EFFECTS OF ZINC AND SULPHUR ON THE YIELD OF MUNGBEAN

By

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CERTIFICATE

This is to certify that thesis entitled, "***Effects Of Zinc And Sulphur On The Yield Of Mungbean***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURAL CHEMISTRY,** embodies the result of a piece of *bona fide* research work carried out by **Tanvir Hasan**, **Registration No. 07-02506** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any institute.

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

……….....................

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EFFECTS OF ZINC AND SULPHUR ON THE YIELD OF MUNGBEAN

(BARI Mung 6)[1]

BY

TANVIR HASAN[2]

ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207, during the kharif season of 2013 to study the " Effects of zinc and sulphur on the yield of Mungbean **(**BARI Mung-6**)**". The experimental soil pH was 5.71 and organic carbon content was 0.68%. Three levels of zinc (0, 4 and 8 kg Zn ha^{-1}) and four levels of sulfur (0, 15, 25 and 35 kg S 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 sulphur and zinc up to certain level. The maximum significant seed and stover yields were obtained with the treatment combination Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). This perticular treatment combination gave the highest seed yield (2.657 t ha^{-1}), stover yield (1.623 t ha^{-1}), plant height (57.20 cm), number of branch plant^{-1} (2.880), yield attributes like number of pods plant^{-1} (20.09), number of seeds pod^{-1} (12.47) and weight of 1000-seeds (44.72 g). On the other hand, minimum seed and stover yields were obtained with control condition. The N, P, K and S concentration of mungbean plant increased significantly from control to Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}) treatment combination and again decreased with increasing sulfur more than 20 kg S ha^{-1}. Application of zinc and sulphur fertilizers increased organic carbon, N, P, K and S status of post-harvest soil significantly.

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[1]Thesis paper entitled presented on 23 February, 2015

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All praises are due to the "Almighty Allah" who enabled the author to pursue higher education in Soil Science and to submit the thesis for the degree of Master of Science (M.S.) in Agricultural Chemistry.

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The author expresses his immense, gratefulness to all of them who co-operate, assisted and inspired his to complete the Master's degree and regret for his inability for not to mention every one by name.

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CHAPTER 1

INTRODUCTION

Mungbean (*Vigna radiata* L.) under the family of Leguminosae is one of the most important short duration, drought tolerant pulse crop in Bangladesh. It belongs to the family Leguminosae. It is originated in Indian subcontinent . Now it is widely grown in China, Thailand, Philippines, Indonesia, Burma, Bangladesh and India. It is also grown in parts of east and central Africa, West Indies, USA and Australia. BARI Mung-6 a high yielding variety fits well in crop rotation between two cereal crops and breaks the buildup of disease, insect and weed syndrome. It fixes nitrogen in symbiosis with *Rhizobia* and enriches the soil. Its root breaks the plough pan of puddled rice fields and goes deep in search of water and nutrients.

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 used as whole or split seeds as Dal (Soup) but in other countries sprouted seeds are widely used as vegetables. It is considered as poor man's meat containing almost triple amount of protein as compared to rice. It has good digestibility and flavour. 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 *et al*., 1981 and Kaul, 1982). 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. 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 of N, P, S, K and Zn containing fertilizer. The excess use of nitrogenous fertilizer increase the vegetative growth of the plant. So it is essential to use recommended dose of fertilizer to achieve the the maximum and sustainable yield goal.

Sulphur plays a remarkable role in protein metabolism, it is required for the synthesis of proteins, vitamins and chlorophyll and also S containing amino acids such as methionine, cysteine, and cystine which are essential components of proteins. Lack of S causes retardation of terminal growth and root development. S deficiency induced chlorosis in young leaves and decrease seed yield by 45% (BARI, 2004).

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 sulphur 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 zinc and sulphur on the growth, yield and yield contributing characters of mungbean.

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

iii. To determine the effects of zinc and sulphur on the nutrient accumulation in mungbean.

CHAPTER 2

REVIEW OF LITERATURE

Pulses are important, both as human and animal food and an excellent source of high quality of vegetable protein. 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 yield improvement of mungbean by fertilizer management practices. Currently the Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Institute of Nuclear Agriculture (BINA) have started extensive research on fertilizer management for yield improvement of this crop. Literature in relation to effect of Zn and S on the yield and nutrient accumulation of mungbean is reviewed and presented below.

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

Habibullah (2012) conducted a field experiment 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)". 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. The results revealed that seed and stover yield of mungbean increased with increasing levels of phosphorus and zinc up to certain level. 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.

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.

Salahuddin *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 prolinc 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 surplassed 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 and Yadav (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/ ha 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^{-l} and 5 kg Zn ha^{-1} and thereafter decreased at 60 kg S ha^{-1}.

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

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 µg g^{-1} Zn and reported that application of 5 µg 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, grain 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 µg 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.

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

Rahman (2012) conducted a field experiment during the kharif season of 2012 to study the effect of potassium and sulphur on the growth and yield of Mungbean (BARI Mung-6). Four levels of potassium (0, 15, 25 and 35 kg K ha^{-1}) and three levels of sulphur (0, 3 and 6 kg S ha^{-1}) were used in the study. The results reveald that grain and stover yield of mungbean increased with increasing levels of potassium and sulphur.The maximum significant grain and stover yield were obtained with the treatment combinations K_2S_2 (25 kg K ha^{-1} + 6 kg S ha^{-1}) and the same treatments combinations gave the highest plant height, number of branch $plant^{-1}$, yield attributes like number of pods $plant^{-1}$, Number of grains pod^{-1}, weight of 1000 seeds. The N, P, K and S concentration of mungbean plant increased significantly from control to K_2S_2 (25 kg K ha^{-1} + 6 kg S ha^{-1}) and again decreased with increasing potassium more than 25 kg K ha^{-1}. Application of Potassium and Sulphur fertilizers increased organic carbon, N, P, K and S status of postharvest soil significantly.

