EFFECTS OF PHOSPHORUS AND ZINC ON THE GROWTH, YIELD AND YIELD CONTRIBUTING CHARACTERS OF MUNGBEAN (BARI Mung-6)

A Thesis

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This is to certify that the thesis entitled **"EFFECTS OF PHOSPHORUS AND ZINC ON THE GROWTH, YIELD AND YIELD CONTRIBUTING CHARACTERS OF MUNGBEAN (BARI Mung-6)"** submitted to the DEPARTMENT OF SOIL SCIENCE, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in SOIL SCIENCE, embodies the results of a piece of bonafide research work carried out by **MD. HABIBULLAH**, Registration No. **11-04677,** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207, during the kharif season of 2012 to study the " Effects of Phosphorus and Zinc on the growth, yield and yield contributing characters of Mungbean (BARI Mung-6)". The experimental soil was loam in texture having pH 5.71 and organic carbon content was 0.68%. Four levels of phosphorus (0, 15, 20 and 25 kg P ha^{-1}) and three levels of zinc (0, 1.5 and 3.0 kg Zn ha^{-1}) were used in the study. Levels of these two nutrient elements made 12 treatment combinations. The experiment was carried out in Randomized complete block design (RCBD) with three replications. The results revealed that seed and stover yield of mungbean increased with increasing levels of phosphorus and zinc up to certain level. Incase of P the maximum significant seed yield (1.5 t ha^{-1}) and stover yield (2.47 t ha^{-1}) were obtained with the treatment P_3 (25 kg P ha^{-1}) and the minimum significant seed yield (1.11 t ha^{-1}) and stover yield (2.06 t ha^{-1}) were obtained with the treatment P_0 (0 kg P ha^{-1}). Incase of Zn the maximum significant seed yield (1.45 t ha^{-1}) and stover yield (2.42 t ha^{-1}) were obtained with the treatment Zn_2 (3 kg Zn ha^{-1}) and the minimum significant seed yield (1.27 t ha^{-1}) and stover yield (2.21 t ha^{-1}) were obtained with the treatment Zn_0 (0 kg Zn ha^{-1}). The maximum significant plant height (52.05 cm), number of branch $plant^{-1}$ (2.87), seed yield (1.68 t ha^{-1}), yield contributing factors like number of pods $plant^{-1}$ (20.86), number of seeds pod^{-1} (12.65) and weight of 1000-seeds (45.11 g) were obtained with the treatment combination P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}). On the other hand minimum seed and stover yields were obtained with P_0Zn_0 (No P and No Zn) treatment combination. The N, P, K and S concentration of mungbean plant increased significantly from control to P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}) treatment combination and again decreased with increasing phosphorus more than 20 kg P ha^{-1}. Application of phosphorus and zinc increase organic carbon, N, P, K and S status of postharvest soil significantly.

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CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

Mungbean (*Vigna radiata* L.) is one of the important pulse crops of Bangladesh, as it is an excellent source of easily digestible protein (Kaul, 1982). It belongs to the family Leguminosae. It is well known that pulse are short duration and droudht tolerent crop in Bangladesh. Though it is one of the inter-continental crops but originated in Indian sub-continent. BARIMUNG-6 is a yield potential, innovated by Bangladesh Agricultural Research Institute (BARI) that fits well in crop rotation between two cereal crops (BARI, 1998). It shows disease, insect and pest resistance compare to other mungbean varieties. It fixes atmospheric nitrogen symbiotically with Rhizobia and enriches the soil. Due to tap root it can go deep in search of water and nutrients. BARI Mung-6 is a prestigious innovation among high yield potential mungbean varieties of Bangladesh Agricultural Research Institute (BARI).

In Bangladesh more than 75% cultivated area is covered by rice whereas the pulses occupy only 2.8% of the total area. Mungbean cultivation covers an area of 57,000 acres producing about 20,000 metric tons (BBS, 2010). The production trend of mungbean in Bangladesh from the year 2006-2007 to 2009-10 was 19, 21, 18 and 20 thousand tons (area 60, 60, 54, 57 thousand ac.), respectively (BBS 2010). During these period mungbean production has fluctuated by 5-20%. At present the average yield of mungbean grain in our country is about 1.2 ton ha^{-1}. In Bangladesh, daily consumption of pulses is only 14.30 g $capita^{-1}$ day^{-1} (BBS, 2010), while World Health Organization (WHO) suggested 45 g $capita^{-1}$ day^{-1} for a balanced diet. Bangladesh imported 195 and 291 thousand tons pulses in 2006-07 and 2007-08 fiscal year (BBS, 2010). But to provide the above-mentioned requirement of 45g $capita^{-1}$ day^{-1} ,the production is to be increased even more than three folds.

Mungbean is rich source of vegetable protein. It is considered as poor man's meat containing almost triple amount of protein as compared to rice. 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). The green plants are used as animal feed and the residues as manure. The crop is potentially useful in improving cropping systems as catch crop due to its rapid growth and early maturing characteristics. Hence, on the nutritional point of view, mungbean is perhaps the best of all other pulses (Khan, 1981 and Kaul, 1982). As a whole, mungbean could be considered as an inevitable component of sustainable agriculture.

In spite of the many advantages of mungbean, the area coverage and the production are in declining trend (BBS, 2010). This trend is mainly due to the substandard methods of cultivation, poor crop stand, imbalanced nutrition or no fertilizer application, poor plant protection measures, and lack of high yielding varieties . Therefore, to meet the situation it is necessary to develop HYV and proper management practices as well as summer mungbean cultivation. The excessive uses of N, P, S, K and Zn containing fertilizer decrease nutrient availability as well as yield. So it is essential to recommend the proper combination of nutrients to achieve the maximum and sustainable yield goal.

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 tranformation in plants (Sangakara *et al.*, 2001) and also essential for energy storage and release in living cells. Experimental findings of Arya and Kalra (1988) revealed that application of phosphorus had no effect on the growth of mungbean, while number of grain 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}.

Importance of Zn as a micronutrient in crop production has increased in recent years, hence considered to be the most yield-limiting micronutrient. Zn deficiency is one of the most common widespread disorders in plants and soils of different regions of Bangladesh. The Zn essentially is being employed in functional and structural component of several enzymes, such as carbonic anhydrase, alcohol dehydrase, alkaline phosphatase, phospholipase, carboxypeptidase (Coleman, 1991) and RNA polymerase (Romheld and Marschner, 1991). Further, plants emerging from seeds with lower Zn could be highly sensitive to biotic and abiotic stresses (Obata *et al.*, 1999) . Zn enriched seeds performs better with respect to seed germination, seedling growth and yield of crops (Cakmak *et al.*, 1996). The farmers of Bangladesh generally grow mungbean with almost no fertilizers. So, there is an ample scope of increasing the yield of mungbean $unit^{-1}$ area by using balanced fertilizers including zinc fertilizer.

Although sporadic research works regarding response of mungbean to phosphorus and zinc were done but the influence of phosphorus and zinc on the yield of mungbean and their interacton effect on seed quality and yield are still scantly.

In Bangladesh, many experiments have been conducted on nutrient requirements of mungbean but reports are very few on the phosphorus and zinc fertilizer requirement and on the combined effects of these elements on mungbean. Considering the above facts the present study is aimed at:

i. To determine the effects of phosphorus on the growth, yield and yield contributing characters of mungbean.

ii. To observe the effectiveness of zinc on the growth, yield and yield contributing characters of mungbean.

iii. To study the interaction effect of phosphorus and zinc on growth, yield and yield contributing characters of mungbean.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

A good 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 the Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Institute of Nuclear Agriculture (BINA) have started extensive research 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 phosphorus on yield and yield contributing characters of mungbean

Kumar *et al.* (2012) reported that increasing levels of phosphorus and sulphur enhanced the growth, plant height, yield attributes like number of nodules plant^{-1}, dry weight of nodules, number of pods plant^{-1}, number of grains pod^{-1}, 1000-grain weight, grain yield, and straw yield showed maximum increase at 45 kg P_2O_5 ha^{-1} and 30 kg S ha^{-1}, respectively. The increase in grain and straw yield with successive increase in phosphorus and sulphur levels, was more at 30 kg S ha^{-1} and 45 kg P_2O_5 kg ha^{-1}. Overall the difference between 20 kg and 30 kg S ha^{-1} was not differed significantly. But the growth characters, yield attributes and yield of Mungbean response significantly the highest level of phosphorus i.e. 45 kg P_2O_5 ha^{-1}.

Yadav. B.K. (2011) observed that number and weight of nodules, grain and straw yield, content of P and S were increased with increasing in level of P and S individually as well as in various combinations. Applied P and S increased grain nitrogen and protein contents.

Available P in soil was increased with increasing levels of phosphorus. Similarly available S in soil was increased with increasing levels of sulphur. The synergistic effect of phosphorus and sulphur was reported on number and weight of nodules plant^{-1}, N, P, S and protein content of clusterbean.

Deshbhratar *et al.* (2010) reported that the results indicated a significant increase in grain yield (14.81 q ha^{-1}) and straw yield (41.26 q ha^{-1}) of pigeonpea after 20 kg S ha^{-1} and 50 kg P_2O_5 ha^{-1} treatment with common dose of nitrogen @ 30 kg ha^{-1}. The increase in grain and straw yield was 102.77 and 52.87 % as compare to higher over control. Maximum number of pods plant^{-1}, maximum number of grains pod^{-1} and test weight by this treatment was also observed as compared to control. Application of S and P improved soil fertility status and S alone did not influence P availability. Hence, in order to maintain the fertility status of the soil at high level, combine application of 20 kg S ha^{-1} with 50 kg P_2O_5 ha^{-1} is essential.

