grain yield increased with increasing levels of N, P and K up to certain level (20 kg N + 50 kg P + 45 kg K ha^{-1}). The highest grain yield (1.69 t ha^{-1}) was found in plants receiving fertilizer dose T_3 (20kg N +50 kg P_2O_5 +3 kg K_2O) and the lowest was recorded in control (T_0) treatment (0.98 t ha^{-1}). The combined effect of variety and fertilizer dose had positive effect on grain yield of mungbean. The highest grain yield of mungbean was recorded in V_1T_3 treatment (1.78 t ha^{-1}). The lowest yield was recorded in V_2T_0 treatment (1.6 t ha^{-1}).

Nutrient contents (NPK) on stover were positively affected by the variety and fertilizer dose. The interaction effect was also found remarkable. The NPK content in stover varied from 1.92% (V_1T_3) to 1.31% (V_1T_0), 0.23% (V_1T_5) to 0.05% (V_2T_0) and 1.35% (V_1T_3) to 0.88% (V_2T_0). NPK contents in stover increased with increasing levels of NPK up to certain level.

Nutrient contents (NPK) on seed were positively affected due to variety and fertilizer dose. The interaction effect was also found remarkable. The NPK content in seed varied from 4.53% (V_1T_3) to 3.55% (V_2T_0), 0.31% (V_2T_3) to 0.14% (V_2T_0) and 1.43% (V_1T_3) to 1.06% (V_1T_0). NPK contents in stover increased with increasing levels of NPK up to certain level (20 kg N + 50 kg P + 45 kg K ha^{-1}).

Nutrient content in post harvest soil was also influenced by different levels of N, P and K. The total N, available P and available K of post harvest soil varied from 0.17% (T_3) to 0.04% (T_0), 26.18 ppm (T_3) to 19.96 ppm (T_0) and 0.53 meq/100g (T_3) to 0.33 meq/100g (T_0) respectively due to the application of N, P and K at different levels.

Considering all the parameters studied the following conclusion may be drawn:-
The growth and yield of mungbean responded significantly by the combined application of nitrogen, phosphorus and potassium fertilizers at 20 kg N ha^{-1}, 50 kg P ha^{-1} and 35 kg K ha^{-1} respectively.

Recommendations:-
Based on the findings of the experiment, it could be said that, application of nitrogen, phosphorus and potassium fertilizers at 20 kg N ha^{-1}, 50 kg P ha^{-1} and 35 kg K ha^{-1} might be the best combination for higher yield of mungbean and also to maintain soil fertility and productivity in Tejgaon series under AEZ No.28.

However, to reach a specific conclusion and recommendation more research work on mungbean should be done in different Agro-ecological zones of Bangladesh because the experiment was conducted for only one cropping season in a specific location only.

Chapter VI

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