Tripathi *et al.* (2012) reported that application of 45 kg S ha^{-1} recorded higher plant height, primary branches, green trifoliates, leaf area index, dry matter accumulation, nodule numbers and nodule dry weight, increased days to maturity, number of pod and higher grain and straw yield as compared to cultivars Pusa Vishal and SML-668, and S application at 15 and 30 kg ha^{-1} , respectively. Nodule number was highest in 45 kg S ha^{-1} in Pusa Vishal and HUM-1. Maximum dry matter recorded with 45 kg S ha^{-1}.

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}.

Shah *et al.* (2011) observed that number and weight of nodules, grain and straw yield, content of P and S were increased with increase 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.

Jahan *et al.* (2009). reported that sulphur (S) requirement of plants has become increasingly importance in India as well as world agriculture. However, to achieve high yields and rates of S fertilizer should be recommended on the basis of available soil S and crop requirement.

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 the effect of S application on Zn uptake in both grain and straw.

Singh and Yadav (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 ha^{-1} 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.

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Singh *et al.* (1997) found significant increase in stover yield of mungbean due to the application of S.

Singh *el al.* (1993) found significant increase of phosphorus concentration in soil mungbean field due to the application of K (30, 60, and 90 kg K_2O ha^{-1}) and S (5,10 and 15 ppm).

CHAPTER 3

MATERIALS AND METHODS

This chapter includes the details of the materials and methods of this research work were described in. The experimental materials, site, climate and weather, land preparation, experimental design, layout, collection of soil and plant samples etc. and analytical methods followed in the experiment to study the effect of zinc and sulphur on the yield of mungbean.

3.1 Experimental site

The research work relating to the study of the effect of zinc and sulphur on the yield of mungbean was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka- 1207 during the *Kharif* season of 2013. 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 Farrn, 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
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

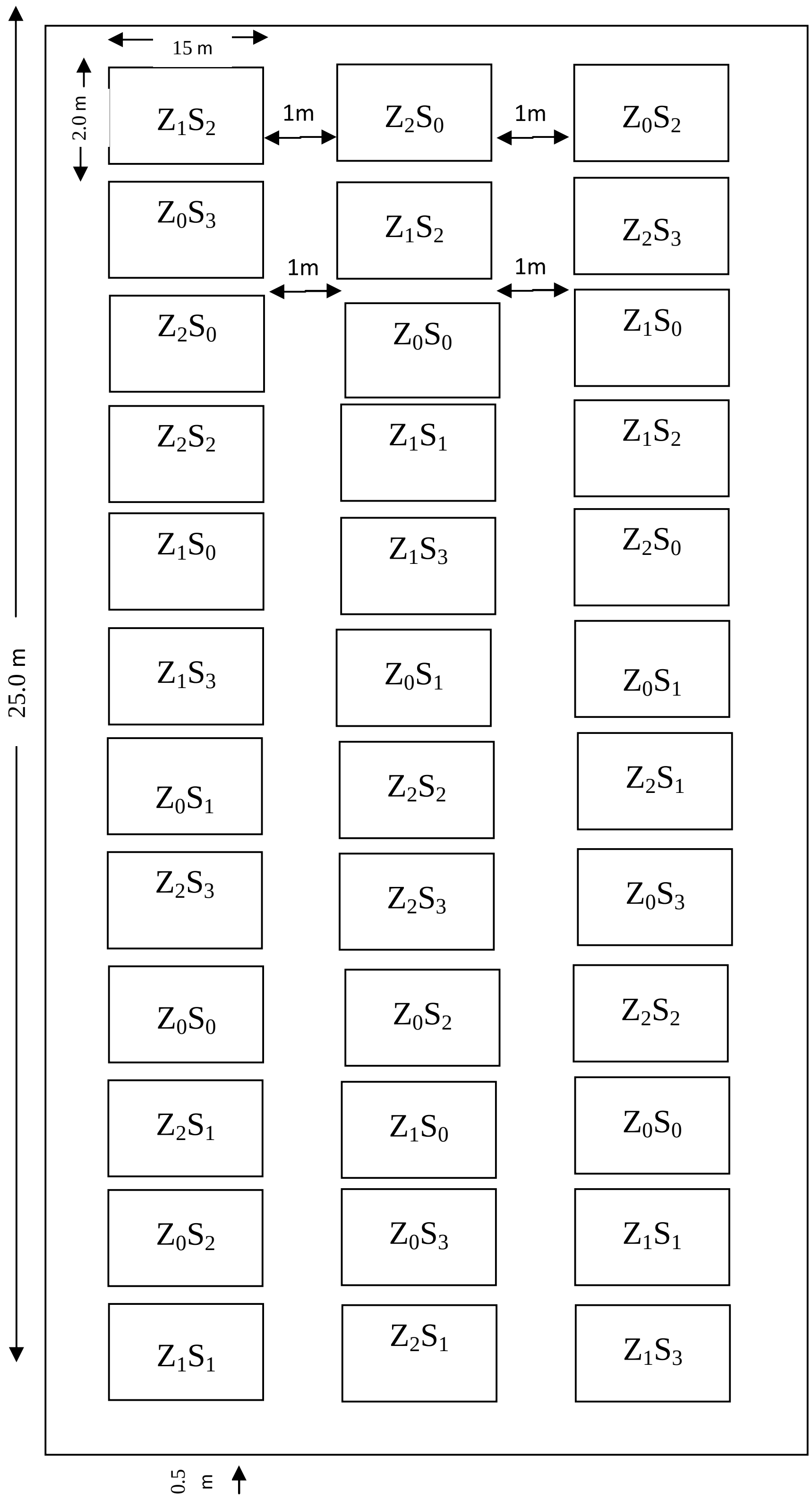
The experimental area has sub-tropical climate characterized by heavy rainfall during May to September and low to no rainfall during rest of the year. The annual precipitation of the site is 1974 mm and potential evapotranspiration is 1197 mm, the average maximum temperature is 30.34^0C and average minimum temperature is 21.21^0C. The average mean temperature is 25.17^0C. The experiment was carried out during kharif season, 2013. The monthly average temperature, humidity and rainfall of the site during the experimental period are enclosed in Appendix II.