Islam *et al.* (2009) observed that application of P and S resulted in significant increase in grain yield ranging from 22 to 35% and 10 to 16% over control, respectively. Effect of P and S application was synergistic and antagonistic at higher level of P (80 kg ha^{-1}). Lower level of P application (40 kg ha^{-1}) resulted in increase in zinc (Zn) uptake by 23 to 25% over control and higher rate (80 kg ha^{-1}) caused decline in Zn uptake. Almost similar observations were recorded regarding effect of S application on Zn uptake in both grain and straw.

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 g kg^{-1} 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 pod^{-1}, 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 plant 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}.

Duary *et al.* (2004) conducted a study on green gram and showed that Rhizobium, 10 kg N ha^{-1}, 30 kg P ha^{-1}, 30 kg K ha^{-1}, 20 kg S ha^{-1} produced the significantly highest seed yield.

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.

Oad *et al.* (2003) conducted a field experiment on the growth and yield performance of mungbean (*Vigna radiata*) 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.

Das *et al.* (2002) studied the effects of vermicompost and chemical fertilizer application on the growth and yield of green gram (*V. radiata cv. Sujata*). 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.

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.

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 100% 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.

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.* (1998) 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).

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.

2.2 Effect of Zn on yield and yield attributing characters of mungbean

Quddus *et al.* (2011) observed that the combination of $Zn_{1.5}B_{1.0}$ produced significantly higher yield (3058 kg ha^{-1}) and (2631 kg ha^{-1}, in the year 2008 and 2009, respectively. The lowest yield (2173 kg ha^{-1}) and (1573 kg ha^{-1}, were found in control (Zn_0B_0) combination. The combined application of zinc and boron were observed superior to their single application in both the years.

Salah Uddin *et al.* (2009) carried out an experiment to investigate the interaction effect of variety and fertilizers on the growth and yield of summer Mungbean during the summer season of 2007. Five levels of fertilizer viz. control, N+P+K, Biofertilizer, Biofertilizer + N +P+K and Bio-fertilizer+ P+ K and three varieties of BARI mung 5, BARI Mung 6 and BINA Mung 5 were also used as experimental variables. Results showed that most of the growth and yield component of mungbean viz. plant height, branch $plant^{-1}$, number of nodules $plant^{-1}$, total dry matter $plant^{-1}$, pods $plant^{-1}$, seed $plant^{-1}$, seed pod^{-1}, weight of 1000-seeds, seed yield and straw yield were significantly influence by the bio-fertilizer (*Bradyrhyzobium* inoculums) treatment except number of leaves and dry weight of nodule. These are influenced by chemical fertilizer and bio-fertilizer also. All the parameters performed better in case of *Bradyrhyzobium* inoculums. BARI mung 6 obtained highest number of nodule $plant^{-1}$ and higher dry weight of nodule. It also obtained highest number of pod $plant^{-1}$, seed $plant^{-1}$, 1000 seed weight and seed yield. Interaction effect of variety and bio-fertilizer (*Bradyrhyzobium*) inoculation was significant of all the parameters.

BARI mung 6 with *Bradyrhyzobium* inoculums produced the highest number of nodule and pod plant^{-1}. It also showed the highest seed yield, stover yield and 1000-seed weight.

Thalooth *et al.* (2006) carried out two field experiments on the effect of foliar application of zinc, potassium or magnesium on growth, yield and yield components and some chemical constituents of mungbean plants grown under water stress conditions. The results revealed that missing one irrigation any of the three studied stages significantly reduced all the tested growth parameters, yield and yield components as well as photosynthetic pigments content as compared with unstressed plants (control). However, subjecting mungbean plants to moisture stress at vegetative stage had the most negative effect on growth parameters. Meanwhile, stress at a pod formation stage produced the least yield and yield components' values. On the other hand, water stress had a stimulating effect on proline and crude protein contents. The present study also indicate that foliar application of Zn K or Mg had a positive effect on growth parameters, yield and yield components but K application surpassed the two other nutrients.

Bandopadhyay *et al.* (2002) reported that the number of pod plant^{-1}, kernel, oil yield of groundnut increased due to application of S with P, K, Zn and B.

Rizk and Abdo (2001) carried out two field experiments where Zn (0.2 or 0.4 g l^{-1}), Mn (1.5 or 2.0 g l^{-1}), B (3.0 or 5.0 g l^{-1}) and a mixture of Zn, Mn and B (0.2, 1.5 and 3.0 g l^{-1}, respectively), in addition to distilled water as control were sprayed once at 35 days after sowing (DAS). All treatments increased yield significantly and its components especially Zn (0.2 g l^{-1}) which showed a highly significant increase in all characters under investigation compared to the control. All adopted treatments increased significantly protein percentage in seeds of the two mungbean cultivars in both seasons.

Singh *et al.* (1997) conducted a field experiment to study the effect of S and Zn on summer green gram (*Vigna radiata*). They reported that application of 30 kg S and 5 kg Zn hat were optimum for plant height, dry matter accumulation, seed protein, yield and S and Zn uptake. Summer Mungbean (*Vigna radiata*) was grown in the field for two years with the application of elemental S (0, 15, 30 and. 45 kg ha^{-1}) in an Inceptisol. Sulphur application significantly improved plant biomass, nodule number and seed weight of mungbean optimum being 30 kg ha^{-1}.

Tripathi *et al.* (1997) conducted a field experiment consisting of 4 levels of S and Zn. They reported that application of S and Zn had conspicuous and significant effect on yield attributes i.e. number of seeds $plant^{-1}$, 1000-grain weight, grain and straw yield of green gram. These characters increased significantly with an increase in S and Zn doses upto 40 kg S ha^{-1} and 5 kg Zn ha^{-1}) and thereafter decreased at 60 kg S ha^{-1}.

Saha *et al.*(1996) conducted a field trial in pre-kharif season of 1993-94 at Pundibari, India yellow sarson (*Brassica campestris*) was given 0, 2-5 or 5 kg borax applied, at soil, 66% soil + 33% foliar application and the residual effects were studied on summer mungbean. In both years, gleen gram seed yield was highest with a combination of 5 kg borax + 2 kg sodium molybdate. Soil application gave higher yields than foliar or soil + foliar application.

Das (1994) reported that Zn and B increased vegetative growth of groundnut. Mo increased nodule number $plant^{-1}$.

Singha *et al.* (1994) fertilized lentil cv. B-77 with 0.6 or 1.2 kg B ha^{-1} as borax 4.4 kg Zn ha^{-1} as Zn sulphate or in various combinations and observed that B + Zn produced the highest seed yield of (2.29 t ha^{-1}) as well as the highest net return.

Singh *et al.* (1993) carried out an experiment on mungbean and revealed that K (30,60 or 90 kg K_2O ha^{-1}) and Zn (5, 10 or 15 ppm) application increased the plant height, branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, pod length, 1000-seed weight, grain yield, stover yield, seed protein, N, P and K contents and increase the availability of N P K in soil, but decreased the Mg and Ca contents.

Dwivedi *et al.* (1990) conducted a experiment and observed that micronutrients (Cu, Zn, B and their mixture) either alone or in mixture significantly increased the yield of soybean.

Saxena S. C. (1990) conducted a laboratory experiment with chickpeas in salinized sand (EC.34 dSm^{-1}) treated with 0, 5 or 10 $\mu g\ g^{-1}$ Zn and reported that application of 5 $\mu g\ g^{-1}$ Zn increased the number of nodule.

Islam *et al.* (1989) stated that seed yield ranged from 554 kg ha^{-1} with dipping seeds in 0.1% ZnO solution to 781 kg ha^{-1} with dipping seed in 0.2% ZnO solution. Yield, plant height, branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, pod length, 1000-seed weight, gain yield and stover yield were significantly affected by Zn rate or application method.

Gangwar and Singh (1988) conducted an experiment using ZnO @ 0.10 and 0.20 $\mu g\ g^{-1}$ to study the effect of Zn on yield and quality of lentil. They reported that significantly higher protein content in seed was recorded in all the treatments of Zn application over control.

Pal (1986) noted that application of Zn, B and a mixture of 6 trace elements to peanut increased yield by 41.9, 34.3 and 80.5%, respectively.

Prasad and Ram (1982) reported that application of Zn at 5 to 10 kg ha^{-1} increased the yield and protein contents of mungbean.

2.3 Interaction effect of P and Zn on yield and yield attributing characters of mungbean

Singh and Humuman (2001) studied in an experiment on mungbean and revealed that maximum dry biomass $plant^{-1}$ (24-8 g $plant^{-1}$) was recorded from 60 kg K_2O ha^{-1}. Grain yield and stover yield was maximum when plants were treated with 30 kg K2O ha^{-1} and 30 mg kg^{-1} Zn (4.3 e $plant^{-1}$). Maximum P content in seeds and stover were recorded from 30 kg K_2O ha^{-1} and Zn 15 mg kg^{-1} (0.63%).

Singh *et al.* (1993) studied in an experiment on mungbean and revealed that maximum dry biomass $plant^{-1}$ (24.5 g $plant^{-1}$) was recorded from 60 kg P_2O_5 ha^{-1}. Grain yield was maximum when plants were treated with 30 kg P_2O_5 ha^{-1} and 30 mg kg^{-1} Zn (4.3 g $plant^{-1}$). Maximum P content were recorded from 30 kg P_2O_5 ha^{-1} and Zn 15mg kg^{-1} (0.63%).

Ahmed *et al.* (1986) studied that P-Zn interaction significantly increased plant height, number of pods $plant^{-1}$, grain and straw yields of mungbean, phosphorus contents decreased on application of Zn and vice-versa. They further stated that P application increased protein but Zn application increased protein only at low doses.

Prasad and Ram (1986) stated that two levels of applied Zn (2.5 and 5.0 μg g^{-1}) increased the concentration of P in mungbean and grain yield.

Patil and Somawanshi (1982) reported that application of P and Zn significantly increased the grain and straw yields of greengram. Plants supplied with P alone contained significantly lower Zn than control plants, whereas increasing incorporation of Zn with P substantially increased Zn concentration but reduced P concentration.

Singh and Bajpai (1982) conducted an experiment in Rajastan with 4 levels of P (0, 20, 40 and 60 kg P ha^{-1}) and three levels of Zn(0, 5 and 10 kg $ZnSO_4$ ha^{-1}). They found that P and

Zn significantly improved the branches and number of pods $plant^{-1}$, grain and straw yields of chickpea.

CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter includes a brief description of the experimental soil, mungbean variety, land preparation, experimental design, treatments, cultural operations, collection of soil and plant samples etc. and analytical methods followed in the experiment to study the effect of phosphorus and zinc on the yield of mungbean.

3.1 Experimental site

The research work relating to the study of the effect of phosphorus and zinc on the yield of mungbean was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during the *Kharif* season of 2012. The map (Appendix i) shows the specific location of experimental site.

3.2 Description of 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 3. 1. Morphological Characteristics of experimental field

Morphological Features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka
AEZ No. and name	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 3.2 Initial physical and chemical properties of the experimental soil

Soil properties	**Value**
A. Physical Properties	
1. Particle size analysis of soil	
% Sand	33.21
% Silt	40.51
%Clay	26.28
2. Soil texture	Loam
B. Chemical Properties	
1. Soil pH	5.71
2. Organic carbon (%)	0.68
3. Organic matter (%)	1.17
4. Total N (%)	0.0533
5.C:N ratio	9.75 : 1
6. Available P (mg kg^{-1})	21.54
7. Available K (meq/100g soil)	0.145
8. Available S (mg kg^{-1})	15.08
9. Available Zn (mg kg^{-1})	1.822

3.3 Description of the mungbean variety

BARIMUNG-6, a high yielding variety of mungbean was released by Bangladesh Agricultural Research Institute, Joydebpur, Gazipur in 2003. It is photo insensitive, semi synchronous maturity, short lifespan (60 to 65 days)and bold seeded crop. Its yield potentiality is about 2 t ha^{-1}. This variety is resistant to yellow mosaic virus diseases, insects and pest attack.

3.4 Climate

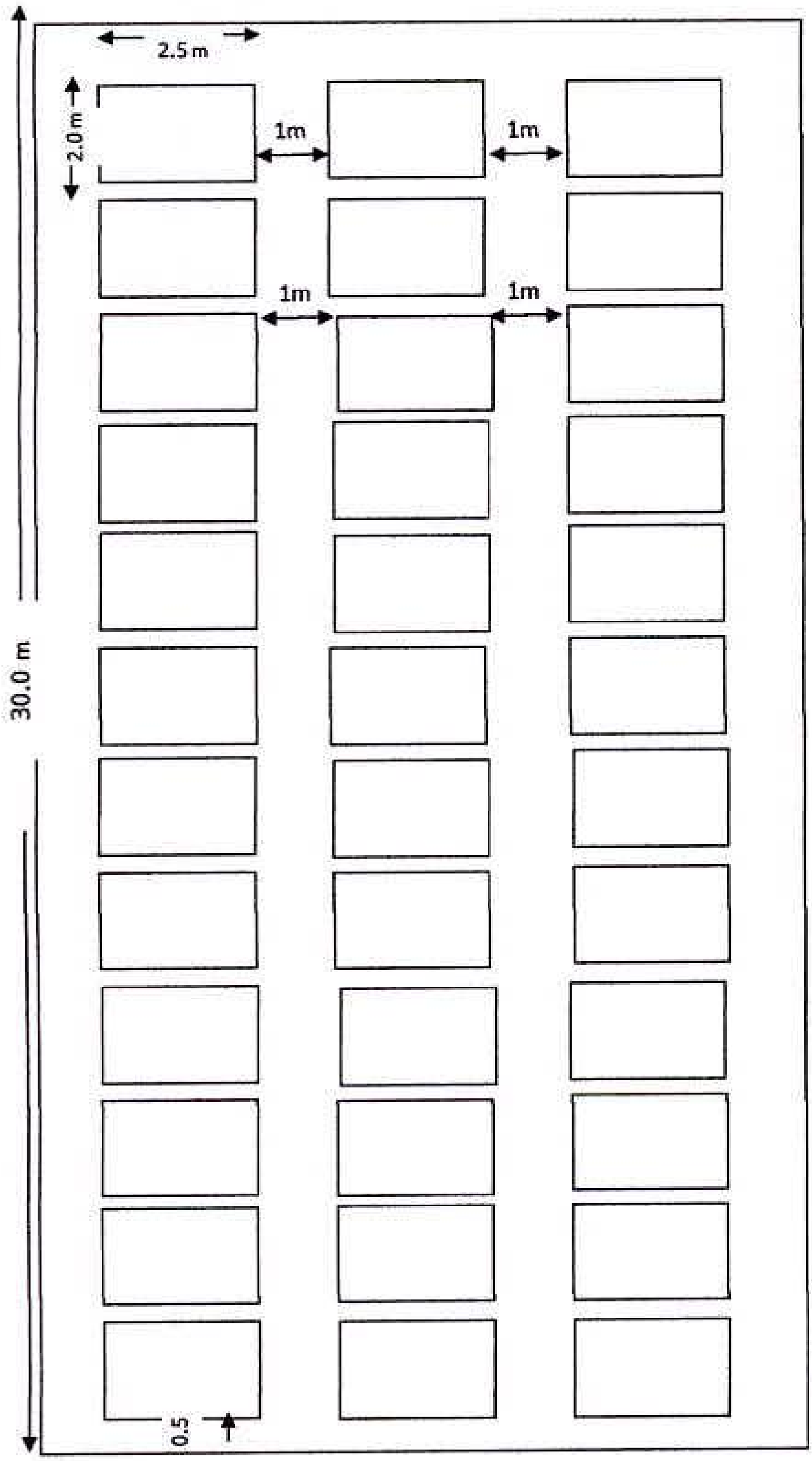
The experimental area has sub-tropical climate characterized by heavy rainfall during May to September and low to no rainfall during rest of the year. The annual precipitation of the site is 1974 mm and potential evapotranspiration is 1197 mm, the average maximum temperature is 30.34^{0}C and average minimum temperature is 21.21^{0}C. The average mean temperature is 25.17^{0}C. The experiment was carried out during kharif season, 2012. The monthly average temperature, humidity and rainfall of the site during the experimental period are enclosed in appendix ii.

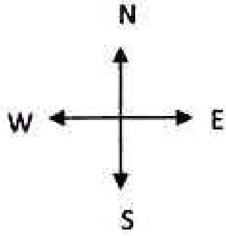
3.5 Preparation of the field

The plot selected for the experiment was opened by power tiller driven rotovator on the 10th April 2012, 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.

3.6 Layout of the experiment

The experiment was laid out in a Randomized Complete Block Design with three replications. The total number of plots was 36, each measuring 2.5 m x 2 m (5 m^2). The treatment combination of the experiment was assigned at random into 12 plots of each at 3 replications. The distance maintained between two plots was 50cm and between blocks was 100 cm.





Plot size: 2.5 m × 2.0 m

Plot spacing: 50 cm

Between replication: 1.0m

Factor A: Phosphorus (P)
1. P_0 = 0 kg P ha^{-1} (Control)
2. P_1 = 15 kg P ha^{-1}
3. P_2 = 20 kg P ha^{-1}
4. P_3 = 25 kg P ha^{-1}

Factor B: Zinc (Zn)
1. Zn_0 = 0 kg Zn ha^{-1} (Control)
2. Zn_1 = 1.5 kg Zn ha^{-1}
3. Zn_2 = 3 kg Zn ha^{-1}

Figure 3.1. Layout of the experimental plot

3.7 Treatments

The experiment consists of 2 Factors i.e. phosphorus and zinc fertilizers. Details of factors and their combinations are presented below:

Factor A: Phosphorus (P)	Factor B: Zinc (Zn)
1. P_0 = 0 kg P ha^{-1} (Control) 2. P_1 = 15 kg P ha^{-1} 3. P_2 = 20 kg P ha^{-1} 4. P_3 = 25 kg P ha^{-1}	1. Zn_0 = 0 kg Zn ha^{-1}(Control) 2. Zn_1 = 1.5 kg Zn ha^{-1} 3. Zn_2 = 3 kg Zn ha^{-1}

Treatment Combinations:

1. P_0 Zn_0 = Control (No P and Zn)
2. P_0 Zn_1 = 0 kg P ha^{-1}+ 1.5 kg Zn ha^{-1}
3. P_0 Zn_2 = 0 kg P ha^{-1}+ 3 kg Zn ha^{-1}
4. P_1 Zn_0 = 15 kg P ha^{-1}+ 0 kg Zn ha^{-1}
5. P_1 Zn_1 = 15 kg P ha^{-1}+ 1.5 kg Zn ha^{-1}
6. P_1 Zn_2 = 15 kg P ha^{-1}+ 3 kg Zn ha^{-1}
7. P_2 Zn_0 = 20 kg P ha^{-1}+ 0 kg Zn ha^{-1}
8. P_2 Zn_1 = 20 kg P ha^{-1}+ 1.5 kg Zn ha^{-1}
9. P_2 Zn_2 = 20 kg P ha^{-1}+ 3 kg Zn ha^{-1}
10. P_3 Zn_0 = 25 kg P ha^{-1}+ 0 kg Zn ha^{-1}
11. P_3 Zn_1 = 25 kg P ha^{-1}+ 1.5 kg Zn ha^{-1}
12. P_3 Zn_2 = 25 kg P ha^{-1} + 3 kg Zn ha^{-1}

3.8 Application of fertilizers

Recommended blanket doses of N, K and Sulphur (20 kg N from urea, 30 kg K from MOP and 15 kg S ha^{-1} from Gypsum, respectively) were applied. The whole amounts of Urea, MOP and Gypsum fertilizer were applied as basal dose during final land preparation. The required amounts of P (from TSP) and Zn (from Zinc oxide) were applied at a time as per treatment combination after field layout of the experiment and were mixed properly through hand spading.