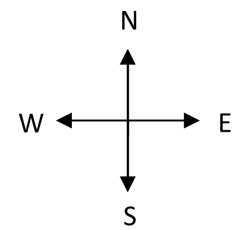
3.5 Land Preparation

The experimental field was thoroughly ploughed and cross ploughed and cleaned prior to seed sowing and application of fertilizers and manure was done in the field. The experimental field was prepared by thorough ploughing followed by laddering to have a good tilth. Finally the land was properly leveled before seed sowing. Finally plots were prepared as per the design.

3.6 Experimental design and layout

Field layout was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The whole plot was divided into three blocks each containing twelve (12) plots of 3m x 1.5m size, giving 36 unit plots. The space was kept 100 cm between the blocks and 50 cm between the plots. Seeds were sown in lines in the experimental plots.





Plot size: 3 m × 1.5 m

Plot spacing: 50 cm

Between replication: 1.0m

Factor A: Zinc (Zn)
Zn_0 = 0 kg Zn ha^{-1} (Control) Zn_1 = 4 kg Zn ha^{-1} Zn_2 = 8 kg Zn ha^{-1}

Factor B:
S_0 = 0 kg S ha^{-1} (Control) S_1 = 15 kg S ha^{-1} S_2 = 25 kg S ha^{-1} S_3 = 35 kg S ha^{-1}

Figure3.1. 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: Zinc (Zn)	**Factor B: Sulphur (S)**
Zn_0 = 0 kg Zn ha^{-1}(Control)	S_0 = 0 kg S ha^{-1} (Control)
Zn_1 = 4 kg Zn ha^{-1}	S_1 = 15 kg S ha^{-1}
Zn_2 = 8 kg Zn ha^{-1}	S_2 = 25 kg S ha^{-1}
	S_3 = 35 kg S ha^{-1}

Treatment Combinations:

1. Zn_0S_0= Control (No Zn and S)
2. Zn_0S_1= 0 kg Zn ha^{-1} + 15 kg S ha^{-1}
3. Zn_0S_2= 0 kg Zn ha^{-1}+ 25 kg S ha^{-1}
4. Zn_0S_3= 0 kg Zn ha^{-1} + 35 kg S ha^{-1}
5. Zn_1S_0= 4 kg Zn ha^{-1} + 0 kg S ha^{-1}
6. Zn_1S_1= 4 kg Zn ha^{-1} + 15 kg S ha^{-1}
7. Zn_1S_2= 4 kg Zn ha^{-1} + 25 kg S ha^{-1}
8. Zn_1S_3= 4 kg Zn ha^{-1} + 35 kg S ha^{-1}
9. Zn_2S_0= 8 kg Zn ha^{-1} + 0 kg S ha^{-1}
10. Zn_2S_1= 8 kg Zn ha^{-1} + 15 kg S ha^{-1}
11. Zn_2S_2= 8 kg Zn ha^{-1} + 25 kg S ha^{-1}
12. Zn_2S_3= 8 kg Zn ha^{-1} + 35 kg S ha^{-1}

3.8 Application of fertilizers

Recommended blanket doses of N, K and P (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 Zn (from Zinc oxide) and S (from gypsum) 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 14^{th} September 2013 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 l0 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 as required sowing of seeds.

3.11 Harvesting

The crop was harvested at maturity on 14^{th} December 2013. 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^{-l}.

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 20th September 2013. 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:

l. 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 $HCIO_4$ 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 was determined by turbidimetric 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 IV

RESULTS AND DISCUSSION

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 Effects of zinc on growth and yield of mungbean

4.1.1 Effect of zinc on plant height

The effects of zinc on the plant height of mungbean are presented in (Table 4.1). Significant variation was observed on plant height when the plot was fertilized with different doses of zinc. Plant height was increased with Zn_2 levels from 0-8 Kg ha^{-1}. The highest plant height (53.92 cm) was obtained with 8 kg Zn ha^{-1} which was significantly higher than all other treatments. The second highest plant height was recorded in Zn_1 Kg ha^{-1} treatment.

Table 4.1 Effect of zinc on growth parameters

Levels of Zn (Kg ha^{-1})	Plant height (cm)	No. of branches $plant^{-1}$	No. of pod $plant^{-1}$	Pod length (cm)
Zn_0	50.97 b	2.02 c	16.27 c	7.52 c
Zn_1	51.74 b	2.22 b	16.88 b	8.14 b
Zn_2	53.92 a	2.38 a	17.92 a	8.84 a
$LSD_{(0.05)}$	0.983	0.075	0.591	0.326
CV (%)	1.11	2.11	2.06	2.34

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 lowest plant height (50.97 cm) was observed in the Zn_0 treatment where no zinc was applied. The result is agreed with the findings of Abbas *et al.* (2011) who observed significant increase in plant height of mungbean due to the application of increasing level of Zn fertilizer.