3.9 Seed sowing

Mungbean seeds were sown on 18th April 2012 in lines following the recommended 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 10 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 of seeds.

3.11 Harvesting

The crop was harvested at maturity on 18th June 2012. 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 on 24^{th} June 2012. 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

Ten randomly selected plants were collected from every individual plot for laboratory analysis at maturity stage of the crop. The samples were collected by avoiding the border area 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 harvesting stage. 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 branches plant^{-1}
3. Number of pods plant^{-1}
4. Pod length (cm)
5. Number of seeds pod^{-1}
6. Weight of 1000-seeds (g)
7. Grain yield (t ha^{-1})
8. Stover yield (t ha^{-1})
9. N, P, K, S and Zn content of plant
10. N P, K, S and Zn contents in seed
11. N, P, K, S and Zn contents in postharvest soil

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 branches plant^{-1}

Number of branches were counted from 10 randomly selected plants at maturity stage from each plot and averaged.

3.13.3 Number of pods plant^{-1}

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

3.13.4 Pod length (cm)

Pod length was measured at maturity stage for l0 pods randomly collected from each plot and averaged.

3.13.5 Number of seeds pod^{-1}

The number of seeds from l0 randomly selected pods from each plot were counted and averaged.

3.13.6 Thousand seed weight

Thousand seeds of mungbean were counted randomly and then weighed plot wise.

3.13.7 Seed yield

Seeds 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.

3.13.8 Stover yield

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

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 $HClO_4$ mixture for the determination of P, K, S and Zn.

3.14.1. a 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-Kjeldahl 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.

3.14.1. b Phosphorous

Phosphorous in the digest was determined by ascorbic acid blue color method with the help of a Spectrophotometer.

3.14.1.c Potassium

The exchangeable potassium content in plant samples were determined by flame photometer.

3.14.1.d Sulphur

Sulphur content in the digests were determined by turbid metric method using a Spectrophotometer.

3.14.1. e Zinc

The zinc content in the digests were determined directly by Atomic Absorption Spectrophotometer.

3.14.2 Soil sample analysis

3.14.2. a 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.

3.14.2. b Available Phosphorous

Available phosphorous was extracted from the soil by Bray-1 method. Phosphorous in the extract was determined by ascorbic acid blue color method with the help of a Spectrophotometer.

3.14.2. c Available Potassium

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

3.14.2.d Available sulphur

Available sulphur was extracted from the soil with Ca $(H_2PO_4)_2.H_2O$. Sulphur in the extract was determined by the turbidimetric method using a Spectrophotometer. The intensity of turbid was measured by spectrophotometer at 420 nm wavelength.

3.14.2.e. Zinc

Zinc content in the digests were extracted by 0.05N HCI solution and determined directly by Atomic Absorption Spectrophotometer.

3.14.3 Statistical analysis

The data were analyzed statistically by 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 the 'F' (variance ratio) test. The significance of the differences among the pairs of treatment means was estimated by the Least Significant Difference (LSD) test at 5% and 1% level of probability.

CHAPTER 4

RESULTS DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

In this section, all the findings from the experiment are presented. The results on different yield attributes, yield and nutrient concentrations in the plants and grains and availability of different nutrients in the soil after harvest of mungbean are presented in this chapter.

4.1 Effect of phosphorus on growth and yield of Mungbean

4.1.1 Effect of phosphorus on plant height, number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1}

The effects of phosphorus on the plant height, number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1} of mungbean are presented in (Table 4.1). Significant variation was observed on growth parameters when the plot was fertilized with different doses of phosphorus. Plant height, number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1} was increased with P levels from 0-20 kg ha^{-1} then declined. The highest plant height (51.09 cm), number of branches plant^{-1} (2.62), number of pods plant^{-1} (19.36) and number of seeds pod^{-1} (11.73) were obtained with 20 kg P ha^{-1}. On the other hand, the lowest plant height (42.24 cm), number of branches plant^{-1} (1.65), number of pods plant^{-1} (14.70) and number of seeds pod^{-1} (9.40) were observed in the P_0 treatment where no phosphorus was applied. The result is agreed with the findings of Kumar *et al.* (2012) who observed significant increase in growth, plant height, yield attributes like number of nodules plant^{-1}, dry weight of nodules, number of pods plant^{-1}, number of grains pod^{-1}, 1000-seed weight, seed yield, and stover yield of mungbean due to the application of increasing level of P fertilizer.

Table 4.1 Effect of phosphorus on growth parameters

Levels of P (kg ha^{-1})	Plant height (cm)	No. of branches $plant^{-1}$	No. of pods $plant^{-1}$	No. of seeds pod^{-1}
P_0	42.24 d	1.65 d	14.70 c	9.40 c
P_1	46.50 c	2.21 c	16.90 b	10.48 b
P_2	51.09 a	2.62 a	19.36 a	11.73 a
P_3	49.89 b	2.44 b	17.63 b	10.80 b
LSD	1.114	0.0927	0.9975	0.696
Significance level	5%	5%	5%	5%

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

4.1.2 Effect of phosphorus on pod length and weight of 1000-seeds

Pod length and weight of 1000-seeds as affected by different doses of phosphorus showed a statistically significant variation (Table 4.2). Among the different doses of P the highest pod length (9.46cm) and weight of 1000-seeds (43.43 g) was observed in P_2 (20 kg P ha^{-1}). The lowest pod length (6.79 cm) and weight of 1000-seeds (40.00 g) were recorded in the P_0 treatment where no P was applied. The result is agreed with the findings of Kumar *et al.* (2012) who observed significant increase in pod length, number of grains pod^{-1}, weight of 1000-seeds, seed yield, and stover yield of mungbean due to the application of increasing level of P fertilizer.

Table 4.2 Effect of phosphorus on yield and yield contributing characters

Levels of P (kg ha^{-1})	Pod length (cm)	Weight of 1000-seeds (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
P_0	6.79 d	40.00 c	1.11 c	2.06 c
P_1	7.59 c	41.89 b	1.29 b	2.23 b
P_2	9.46 a	43.43 a	1.50 a	2.46 a
P_3	8.84 b	42.97 ab	1.50 a	2.47 a
LSD	0.54	1.18	0.075	0.075
Significance level	5%	5%	5%	5%

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

4.1.3 Effect of P on seed yield and stover yield

Significant variation was observed on the seed yield and stover yield of mungbean when different doses of P were applied (Table 4.2). The highest seed yield (1.50 t ha^{-1}) was recorded in P_2 (20 kg P ha^{-1}) but the highest stover yield (2.47 t ha^{-1}) was recorded in P_3 (30 kg P ha^{-1}) treatment. The lowest seed yield (1.11 t ha^{-1}) and stover yield (2.06 t ha^{-1}) of mungbean was recorded in the P_0 treatment where no P was applied. There was no significant difference between P_2 and P_3 treatments. The result is agreed with the findings of Oad *et al.* (2003) who observed significant increase in grain yield, and straw yield of mungbean due to the application of 100 kg P fertilizer.

4.2 Effect of zinc on growth and yield of Mungbean

4.2.1 Effect of Zinc on plant height, number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1}

Mungbean plants showed significant variation in respect of plant height, number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1} when zinc in different doses were applied (Table 4.3). Among the different fertilizer doses, Zn_2 (3 kg Zn ha^{-1}) showed the highest plant height (48.26 cm), number of branches $plant^{-1}$ (2.41), number of pods $plant^{-1}$ (18.30) and number of seeds pod^{-1} (11.1). On the contrary, the lowest plant height (46.56 cm), number of branches $plant^{-1}$ (2.04), number of pods $plant^{-1}$ (16.12) and number of seeds pod^{-1} (9.94) was observed in the treatment where no sulphur was applied. Islam *et al.* (1989) found significant increase in plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$ and number of seeds pod^{-1} of mungbean due to the application of 0.1% - 0.2% ZnO solution.

Table 4.3 Effect of Zinc on growth parameters

Levels of Zn (kg ha^{-1})	Plant height (cm)	No. of branches $plant^{-1}$	No. of pods $plant^{-1}$	No. of seeds pod^{-1}
Zn_0	46.56 b	2.04 c	16.12 b	9.94 b
Zn_1	47.46 ab	2.24 b	17.02 b	10.7 a
Zn_2	48.26 a	2.41 a	18.30 a	11.1 a
LSD	1.11	0.09	0.99	0.69
Significance level	5%	5%	5%	5%

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

4.2.2 Effects of zinc on Pod length and weight of 1000-seeds

Application of Zn at different doses showed a significant variation on the pod length and weight of 1000-seeds of mungbean (Table 4.4). Among the different Zn doses, Zn_2 (3 kg Zn ha^{-1}) showed the highest pod length (8.78 cm) and weight of 1000-seeds (43.23 g). On the other hand, the lowest pod length (7.50 cm) and weight of 1000-seeds (40.91 g) was recorded with Zn_0 treatment where no Zn was applied. Islam *et al.* (1989) found significant increase in pod length of mungbean due to the application of 0.1% - 0.2% ZnO solution.

Table 4.4 Effects of zinc on yield and yield contributing characters

Levels of Zn (kg ha^{-1})	Pod length (cm)	Weight of 1000-seeds (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Zn_0	7.50 c	40.91 b	1.27 c	2.21 b
Zn_1	8.23 b	42.06 ab	1.34 b	2.28 b
Zn_2	8.78 a	43.23 a	1.45 a	2.42 a
LSD	0.54	1.18	0.07	0.07
Significance level	5%	5%	5%	5%

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

4.2.3 Effect of Zn on seed yield and stover yield

Different doses of Zn showed significant variations in respect of seed yield and stover yield of mungbean (Table 4.4). Among the different doses of Zn fertilizer, Zn_2 (3 kg Zn ha^{-1}) produced the highest seed yield (1.451 t ha^{-1}) and stover yield (2.423 t ha^{-1}) of mungbean. On the contrary, the lowest seed yield (1.27 t ha^{-1}) and stover yield (2.218 t ha^{-1}) of mungbean were found in Zn_0 where no Zn fertilizer was applied. In case of stover yield Zn_0 and Zn_1 were statistically similar.