4.1.2 Effect of zinc on number of branches $plant^{-1}$

Significant variation was observed in number of branches $plant^{-1}$ of mungbean when different doses of zinc were applied (Table 4.1). The highest number of branches $plant^{-1}$ (2.38) was recorded in Zn_2 (8 Kg Zn ha^{-1}). The lowest number of branches $plant^{-1}$ (2.02) was recorded in the Zn control plot. Abbas *et* *al.*(2011) found significant increase in number of branches of mungbean with successive increase in Zn_2SO_4 levels at 75 Kg ha^{-1}**.**

4.1.3 Effect of zinc on number of pods plant^{-1}

Different doses of zinc showed significant variation was in respect of number of pods plant^{-1} of mungbean when different doses of zinc were applied (Table 4.1). The highest number of pods plant^{-1} (17.92) was recorded in Zn_2 (8 Kg Zn ha^{-1}). The lowest number of pods plant^{-1} (16.27) was recorded in the Zn_0 treatment where no zinc was applied. Abbas *et al.* (2010) found significant increase in number of pods plant^{-1} of mungbean.

4.1.4 Effect of zinc on pod length

Pod length as affected by different doses of zinc showed a statistically significant variation (Table 4.1). Among the different doses of Zn the highest pod length (8.84 cm) was observed in Zn_2 (8 Zn ha^{-1}). The lowest pod length (7.52 cm) was recorded in the Zn_0 treatment where no Zn was applied. Abbas *et al.*(2011) found significant increase on pod length of mungbean with successive increase in Zn_2SO_4 levels at 75 Kg ha^{-1}**.**

4.1.5 Effect of zinc on number of seeds pod^{-1}

Zinc had significant variation on number of seeds pod^{-1} of mungbean when different doses of zinc were applied (Table 4.2).The highest number of seeds pod^{-1} (11.04) was recorded in Zn_2(8 Kg Zn ha^{-1}). The lowest number of seeds pod^{-1} (9.90) was recorded in the Zn_0 treatment where zinc was applied.

Table 4.2 Effect of zinc on yield and yield contributing characters

Levels of Zn (Kg ha^{-1})	No. of seed/pod	Weight of 1000-seeds (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})

Zn_0	9.90 b	40.53 c	2.22 b	1.26 b
Zn_1	10.78 a	41.88 b	2.27 b	1.33 ab
Zn_2	11.04 a	43.16 a	2.41 a	1.39 a
$LSD_{(0.05)}$	0.278	0.842	0.119	0.107
CV (%)	1.59	1.19	3.12	4.4

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

4.1.6 Effect of zinc on weight of 1000-seed

Significant variation was observed on the weight of 1000 seed of mungbean when different doses of Zn were applied (Table 4.2). The maximum weight of 1000-seed (43.16 g) was found in Zn_2 (8 Kg Zn ha^{-1}). The lowest weight of 1000-seed (40.53 g) was recorded in the treatment where no Zn was applied. Sangaznara (1990) found significant increase in weight of 1000-seed of mungbean due to the application of 0-120 Kg ZnO ha^{-1}.

4.1.7 Effect of Zn on grain yield

Significant variation was observed on the grain yield of mungbean when different doses of Zn were applied (Table 4.2). The highest grain yield of mungbean (2.41 t ha^{-1}) was recorded in Zn_2 (8 Kg Zn ha^{-1}). The lowest grain yield of mungbean (2.22 t ha^{-1}) was recorded in the Zn_0 treatment where no Zn was applied. These findings are similar with some other researcher’s findings, Jahan *et al.* (2009) who obtained highest mungbean grain yield due to the application of 35 Kg Zn ha^{-1}

4.1.8 Effect of Zn on stover yield

Significant variation was observed on the stover yield of mungbean when different doses of Zn were applied (Table 4.2). The highest stover yield of mungbean (1.39 t ha^{-1}) was recorded in Zn_2 (8 Kg Zn ha^{-1}). The lowest stover yield (1.26 t ha^{-1}) was recorded in the Zn_0 treatment where no Zn was applied. Jahan *et al.* (2009) found significant increase in stover yield of mungbean due to the application of increasing level of Zn fertilizer.

4. 2 Effects of sulphur on growth and yield of mungbean

4.2.1 Effect of sulphur on plant height

Mungbean plants showed significant variation in plant height when sulphur fertilizers in different doses were applied (Table 4.3). Among the different fertilizer doses, S_2 (25Kg S ha^{-1}) showed the highest plant height (53.55 cm). On the contrary, the lowest plant height (48.14 cm) was observed in the treatment where no sulphur was applied. Znumar *et al.* (2012) found significant increase in plant height of mungbean due to the application of 30 Kg S ha^{-1}.

4.2.2 Effect of sulphur on number of branches plant^{-1}

Different doses of S fertilizers shoved significant variations in respect of number of branches plant^{-1} (Table 4.3). Among the different doses of fertilizers, S_2 (25 Kg S ha^{-1}) showed the highest number of branches plant^{-1} (2.60). On the contrary, the lowest number of branches plant^{-1} (1.63) was observed with S_0, where no sulphur fertilizer was applied. The result accords with the findings of Tripathi *et al.* (2012) who observed significant increase in number of branches plant^{-1} of mungbean due to the application at 45 Kg S ha^{-1}.

Table 4.3 Effect of sulphur on growth parameters

Levels of S (Kg ha^{-1})	Plant height (cm)	No. of branches plant^{-1}	No. of pod plant^{-1}	Pod length (cm)
S_0	48.14 c	1.63 d	14.82 d	6.84 d
S_1	49.12 c	2.21 c	16.71 c	7.65 c
S_2	53.55 a	2.60 a	18.94 a	9.30 a
S_3	52.04 b	2.38 b	17.62 b	8.87 b

$LSD_{(0.05)}$	0.983	0.076	0.591	0.326
CV (%)	1.11	2.11	2.06	2.34

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 sulphur fertilizers on number of pods plant^{-1}

Different doses of sulphur fertilizers showed significant variations in respect of number of pods plant^{-1} (Table 4.3). Among the different doses of fertilizers. S_2 (25 Kg S ha^{-1}) produced the highest number of pods plant^{-1} (18.94). On the contrary, the lowest number of branches plant^{-1} (14.82) was observed with S_0, where no sulphur fertilizer was applied. This findings is inconformity with the results of Tripathi *et al.* (2012) who observed significant increase in number of pods plant^{-1} of mungbean due to the application at 45 Kg S ha^{-1}.

4.2.4 Effect of sulphur on Pod length

Application of sulphur fertilizers at different doses showed a significant variation on the pod length of mungbean (Table 4.3). Among the different S fertilizer doses, S_2 (25 Kg S ha^{-1}) showed the highest pod length (9.309 cm). On the other hand, the lowest pod length (6.84 cm) was recorded with S_0 treatment where no S was applied. Singh *et al.* (1997) found significant increase in pod length of mungbean due to the application of 30 Kg ha^{-1}.

4.2.5 Effect of sulphur on number of seeds pod^{-1}

There was significant variation in respect of number of seeds pod^{-1} due to the application of S (Table 4.4). Among the different doses of fertilizers S_2 showed the highest number of seeds pod^{-1} (11.72). On the other hand, the lowest pod length (9.39 cm) was recorded with S_0 treatment where no S was applied.

Table 4.4 Effect of sulphur fertilizer on yield and yield contributing characters and the yield.

Levels of S (Kg ha^{-1})	No. of seed/pod	Weight of 1000-seeds (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
S_0	9.39 d	39.65 c	2.10 c	1.11 c
S_1	10.38 c	41.72 b	2.22 b	1.28 b
S_2	11.72 a	43.20 a	2.46 a	1.48 a
S_3	10.80 b	42.87 a	2.42 a	1.44 a
$LSD_{(0.05)}$	0.278	0.842	0.119	0.107
CV (%)	1.59	1.19	3.12	4.4

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

4.2.6 Effect of sulphur on weight of 1000-seed

Different doses of sulphur fertilizers showed significant variations in respect of the weight of 1000-seed (Table 4.4). Sulphur fertilization at S_2 (25 Kg S ha^{-1}) produced the highest weight of 1000-seed (43.20 g). On the contrary, the lowest weight of 1000-seed (39.65 g) was observed with S_2 where no S fertilizer was applied. Islam *et al.* (2009) found significant increase in weight of 1000- seed of mungbean due to the application of increasing level of S.

4.2.7 Effect of sulphur on grain Yield

Different doses of sulphur fertilizers showed significant variations in grain yield of mungbean (Table 4.4).Among the different doses of S fertilizers, S_2 (25 Kg S ha^{-1}) produced the highest grain yield of mungbean (2.46 t ha^{-1}). On the contrary, the lowest grain yield of mungbean (2.10 t ha^{-1}) was found in S_0 where no S fertilizer was applied. Islam *et al.* (2009) observed that application of S resulted in significant increase in grain yield ranging from 22 to 35% and 10 to 16% over control, respectively.

4.2.8 Effect of sulphur on stover yield

Different doses of S fertilizers showed significant variations in respect stover yield of mungbean (Table 4.4). Application of S_2 at 25 Kg S produced the highest stover yield (1.48 t ha^{-1}). On the contrary, the lowest stover yield (1.11 t ha^{-1}) was observed with S_0, where no S fertilizer was applied. The results are in agreement with the findings of Singh and Yadav (1997) found significant increase in stover yield of mungbean due to the application of S.

4. 3 Effects of Zinc and sulphur on growth and yield of mungbean

4.3.1 Interaction effect of zinc and sulphur on plant height

Combined application of different doses of zinc and sulphur fertilizers showed significant effect on the plant height of mungbean (Fig. 4.1). The lowest plant height (46.60 cm) was observed in the treatment combination of Zn_0S_0 (No zinc and No sulphur).On the other hand the highest plant height (57.20) was recorded with Zn_2S_2 (8 kg Zn ha^{-1} + 25 kg Zn ha^{-1}). Bandopadhyay *et al.*, (2002) found significant incease in plant height of mungbean due to the application of increasing level of Zn and fertilizer.