4.3 Interaction effects of phosphorus and zinc on growth and yield of Mungbean

4.3.1 Interaction effects of phosphorus and zinc on plant height, number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1}

Combined application of different doses of phosphorus and zinc showed significant effect on the plant height, number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1} of mungbean (Table 4.5). The lowest plant height (41.23 cm), number of branches plant^{-1} (1.54), number of pods plant^{-1} (14.05) and number of seeds pod^{-1} (8.71) were observed in the treatment combination of P_0Zn_0 (No phosphorus and No zinc).

Table 4.5 Interaction effect of phosphorus and zinc on growth parameters

Interaction of P and Zn	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}
P_0Zn_0	41.23 h	1.54 i	14.05 g	8.71 f
P_0Zn_1	42.14 h	1.59 i	14.64 fg	9.29 ef
P_0Zn_2	43.34 g	1.83 h	15.41 f	10.19 cd
P_1Zn_0	45.13 f	2.04 g	15.57 f	9.94 de
P_1Zn_1	46.26 e	2.24 f	16.62 e	10.66 b-d
P_1Zn_2	48.13 d	2.36 de	18.51 bc	10.82 bc
$P_2 Zn_0$	49.95 c	2.30 ef	17.84 cd	10.56 b-d
P_2Zn_1	51.27 ab	2.68 b	19.36 b	11.99 a
P_2Zn_2	52.05 a	2.87 a	20.86 a	12.65 a
P_3Zn_0	49.94 c	2.29 ef	17.01 de	10.57 bcd
P_3Zn_1	50.19 bc	2.44 d	17.46 cde	11.00 b
P_3Zn_2	49.53 c	2.59 c	18.42 bc	10.84 bc
LSD	1.11	0.09	0.99	0.69
Significance level	5%	5%	5%	5%

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

On the other hand the highest plant height (52.05 cm), number of branches plant^{-1} (2.87), number of pods plant^{-1} (20.86) and number of seeds pod^{-1} (12.65) were recorded with P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}) treatment combination. Ahmed *et al.* (1986) found significant increase in plant height, number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1} of mungbean due to the application of increasing level of P and Zn fertilizers.

4.3.2 Interaction effect of phosphorus and zinc on pod length and weight of 1000-seeds

Combined effects of P and Zn produced significant variation on pod length (Table 4.6) and weight of 1000-seeds (Table 4.6). The highest pod length (10.55 cm) and weight of 1000-seeds (45.11g) were recorded in P_2Zn_2 (20 kg P ha^{-1}+ 3 kg Zn ha^{-1}) treatment combination. On the other hand, the lowest pod length (6.42 cm) and weight of 1000-seeds (38.96g) were found in P_0Zn_0. Singh *et al.* (1993) found significant increase in pod length and weight of 1000-seeds of mungbean due to the application of increasing level of P fertilizer.

Table 4.6 Interaction effect of phosphorus and zinc on yield and yield contributing characters

Interaction of P and Zn	Pod length (cm)	Weight of 1000-seed (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
$P_0 Zn_0$	6.42 g	38.96 g	1.08 g	2.07 gh
$P_0 Zn_1$	6.86 fg	39.52 fg	1.12 g	2.00 h
$P_0 Zn_2$	7.11 f	41.51 de	1.15 fg	2.13 fg
$P_1 Zn_0$	7.26 f	40.67 ef	1.20 f	2.14 fg
$P_1 Zn_1$	7.27 f	41.88 c-e	1.29 e	2.17 f
$P_1 Zn_2$	8.26 e	43.12 bc	1.39 d	2.37 de
$P_2 Zn_0$	7.92 e	42.00 cd	1.38 d	2.30 e
$P_2 Zn_1$	9.91 b	43.16 bc	1.46 cd	2.42 cd
$P_2 Zn_2$	10.55 a	45.11 a	1.68 a	2.65 a
$P_3 Zn_0$	8.41 de	42.01 cd	1.41 d	2.42 cd
$P_3 Zn_1$	8.89 cd	43.69 b	1.52 bc	2.46 bc
$P_3 Zn_2$	9.24 c	43.20 bc	1.57 b	2.53 b
LSD	0.543	1.180	0.075	0.075
Significance level	5%	5%	5%	5%

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

4.3.3 Interaction effect of P and Zn on seed yield and stover yield

The combined effect of different doses of P and Z on the seed yield and stover yield of mungbean was statistically significant (Table 4.6). The highest seed yield (1.683 t ha^{-1}) and stover yield (2.657 t ha^{-1}) of mungbean were recorded with the treatment combination of P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}). On the other hand the lowest seed yield (1.08 t ha^{-1}) and stover yield (2.003 t ha^{-1}) of mungbean were found in P_0Zn_0 (No P and No Zn) and P_0Zn_1 (No P and 1.5 kg Zn) treatment combinations, respectively. Singh and Bajpai (1982) found that P and Zn significantly improved the grain as well as stover yields of chickpea.

4.4 Effects of phosphorus on N, P, K, S and Zn concentrations in mungbean stover

4.4.1 Effect of P on nitrogen and phosphorus concentrations in mungbean stover

Application of P showed significant variation in the nitrogen and phosphorus concentrations in mungbean stover (Table 4.7). The N and P concentrations in mungbean stover increased with increasing level of P up to 20 Kg P ha^{-1}. The highest concentrations of nitrogen (0.74%) and phosphorus (0.58%) in stover were recorded in P_1 (15 kg P ha^{-1}) and P_2 (20 kg P ha^{-1}) treatment, respectively. On the other hand, the lowest concentrations of nitrogen (0.63%) and phosphorus (0.40%) in stover were recorded in the P_0 treatment where no P was applied.

Table 4.7 Effect of phosphorus on N, P, K, S and Zn concentrations in mungbean stover

Levels of P (kg ha-1)	N %	P %	K %	S %	Zn %
P_0	0.63 c	0.40 c	0.81c	0.105	0.004
P_1	0.74 a	0.55 a	1.12 b	0.310	0.006
P_2	0.71 ab	0.58 a	1.40 a	0.123	0.007
P_3	0.68 bc	0.46 b	1.14 b	0.112	0.007
LSD	0.053	0.053	0.053	-	-
Significance level	5%	5%	5%	NS	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

NS: Non significant

4.4.2 Effect of P on potassium and sulphur concentrations in stover

A statistically significant variation was observed in potassium and sulphur concentrations in stover of mungbean with different doses of phosphorus (Table 4.7). The highest concentrations of potassium (1.40%) and sulphur (0.310 %) in stover were recorded in P_2 (20 kg P ha^{-1}) and P_1 (15 kg P ha^{-1}) treatment, respectively. On the other hand, the lowest concentrations of potassium (0.81%) and sulphur (0.105%) in stover were recorded in the P_0 treatment where no P was applied. But concentration of sulphur in stover is statistically non significant.

4.4.3 Effect of P on zinc concentration in mungbean stover

A statistically insignificant variation was observed in zinc concentration in stover of mungbean with different doses of P (Table 4.7). Among the different doses of P the highest zinc concentration in plant (0.007 %) was recorded in both of P_2 (20 kg P ha^{-1}) and

P_3 (25 kg P ha^{-1}) treatments. On the other hand, the lowest zinc concentration (0.004 %) was recorded in the P_0 treatment where no P was applied.

4.5 Effects of zinc on N, P, K, S and Zn concentrations in mungbean stover

4.5.1 Effect of Zn on nitrogen and phosphorus concentrations in mungbean stover

The effect of different doses of zinc showed statistically significant difference in nitrogen and phosphorus concentrations in mungbean stover (Table 4.8). The highest concentrations of nitrogen (0.75%) and phosphorus (0.53%) among the treatments of zinc were observed in Zn_2 (3 kg Zn ha^{-1}). The lowest concentrations of nitrogen (0.61%) and phosphorus (0.44%) were observed in Zn_0 (control condition) treatment. But there was no significant difference between Zn_1 and Zn_2 treatments for nitrogen and phosphorus concentrations in mungbean stover.

Table 4.8 Effect of zinc on N, P, K, S and Zn concentrations in mungbean stover

Levels of Zn (kg ha^{-1})	N (%)	P (%)	K (%)	S (%)	Zn (%)
Zn_0	0.61 b	0.44 b	1.04 c	0.094 b	0.006
Zn_1	0.70 a	0.52 a	1.13 b	0.119 ab	0.007
Zn_2	0.75 a	0.53 a	1.18 a	0.150 a	0.008
LSD	0.053	0.053	0.053	0.245	-
Significance level	5%	5%	5%	5%	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

NS: Non significant

4.5.2 Effect of Zn on potassium and sulphur concentrations in mungbean stover

The effect of different doses of Zn showed a statistically significant variation in the potassium and sulphur concentrations in mungbean stover (Table 4.8). The accumulation of K increased in a higher treand due to Zn application. The highest concentrations of potassium (1.18%) and sulphur (0.150 %) in stover were recorded in Zn_2 treatment. On the other hand, the lowest concentrations of potassium (1.04%) and sulphur (0.094%) in stover were recorded in the Zn_0 where no Zn was applied.

4.5.3 Effect of Zn on zinc concentration in mungbean stover

The effect of different doses of Zn showed a statistically insignificant variation in the zinc concentration in stover of mungbean (Table 4.8). The highest zinc concentration (0.008 %) in stover among different doses of Zn fertilizers was recorded with Zn_2. The lowest zinc concentration (0.006 %) was observed in the treatment Zn_0 where no Zn fertilizer was applied. Singh *et al.* (1997) found significant increase of zinc concentration in summer green gram due to the application of 5 kg Zn ha^{-1}.

4.6 Interaction effects of phosphorus and zinc on N, P, K, S and Zn concentrations in Mungbean stover

4.6.1 Interaction effect of P and Zn on nitrogen and phosphorus concentrations in mungbean stover

Significant effect of combined application of different doses of P and Zn on the nitrogen and phosphorus concentration was observed in the stover of mungbean (Table 4.9). The highest concentrations of nitrogen (0.82%) at P_1Zn_2 (15 kg P ha^{-1} + 3 kg Zn ha^{-1}) treatment and phosphorus (0.67%) at P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}) treatment were recorded in the stover. On the other hand, the lowest concentrations of nitrogen (0.52%) and phosphorus (0.35%) were found at P_0Zn_0 (No P + No Zn) treatment in stover. Prasad and Ram (1986) found that application of Zn (2.5 and 5.0 µg g^{-1}) increased the concentration of P in mungbean and grain yield.

Table 4.9 Interaction effects of phosphorus and zinc on N P K S and Zn concentrations in mungbean stover

Interaction of P and Zn	N %	P %	K %	S %	Zn %
P_0Zn_0	0.52 f	0.35 f	0.65 j	0.084 c	0.004
P_0Zn_1	0.60 e	0.42 e	0.86 i	0.118 a-c	0.006
P_0Zn_2	0.75 bc	0.44 de	0.91 i	0.141 a-c	0.006
P_1Zn_0	0.64 e	0.47 c-e	1.05 h	0.094 bc	0.006
P_1Zn_1	0.76 bc	0.57 b	1.06 gh	0.120 a-c	0.006
P_1Zn_2	0.82 a	0.61 b	1.25 d	0.149 ab	0.006
P_2 Zn_0	0.62 e	0.48 cd	1.34 c	0.095 bc	0.006
P_2Zn_1	0.71 cd	0.58 b	1.41 b	0.119 a-c	0.007
P_2Zn_2	0.80 ab	0.67 a	1.47 a	0.162 a	0.007
P_3Zn_0	0.66 de	0.45 de	1.13 ef	0.104 bc	0.007
P_3Zn_1	0.73 c	0.51 c	1.18 e	0.117 a-c	0.008
P_3Zn_2	0.64 e	0.42e	1.10 fg	0.137 a-c	0.007
LSD	-	0.053	0.053	0.245	-
Significance level	NS	5%	5%	5%	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

NS : Non significant

4.6.2 Interaction effect of P and Zn on potassium and sulphur concentrations in mungbean stover

Significant effect of combined application of different doses of P and Zn on the potassium concentration was observed in stover of mungbean (Table 4.9). The highest concentrations of potassium (1.47%) and sulphur (0.162%) were recorded at P_2Zn_2 (20 kg P ha^{-1} + 3 kg

Zn ha^{-1}) treatment in the stover. On the other hand, the lowest concentrations of potassium (0.65%) and sulphur (0.084%) were found at P_0Zn_0 (No P + No Zn) treatment in stover. Prasad and Ram (1986) found that application of Zn (2.5 and 5.0 µg g^{-1}) increased the concentration of P in mungbean and grain yield

4.6.3 Interaction effect of P and Zn on zinc concentrations in mungbean stover

Insignificant effect of combined application of different doses of P and Zn on the zinc concentration was observed in stover of mungbean (Table 4.9). The highest concentration of zinc (0.008 %) in the stover was recorded with the P_3Zn_1 (25 kg P ha^{-1} + 1.5 kg Zn ha^{-1}) treatment combination. On the other hand, the lowest zinc concentration (0.004 %) was found in P_0Zn_0 (No P + No Zn) treatment combination.

4.7 Effects of phosphorus on total N, P, K, S and Zn concentrations in Mungbean seed

4.7.1 Effect of P on nitrogen and phosphorus concentrations in mungbean seeds

Application of P showed significant variation in the nitrogen and phosphorus concentrations in mungbean seeds (Table 4.10). The highest concentrations of nitrogen (7.02%) and phosphorus (0.67%) in seeds were recorded in P_2 (20 kg P ha^{-1}) treatment. On the other hand, the lowest concentrations of nitrogen (6.41%) and phosphorus (0.47%) in seeds were recorded in the P_0 treatment where no P was applied.

Table 4.10 Effect of potassium on N, P, K, S and Zn concentrations in mungbean seeds

Levels of P (Kg ha^{-1})	N %	P %	K %	S %	Zn %
P_0	6.41 c	0.47 c	1.21 c	0.337 c	0.004
P_1	6.52 b	0.59 bc	1.62 b	0.470 ab	0.006
P_2	7.02 a	0.67 a	1.90 a	0.522 a	0.007
P_3	6.50 bc	0.53 b	1.87 a	0.432 b	0.006
LSD	0.092	0.053	0.0535	0.0535	-
Significance level	5%	5%	5%	5%	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

NS: Non significant

4.7.2 Effect of P on phosphorus and sulphur concentrations in seeds

A statistically significant variation was observed in potassium and sulphur concentrations in seeds of mungbean with different doses of P (Table 4.10). The highest concentration of potassium (1.90%) and sulphur (0.522 %) in stover was recorded in P_2 (20 kg P ha^{-1}) treatment. On the other hand, the lowest concentration of potassium (1.21%) and sulphur (0.337%) in seed was recorded in the P_0 treatment where no P was applied. But concentrations of potassium at P_2 (20 kg P ha^{-1}) and P_3 (25 kg P ha^{-1}) treatments in mungbean seed was statistically identical. Nita *et al.* (2002) found significant increase in potassium concentration in seed of mungbean due to the application of 0, 20 and 40 kg P ha^{-1}.

4.7.3 Effect of P on zinc concentrations in mungbean seeds

Different doses of phosphorus did not influence zinc concentration in seeds (Table 4.10). However, the highest zinc concentration in seeds (0.007 %) was recorded in P_2 (20 kg P ha^{-1}) treatment. The lowest zinc concentration in seeds (0.004 %) was recorded in the P_0 treatment where no K was applied.

4.8 Effects of zinc on N, P, K, S and Zn concentrations in Mungbean seeds

4.8.1 Effect of Zn on nitrogen and phosphorus concentrations in mungbean seeds

The effect of different doses of zinc showed statistically significant differences in nitrogen concentration of mungbean seeds (Table 4.11). The highest concentrations of nitrogen (6.90%) and phosphorus (0.66%) among the treatments of zinc were observed in Zn_2 (3 kg Zn ha^{-1}). The lowest concentrations of nitrogen (6.32%) and phosphorus (0.48%) were observed in Zn_0 (control condition) treatment. Prasad and Ram (1986) found that application of Zn (2.5 and 5.0 µg g^{-1}) increased the concentration of P in mungbean and grain yield.

Table 4.11 Effect of zinc on N P K S and Zn concentrations in mungbean seeds

Levels of Zn (Kg ha^{-1})	N %	P %	K %	S %	Zn %
Zn_0	6.32 c	0.48 c	1.53 b	0.346 c	0.006
Zn_1	6.62 b	0.56 b	1.71 a	0.456 b	0.007
Zn_2	6.90 a	0.66 a	1.71 a	0.518 a	0.008
LSD	0.092	0.053	0.053	0.0535	-
Significance level	5%	5%	5%	5%	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

NS : Non significant

4.8.2 Effect of Zn on potassium and sulphur concentrations in mungbean seed

The effect of different doses of Zn showed a statistically significant variation in the potassium and sulphur concentrations in mungbean seed (Table 4.11). The accumulation of K increased in higher level due to Zn application. The highest concentration of potassium (1.71%) was found in Zn_1 and Zn_2 and sulphur (0.518 %) in seed were recorded in Zn_2 (3 kg Zn ha^{-1}) treatment. On the other hand, the lowest concentration of potassium (1.53%) and sulphur (0.346%) in seed were recorded in the Zn_0 treatment where no Zn was applied. Singh *et al.* (1993) found significant increase of potassium concentration in mungbean due to the application of Zn (5, 10 and 15 ppm). Application of Zn increased sulphur concentration in summer green gram was observed by Singh *et al.* (1997).

4.8.3 Effect of Zn on zinc concentrations in mungbean seed

Zinc did not show significant increase in Zn concentration in mungbean seeds (Table 4.11). The highest zinc concentration in seed (0.008 %) was recorded with Zn_2 (3 kg Zn ha^{-1}) and the lowest (0.006 %) was observed in Zn_0 treatment where no Zn was applied.

4.9 Interaction of phosphorus and zinc on N, P, K, S and Zn concentration in Mungbean seeds

4.9.1 Interaction effect of P and Zn on nitrogen and phosphorus concentrations in mungbean seeds

Significant effects of combined application of different doses of P and Zn on the nitrogen and phosphorus concentration were observed in the seed of mungbean (Table 4.12). The highest concentration of nitrogen (7.46%) and phosphorus (0.69%) were recorded in the seeds of mungbean at P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}) treatment combination. On the other hand, the lowest concentration of nitrogen (5.74%) and phosphorus (0.42%) were found in seeds of mungbean at P_0Zn_0 (No P + No Zn) treatment. Singh *et al.* (1993) found significant increase of nitrogen concentration in mungbean due to the application of increasing level of P fertilizer.