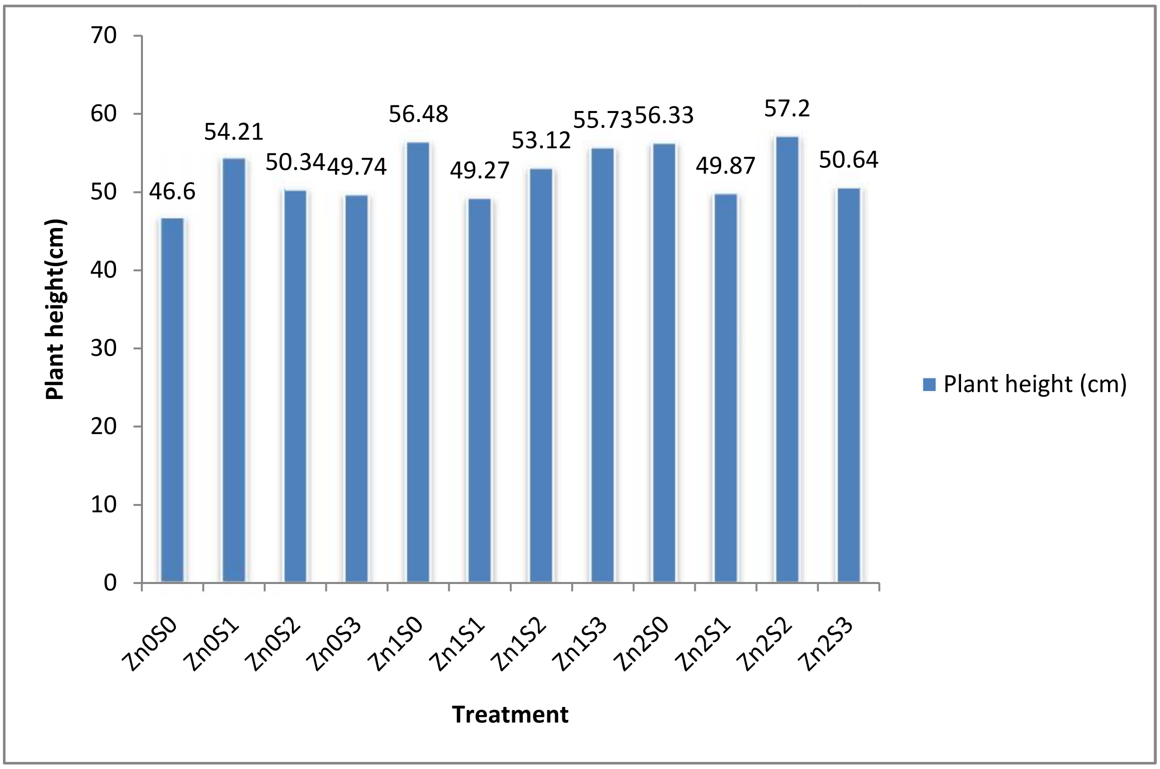


Fig. 4.1: Interaction effect of zinc and sulphur on plant height

Table 4.5 Interaction effect of zinc and sulphur on growth parameters

Interaction of Zn and S	No. of branches plant^{-1}	No. of pod plant^{-1}	Pod length (cm)
Zn_0S_0	1.52 i	14.36 g	6.62 g
Zn_0S_1	2.05 g	15.68 f	7.25 f
Zn_0S_2	2.29 e	17.69 cd	7.72 e
Zn_0S_3	2.20 f	17.34 d	8.51 cd
Zn_1S_0	1.56 i	14.71 g	6.73 g
Zn_1S_1	2.27 ef	16.33 e	7.42 ef
Zn_1S_2	2.64 b	19.03 b	9.71 b
Zn_1S_3	2.40 d	17.43 d	8.67 c
Zn_2S_0	1.82 h	15.40 f	7.18 f
Zn_2S_1	2.31 e	18.11 c	8.27 d
Zn_2S_2	2.88 a	20.09 a	10.48 a
Zn_2S_3	2.53 c	18.08 c	9.44 b
$LSD_{(0.05)}$	0.076	0.591	0.326
CV (%)	2.11	2.06	2.34

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

4.3.2 Interaction effect of zinc and sulphur on number of branches plant^{-1}

The combined effect of different doses of Zn and S fertilizers on the number of branches plant^{-1} of mungbean was statistically significant (Table 4.5). The highest number of branches plant^{-1} (2.88) was recorded with the treatment combination of Zn_2S_2 (8 kg Zn ha^{-1}+ 25 kg Zn ha^{-1}). On the other, hand the lowest number of branches plant^{-1} (1.52) was found in control treatment (No Zn and No S). Bandopadhyay *et al.* (2002) found significant increase in number of branches plant^{-1} of mungbean due to the application of increasing level of Zn and S fertilizer.

4.3.3 Interaction effect of zinc and sulphur on number of pods plant^{-1}

The combined effect of different doses of zinc and sulphur fertilizer on number of pods plant^{-1}of mungbean was significant (Table 4.5). The highest number of pods plant^{-1} (20.09) was found with the treatment combination of Zn_2S_2 (8 kg Zn ha^{-1}+ 25 kg Zn ha^{-1}). On the other hand, the lowest number of pods plant^{-1} (14.36) was found in Zn_0S_0 (0 Kg Zn ha^{-1} + 0 Kg S ha^{-1}). Bandopadhyay *et al.* (2002) found significant increase in number of pods plant^{-1} of mungbean due to the application of increasing level of Zn and S fertilizer.

4.3.4 Interaction effect of zinc and sulfur on pod length

Combined effects of Zn and S fertilizers produced significant variation on pod length (Table 4.5). The highest pod length (10.48 cm) was recorded in the treatment combination of Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). On the other hand, the lowest pod length (6.62 cm) was found in Zn_0S_0.

4.3.5 Interaction effect of zinc and sulphur on number of seeds pod^{-l}

The combined effect of different doses of Zn and S fertilizers on number of seeds pod^{-l} of mungbean was statistically significant (Table 4.6). The highest number of seeds pod^{-l} (12.47) was recorded with the treatment combination of Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). On the other hand, the lowest number of seeds pod^{-l} (8.43) was found in Zn_0S_0 treatment (No Zn and No S).

4.3.6 Interaction effect of zinc and sulphur on weight of 1000-seed

The combined effect of different doses of Zn and S fertilizers on the weight of 1000-seed of mungbean was statistically significant (Fig. 4.2). The highest weight of 1000-seed (44.72 g) was recorded with the treatment combination of Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). On the other hand, the lowest weight of 1000-seed (38.40 g) was found in Zn_0 S_0 (0 Kg Zn ha^{-1}+ 0 Kg S ha^{-1}).