Table 4.12 Interaction effects of phosphorus and zinc on N P K S and Zn concentrations in mungbean seeds

Interaction of P and Zn	N %	P %	K %	S %	Zn %
P_0Zn_0	5.74 h	0.42 f	1.16 h	0.246 f	0.004
P_0Zn_1	6.79 cd	0.47d-f	1.24 g	0.340e	0.005
P_0Zn_2	6.97 b	0.53 b-d	1.24 g	0.426 cd	0.005
P_1Zn_0	6.22 f	0.49 c-e	1.46 f	0.390 de	0.006
P_1Zn_1	6.28 f	0.52 b-d	1.62 e	0.463 c	0.006
P_1Zn_2	7.05 b	0.53 bc	1.77 d	0.556 b	0.007
P_2 Zn_0	6.75 d	0.51 cd	1.57 e	0.356 e	0.007
P_2Zn_1	6.85 c	0.63 b	1.91 c	0.560 b	0.007
P_2Zn_2	7.46 a	0.69a	2.21 a	0.650 a	0.008
P_3Zn_0	6.59 e	0.49c-e	1.91 c	0.393 de	0.007
P_3Zn_1	6.55 e	0.61 b	2.07 b	0.463 c	0.006
P_3Zn_2	6.10 g	0.44 ef	1.62 e	0.440 cd	0.005
LSD	0.0927	0.053	0.0535	0.0535	-
Significance level	5%	5%	5%	5%	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

NS: Non significant

4.9.2 Interaction effect of P and Zn on potassium and sulphur concentrations in mungbean seeds

Significant effects of combined application of different doses of P and Zn on the potassium and sulphur concentrations were observed in seeds of mungbean (Table 4.12). The highest concentration of potassium (2.21%) and sulphur (0.65%) were recorded in seeds at P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}) treatment combination. On the other hand, the lowest concentration of potassium (1.16%) and sulphur (0.246%) were found in seeds at P_0Zn_0 (No P + No Zn) treatment combination. Singh *et al.* (1993) found significant increase of potassium concentration in mungbean due to the application of P and Zn.

4.9.3 Interaction effect of K and Zn on zinc concentration in mungbean seeds

There was no significant effect of combined application of P and Zn on the zinc concentration in mungbean seeds (Table 4.12). The highest concentration of zinc in the seeds (0.008 %) was recorded with the P_2Zn_2 (20 kg P ha^{-1}+ 3 kg Zn ha^{-1}) treatment combination which may be due to the higher supply and subsequent assimilation of this element in the seeds. It was observed that the lowest zinc concentration (0.004 %) in seeds was in P_0Zn_0 (No P + No Zn) treatment combination.

4.10 Effect of phosphorus on nutrient status of the post harvest soil of mungbean field

4.10.1 Effect of phosphorus on available nitrogen and phosphorus contents in the post harvest soil of mungbean field

A statistically insignificant variation was observed in available nitrogen content in post harvest soil of mungbean field with different doses of P (Table 4.13). But there was a significant variation in available phosphorus content at different doses of P. The highest content of available phosphorus(19.89 ppm) in soil was recorded in P_2 (20 kg P ha^{-1}). The lowest available phosphorus content (16.94 ppm) in soil was found in P_0 treatment where no P was applied.

4.10.2 Effect of phosphorus on available potassium and sulphur contents in the post harvest soil of mungbean field

A statistically significant variation was observed in available potassium and sulphur contents in the post harvest soil of mungbean with different doses of P (Table 4.13). The highest content of available potassium (67.76 ppm) and sulphur (23.52 ppm) in soil were recorded in P_2 (20 kg P ha^{-1}) and P_3 (25 kg P ha^{-1}) treatments, respectivelly. On the other hand the lowest content of available potassium (46.47 ppm) and sulphur (19.38 ppm) in soil were recorded in P_0 treatment.

Table 4.13 Effect of phosphorus on available N, available P, available K, available S and available Zn contents in the post harvest soil of mungbean field

Levels of P (Kg ha^{-1})	N (%)	Available P (ppm)	Available K (ppm)	Available S (ppm)	Available Zn (ppm)
P_0	0.0793	16.94 c	46.47d	19.38d	0.53c
P_1	0.0843	17.93 b	52.74c	20.39 c	0.74b
P_2	0.0944	19.89 a	67.76 a	23.17 b	1.07a
P_3	0.0795	19.27 a	56.29b	23.52 a	1.06a
LSD	-	0.6752	1.692	0.0535	0.031
Significance level	NS	5%	5%	5%	5%

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

NS : Non significant

4.10.3 Effect of phosphorus on available zinc content in the post harvest soil of mungbean field

A statistically significant variation was observed in available zinc content in the post harvest soil of mungbean with different doses of P application (Table 4.13). Considering the different doses of P, the highest available zinc content in soil (1.07 ppm) was recorded in P_2 (20 kg P ha^{-1}) treatment. The lowest available zinc content in soil (0.53 ppm) was recorded in treatment with no P application. But treatment P_2 and was statistically similar.

4.11 Effect of zinc on the nutrient status of the post harvest soil of mungbean field

4.11.1 Effect of zinc on nitrogen and phosphorus content in the post harvest soil of mungbean field

The effect of different doses of zinc did not show significant variation in the available nitrogen content in post harvest soil (Table 4.14). But in case of available phosphorus content, it showed significant variation among the treatments. The highest available phosphorus content (20.70 ppm) in soil showed in Zn_2 (1.5 kg Zn ha^{-1}) treatment. The lowest available phosphorus content (14.72 ppm) in soil was observed in Zn_0 treatment where no Zn was applied.

4.11.2 Effect of zinc on available potassium and sulphur contents in the post harvest soil of mungbean field

The effect of different doses of zinc fertilizer produced significant differences in the available potassium and sulphur contents in soil of mungbean field (Table 4.14). Among the different doses of Zn fertilizer, Zn_1 (1.5 kg Zn ha^{-1}) gave the highest available potassium content (56.48 ppm) and Zn_2 (3 kg Zn ha^{-1}) gave the highest available sulphur content (23.55 ppm) in soil. The lowest content of available potassium (53.33 ppm) and sulphur (20.21 ppm) in soil was observed in the Zn_0 treatment where no Zn fertilizer was applied.

Table 4.14 Effect of zinc on available N, available P, available K, available S and available Zn contents of the post harvest soil of mungbean field

Levels of Zn (Kg ha^{-1})	Available N (%)	Available P (ppm)	Available K (ppm)	Available S (ppm)	Available Zn (ppm)
Zn_0	0.079	14.72 b	53.33 b	20.21 c	0.43c
Zn_1	0.087	20.10 a	56.48 a	21.15 b	0.67b
Zn_2	0.086	20.70 a	56.43 a	23.55 a	1.01a
LSD	-	0.67	1.69	0.053	0.023
Significance level	NS	5%	5%	5%	5%

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

NS : Non significant

4.11.3 Effect of zinc on available zinc content in the post harvest soil of mungbean field

The effect of different doses of zinc fertilizer showed significant variation in the zinc content in postharvest soil of mungbean field (Table 4.14). Among the different treatments of fertilizer doses, Zn_2 (3 kg Zn ha^{-1}) showed the highest zinc content (1.01 ppm) in soil, which was statistically different from other treatments. The lowest zinc content (0.43 ppm) in soil was observed in the treatment Zn_0 where no Zn was applied.

4.12 Interaction effects of phosphorus and zinc on nutrient status of the post harvest soil of mungbean field

4.12.1 Interaction effect of phosphorus and zinc on nitrogen and phosphorus contents in the post harvest soil of mungbean field

There was no significant effect on soil nitrogen was observed in postharvest soil due to combined application of P and Zn (Table 4.15). But there was a significant effect on available phosphorus content in postharvest soil due to combined application of P and Zn fertilizers.

Table 4.15 Interaction effects of phosphorus and zinc on total N, available P, available K, available S and available Zn contents in the post harvest soil of mungbean field

Interaction of P and Zn	Total N (%)	Available Phosphorus (ppm)	Available K (ppm)	Available S (ppm)	Available Zn (ppm)
P_0Zn_0	0.0735	12.25 j	41.11 i	17.27 g	0.42 f
P_0Zn_1	0.0786	18.57 f	49.04 h	19.15 f	0.56 e
P_0Zn_2	0.0856	19.93 de	49.21 h	21.71 d	0.61 de
P_1Zn_0	0.0786	13.80 i	51.53 g	19.16 f	1.16 ab
P_1Zn_1	0.0856	19.45 e	52.80 fg	20.27 e	0.46 ef
P_1Zn_2	0.0885	20.55 cd	53.90 f	21.74 d	0.68 f
P_2 Zn_0	0.0820	15.80 h	64.36 c	20.28 e	1.04 c
P_2Zn_1	0.0940	21.36 b	67.36 b	22.07 d	1.17 ab
P_2Zn_2	0.1071	22.33 a	71.51 a	27.19 a	1.21 a
P_3Zn_0	0.0846	16.97 g	61.08 d	23.75 b	0.86 d
P_3Zn_1	0.0907	21.03 bc	56.74 e	23.07 c	1.06 bc
P_3Zn_2	0.0633	19.81 e	51.04 g	23.65 b	1.15 b
LSD	-	0.6752	1.692	0.4216	0.162
Significance level	NS	5%	5%	5%	5%

The highest available phosphorus content (22.33 ppm) was recorded in the treatment combination with P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}). The lowest available phosphorus content (12.25 ppm) was recorded in the treatment combination with P_0Zn_0 (0 kg P ha^{-1} + 0 kg Zn ha^{-1})

4.12.2 Interaction effect of phosphorus and zinc on available potassium and sulphur contents of the post harvest soil of mungbean field

Significant effect of combined application of different doses of P and Zn on the potassium and sulphur concentration was observed in soil of mungbean field (Table 4.15). The highest content of available potassium (71.51 ppm) and sulphur (27.19 ppm) were recorded in P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}) treatment combination. On the other hand, the lowest content of available potassium (41.11 ppm) and sulphur (17.27 ppm) in the post harvest soil were found in P_0Zn_0 (control condition) treatment.

4.12.3 Interaction effect of phosphorus and zinc on available zinc content of the post harvest soil of mungbean field

Significant effect of combined application of different doses of P and Zn on the available zinc content was observed in soil of mungbean field (Table 4.15). The highest zinc content (1.21 ppm) was recorded in the treatment combination of P_2Zn_2 (20 kg P ha^{-1}+ 3 kg Zn ha^{-1}). The lowest available zinc content (0. 42 ppm) in post harvest soil sample was found in P_0Zn_0 treatment combination.

CHAPTER 5

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

This experiment was conducted at the Sher-e-Bangla Agricultural University Farm Dhaka 1207, (Tejgaon series under AEZ No.28) from April-June of 2012, to study the "Effect of Phosphorus and Zinc on the growth, yield and yield contributing characters of Mungbean (BARI Mung-6)". The soil was silty clay loam in texture having pH 5.71 and organic carbon content of 0.68%. Four levels of phosphorus (0, 15, 20 and 25 kg P ha^{-1}) and three levels of zinc (0, 1.5 and 3.0 kg Zn ha^{-1}) were used in the study. Levels of these two nutrient elements make 12 treatment combinations. The experiment was carried out in Randomized Complete Block Design (RCBD) with three replications.

Recommended blanket doses of N, K and Sulphur (20 kg N from urea, 30 kg K from MOP and 15 kg S ha^{-1} from Gypsum, respectively) were applied. The whole amounts of Urea, MOP and Gypsum fertilizer were applied as basal dose during final land preparation. The required amounts of P (from TSP) and Zn (from Zinc oxide) were applied at a time as per treatment combination after field layout of the experiment and were mixed properly through hand spading.

Mungbean seeds were sown on 18^{th} April 2012 and the crop was harvested on 18^{th} June 2012. The data were collected plot wise for plant height (cm), number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, pod length (cm), weight of 1000-seeds (g), seed yield (t ha^{-1}) and stover yield (t ha^{-1}) . The plot wise post harvest soil samples from 0-15 cm depth were collected and analyzed for N, P, K, S and Zn contents. Seed and stover samples were also chemically analyzed for N, P, K, S and Zn concentrations. All the data were statistically analyzed following F-test and the mean comparison was made by LSD. The results of the experiment are stated below.

Plant height was significantly affected by different levels of P and Zn. Plant height increased with increasing levels of P and Zn individually. The individual application of P @ 20 kg ha^{-1} (P_2) produced the tallest plant (51.09 cm) whereas application of Zn @ 3 kg ha^{-1} produced the tallest plant height (48.26 cm) . The tallest plant (52.05 cm) was found in P_2Zn_2 treatment combination which was higher over control treatment. The individual application of P and Zn showed positive effect on the number of branches $plant^{-1}$, number of pod $plant^{-1}$, number of seeds pod^{-1}, weight of 1000 seeds, seed yield and stover yield. All the plant characters increased with increasing levels of P and Zn up to P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}).

Like all other plant characters, seed yield of mungbean was influenced significantly due to application of P and Zn. Seed yield increased with increasing levels of P and Zn up to certain level. The highest seed yield (1.508 t ha^{-1}) was found in plants receiving P @ 20 kg ha^{-1} and the lowest grain yield (1.119 t ha^{-1}) was recorded in P_0 treatment. The individual application of Zn @ 3 kg ha^{-1} produced the highest amount of seed yield (1.451 t ha^{-1}). The combined application of P and Zn had positive effect on seed yield of mungbean. The highest seed yield (1.683 t ha^{-1}) of mungbean was recorded in P_2Zn_2 treatment. The lowest seed yield (1.08 t ha^{-1}) was recorded in P_0Zn_0 treatment. Combined application of P @ 20 kg ha^{-1} and Zn @ 3 kg ha^{-1} produced higher seed yield as compared to control treatment significantly.

Nutrient concentration (N, P, K, S and Zn) in stover were positively affected due to P and Zn fertilization. The interaction effect of P and Zn was also found remarkable. The N, P, K, S and Zn concentration in stover varied from 0.52% N in P_0Zn_0 treatment to 0.82 % N in P_1Zn_2 treatment, 0.35% P in P_0Zn_0 treatment to 0.67% P in P_2Zn_2 treatment, 0.65 % K in P_0Zn_0 treatment to 1.47% K in P_2Zn_2 treatment, 0.084% S in P_0Zn_0 treatment to 0.162 % S in P_2Zn_2 and 0.004 % Zn in P_0Zn_0 to 0.008 % Zn in P_3Zn_1 treatment, respectively. Nitrogen (N), P, K, S and Zn concentration in stover increased with increasing levels of P and Zn up to certain level.

Nutrient concentration (N, P, K, S and Zn) in seeds were positively affected due to P and Zn fertilization. The interaction effect of P and Zn was also found remarkable. The N, P, K, S and Zn concentration in seeds varied from 5.74% N in P_0Zn_0 treatment to 7.46% N in P_2Zn_2 treatment, 0.42 % P in P_0Zn_0 treatment to 0.69% P in P_2Zn_2 treatment, 1.16 % K in P_0Zn_0 treatment to 2.21 % K in P_2Zn_2 treatment, 0.246% S in P_0Zn_0 treatment to 0.65 % S in P_2Zn_2 and 0.004% Zn in P_0Zn_0 to 0.008% Zn in P_2Zn_2 treatment, respectively. The N, P, K, S and Zn concentration in seeds also increased with increasing level of P and Zn up to certain level.

Nutrient content in post harvest soil was also influenced by different levels of P and Zn application. The available N, available P, available K, available S and available Zn of post harvest soil varied from 0.0633 to 0.1073% N, 12.25 to 22.33 ppm P, 41.11 to 71.51 ppm K, 17.27 to 27.19 ppm S and 0.42 to 1.21 ppm Zn, respectively due to combined application of P and Zn at different levels. The addition of P and Zn not only increased the yield but also protect the soil from total exhaustion of nutrients.

Considering all the parameters studied the following conclusion may be drawn:-

The growth and yield of mungbean responded significantly by the combined application of Phosphorus and Zinc fertilizers @ 20 kg P ha^{-1} and 3 kg Zn ha^{-1} respectively.

Based on the results of the present study, the following recommendation may be drawn -

Application of Phosphorus and Zinc fertilizers @ 20 kg P ha^{-1} and 3 kg Zn ha^{-1} may be the best combination for higher yield of mungbean and also to maintain soil fertility and productivity than their individual application in Tejgaon series under AEZ No.28.

Recommendation may vary from soil to soil. However, to reach a specific conclusion and recommendation more research work on mungbean should be done in different Agro-ecological zones of Bangladesh.

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APPENDICES

Appendix i.: Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207.

The map of Bangladesh showing experimental site

Appendix ii. Records of meteorological information (monthly) during the period from March, 2012 to July, 2012

Name of the Months	Air temperature (^0C)		Relative humidity	Rainfall (mm)
	Maximum	Minimum		
March, 2012	32	20	45	61
April, 2012	34	23	55	137
May, 2012	33	24	72	245
June, 2012	32	26	79	315
July, 2012	31	26	79	329

Source: http://www.dhaka.climatemps.com/

Appendix-iii: Some Commonly Used Abbreviations and Symbols

Abbreviations	Full word
%	Percent
@	At the rate
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BINA	Bangladesh Institute of Nuclear Agriculture
CEC	Cation Exchange Capacity
cm	Centi-meter
CV%	Percentage of coefficient of variation
df	Degrees of Freedom
DMRT	Duncan's Multiple Range Test
et al.	and others
etc	Etcetera
FAO	Food and Agricultural Organization
g	gram
hr.	Hours
j.	Journal
Kg ha^{-1}	kiligrams per hectare
kg	kilogram
m	Meter
m^2	square meter
MSE	Mean square of the error
No.	Number
ppm	parts per million
RCBD	randomized complete block design

Rep.	replication
Res.	research
SAU	Sher-e-Bangla Agricultural University
Sc.	science
SE	Standard Error
Univ.	University
var.	variety

Appendix iv: ANOVA Table for growth and Yield Parameters

ANOVA Table for Plant Height

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.280	0.140	0.3234
Factor A	3	425.250	141.750	327.3010
Factor B	2	17.292	8.646	19.9637
AB	6	10.588	1.765	4.0746
Error	22	9.528	0.433	
Total	35	462.938		

Coefficient of Variation: 1.39%

ANOVA Table for Number of Branch per Plant

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.034	0.017	6.4923
Factor A	3	4.780	1.593	608.1391
Factor B	2	0.822	0.411	156.9514
AB	6	0.116	0.019	7.3531
Error	22	0.058	0.003	
Total	35	5.810		

Coefficient of Variation: 2.29%

ANOVA Table for Number of Pod per Plant

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	4.881	2.441	7.0425
Factor A	3	100.438	33.479	96.6092
Factor B	2	28.849	14.425	41.6242
AB	6	4.031	0.672	1.9389
Error	22	7.624	0.347	
Total	35	145.824		

Coefficient of Variation: 3.43%

ANOVA Table for Pod Length

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.783	0.391	3.8124
Factor A	3	39.029	13.010	126.7186
Factor B	2	9.983	4.992	48.6199
AB	6	5.039	0.840	8.1805
Error	22	2.259	0.103	
Total	35	57.093		

Coefficient of Variation: 3.92%

ANOVA Table for Number of Seed per Pod

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.213	0.106	0.6318
Factor A	3	24.927	8.309	49.3038
Factor B	2	8.653	4.327	25.6735
AB	6	3.123	0.520	3.0881
Error	22	3.708	0.169	
Total	35	40.624		

Coefficient of Variation: 3.87%

ANOVA Table for Thousand Seed Weight

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	1.571	0.785	1.6152
Factor A	3	62.709	20.903	42.9857
Factor B	2	32.341	16.171	33.2542
AB	6	6.612	1.102	2.2661
Error	22	10.698	0.486	
Total	35	113.931		

Coefficient of Variation: 1.66%

ANOVA Table for Graind Yield

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.008	0.004	2.2499
Factor A	3	0.942	0.314	167.6827
Factor B	2	0.197	0.099	52.7249
AB	6	0.050	0.008	4.4606
Error	22	0.041	0.002	
Total	35	1.239		

Coefficient of Variation: 3.19%

ANOVA Table for Stover Yield

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.002	0.001	0.3810
Factor A	3	1.016	0.339	142.1224
Factor B	2	0.265	0.132	55.5663
AB	6	0.064	0.011	4.4854
Error	22	0.052	0.002	
Total	35	1.400		

Coefficient of Variation: 2.12%