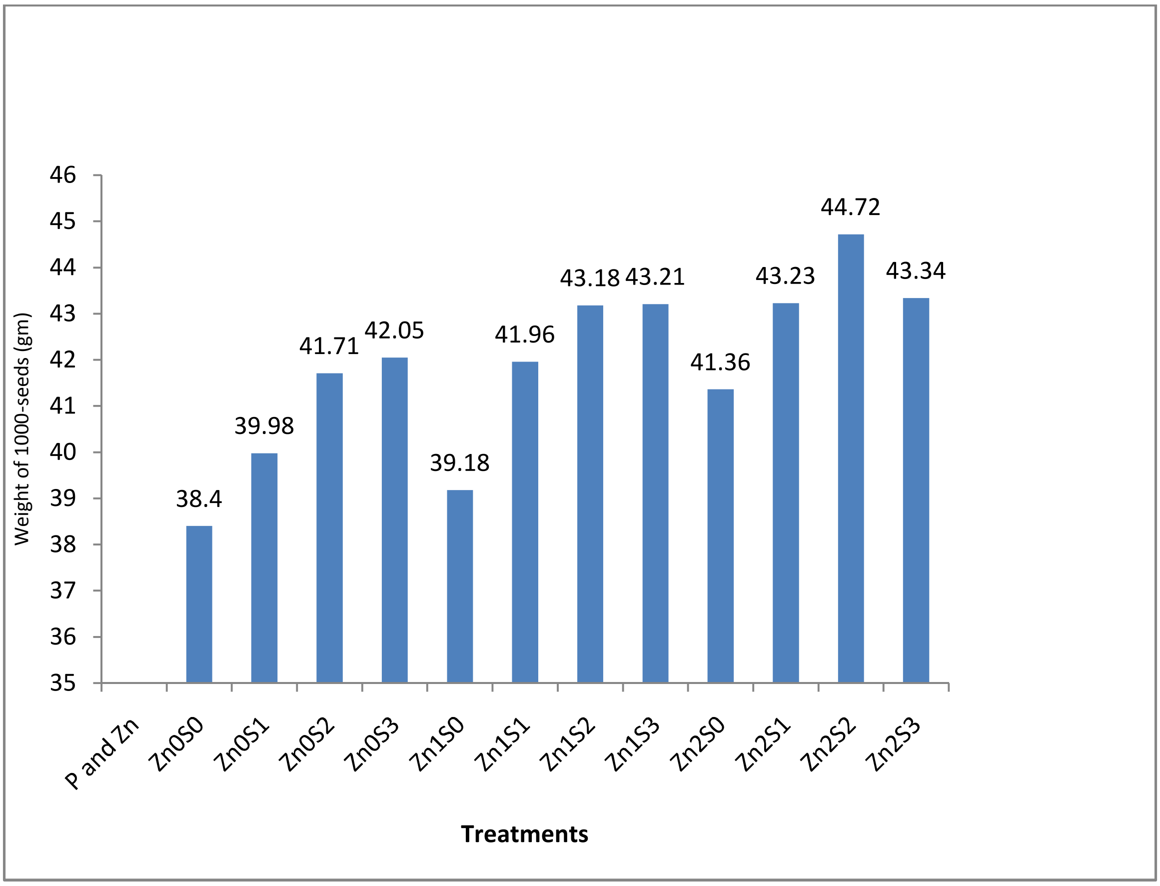


Fig. 4.2 : **Interaction effect of zinc and sulphur on weight of 1000-seed**

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

Interaction of Zn and S	No. of seed/pod	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Zn_0S_0	8.43 h	2.04 e	1.05 f
Zn_0S_1	9.79 f	2.13 de	1.21 de
Zn_0S_2	10.71 cd	2.31 c	1.37 bc
Zn_0S_3	10.67 d	2.39 bc	1.41 b
Zn_1S_0	9.51 g	2.11 de	1.12 ef
Zn_1S_1	10.64 d	2.17 d	1.27 cd
Zn_1S_2	11.99 b	2.43 bc	1.45 b
Zn_1S_3	11.00 c	2.38 c	1.48 b
Zn_2S_0	10.23 e	2.14 de	1.16 de
Zn_2S_1	10.72 cd	2.35 c	1.37 bc
Zn_2S_2	12.47 a	2.65 a	1.62 a
Zn_2S_3	10.73 cd	2.51 b	1.43 b
$LSD_{(0.05)}$	0.278	0.120	0.107
CV(%)	1.59	3.12	4.4

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

4.3.7 Interaction effect of zinc and sulphur fertilizers on grain yield

The combined effect of different doses of Zn and S fertilizers on the grain yield of mungbean was significant (Table 4.6 and Fig. 4.4). The highest grain yield of mungbean (2.65 t ha^{-1}) was recorded with the treatment combination of Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). On the other hand the lowest grain yield of mungbean (2.04 t ha^{-1}) was found in Zn_0S_0 treatment (No Zn and No S).

4.3.8 Interaction effect of zinc and sulphur on stover yield

The combined effect of different doses of Zn and S fertilizers on the stover yield was significant (Table 4.6). The highest stover yield (1.62 t ha^{-1}) was recorded with the treatment combination of Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). On the other hand, the lowest stover yield (1.05 t ha^{-1}) was found in treatment Zn_0S_0 (0 Kg Zn ha^{-1}+ 0 Kg S ha^{-1}).

4.4 Effect of zinc on nutrient content in mungbean stover

4.4.1 Effect of Zn on nitrogen content in mungbean stover

Application of Zn showed significant variation in the nitrogen concentration in mungbean stover (Table 4.7).The N concentration in mungbean stover increased with increasing level of Zn fertilizer up to 25 Kg Zn ha^{-1}. The highest nitrogen concentration in stover (0.740 %) was recorded in Zn_1 (15 Kg Zn ha^{-1}). On the other hand, the lowest nitrogen concentration in stover (0.630 %) was recorded in the Zn_0 treatment where no Zn was applied.

4.4.2 Effect of Zn on phosphorus content in mungbean stover

Application of Zn showed significant variation in the phosphorus concentration in mungbean stover (Table 4.7). The highest phosphorus concentration in stover (0.582 %) was recorded in Zn_2 (25 Kg Zn ha^{-1}). On the other hand, the lowest phosphorus concentration in stover (0.405 %) was recorded in the Zn_0 treatment where no Zn was applied.

Table 4.7 Effect of zinc on total N, P, Zn and S concentrations in mungbean stover

Treatments	Total N%	P%	Zn%	S%
Zn_0	0.630 c	0.405 c	0.006	0.102 a
Zn_1	0.740 a	0.553 a	0.007	0.103 a
Zn_2	0.715 ab	0.582 a	0.008	0.123 a
LSD$_{(0.05)}$	0.0536	0.0536	NS	0.245
CV (%)	3.89	5.05	2.02	3.49

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

4.4.3 Effect of Zn on zinc content in stover

A statistically significant variation was observed in zinc concentration in stover of mungbean with different doses of zinc (Table 4.7). The highest zinc concentration among the different doses of zinc (0.008%) was recorded in Zn_2 (25 Kg Zn ha^{-1}). on the other hand, the lowest zinc concentration (0.006%) was recorded in the Zn_0 treatment where no Zn was applied.

4.4.4 Effect of Zn on sulphur content in mungbean stover

A statistically non significant variation was observed in sulphur concentration in stover of mungbean with different doses of Zn (Table 4.7). Among the different doses of Zn the highest sulphur concentration in plant (0.1230 %) was recorded in Zn_2 (25 Kg Zn ha^{-1}) treatment. On the other hand, the lowest sulphur concentration (0.102 %) was recorded in the Zn_0 treatment where no Zn was applied.

4.5 Effect of sulphur on nutrient content in mungbean stover

4.5.1 Effect of S on nitrogen content in mungbean stover

The effect of different doses of sulphur showed statistically significant difference in nitrogen concentration in mungbean stover (Table 4.8). The highest nitrogen concentration among the treatments of sulphur (0.767 %) was observed in S_2 (25 Kg S ha^{-1}). The lowest nitrogen concentration (0.625 %) was observed in S_0 (control condition) treatment.

4.5.2 Effect of S on phosphorus content in mungbean Stover

The effect of different doses of sulphur showed statistically significant difference in phosphorus concentration in mungbean stover (Table 4.8). The highest phosphorus concentration of 0.538 % was observed in S_2 (25 Kg Zn ha^{-1}) treatment. The lowest phosphorus concentration of 0.430 % was observed in S_0 (control condition) treatment.

Table 4.8 Effect of sulphur on total N P Zn and S concentrations in mungbean stover

Treatments	Total N%	P%	Zn%	S%
S_0	0.625 b	0.430 b	0.004	0.095 b
S_1	0.704 a	0.523 a	0.006	0.119 ab
S_2	0.767 a	0.538 a	0.008	0.152 a
S_3	0.707 b	0.479 b	0.007	0.102 b
LSD$_{(0.05)}$	0.0536	0.0536	NS	0.0536
CV (%)	3.89	5.05	2.02	3.49

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

NS: Non significant

4.5.3 Effect of S on Zn content in mungbean stover

The effect of different doses of S fertilizers showed a statistically significant variation in the zinc concentration in mungbean stover (Table 4.8). The accumulation of Zn increased in higher level of S fertilizer application. The highest zinc concentration among the different doses of S fertilizers (0.008%) was recorded with S_2 treatment. The lowest zinc concentration (0.004%) was observed in the fertilizer combination S_0 where no S fertilizer was applied.

4.5.4 Effect of sulphur on sulphur content in mungbean stover

The effect of different doses of S fertilizers showed a statistically insignificant variation in the sulphur concentration of stover of mungbean (Table 4.8). The highest sulphur concentration in plant among different doses of S fertilizers (0.152 %) was recorded with S_2 treatment. The lowest sulphur concentration (0.095 %) was observed in the treatment S_0 where no S fertilizer was applied.

4.6 Effect of zinc and sulphur on nutrient content in mungbean stover

4.6.1 Interaction effect of zinc and sulphur on nitrogen concentrations in mungbean stover

Significant effect of combined application of different doses of Zn and S fertilizers on the nitrogen concentration was observed in the stover of mungbean (Table 4.9). The highest concentration of nitrogen in the stover (0.821 %) was recorded with the highest dose of Zn_1S_2 (8 kg Zn ha^{-1} + 25kg S ha^{-1}. On the other hand, the lowest nitrogen concentration (0.531 %) in stover was found in Zn_0S_0 (No Zn+ No S) treatment.

4.6.2 Interaction effect of zinc and sulphur on phosphorus concentrations in mungbean stover

Significant effect of combined application of different doses of phosphorus and zinc fertilizers on the phosphorus concentration was observed in the stover of mungbean (Table 4.9). The highest concentration of zinc in the stover (0.674 %) was recorded with Zn_2S_2 (8 kg Zn ha^{-1} + 25kg S ha^{-1}) treatment. on the other hand, the lowest zinc concentration (0.344 %) was found in Zn_0S_0 (No Zn + No S) treatment.

Table 4.9 Interaction effect of zinc and sulphur on N P Zn and S concentrations in mungbean stover

Treatments	Total N%	P%	Zn%	S%
Zn_0S_0	0.531 f	0.344 f	0.004	0.084 c

Zn_0S_1	0.606 e	0.427 e	0.006	0.118 a-c
Zn_0S_2	0.753 bc	0.446 de	0.006	0.141 a-c
Zn_0S_3	0.641 e	0.476 c-e	0.006	0.094 bc
Zn_1S_0	0.761 bc	0.570 b	0.006	0.120 a-c
Zn_1S_1	0.807 ab	0.612 b	0.006	0.149 ab
Zn_1S_2	0.714 cd	0.586 b	0.007	0.119 a-c
Zn_1S_3	0.663 de	0.453 de	0.007	0.104 bc
Zn_2S_0	0.648 e	0.424 e	0.007	0.137a-c
Zn_2S_1	0.737 c	0.513 c	0.008	0.117 a-c
Zn_2S_2	0.821 a	0.674 a	0.007	0.172 a
Zn_2S_3	0.737 c	0.513 c	0.008	0.117 a-c
LSD$_{(0.05)}$	0.0536	0.0536	NS	0536
CV (%)	3.89	5.05	2.02	3.49

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

NS: Non significant

4.6.3 Interaction effect of Zn and S on total zinc content in mungbean stover

Significant effect of combined application of different doses of Zn and S fertilizers on the zinc concentration was observed in stover of mungbean (Table 4.9). The highest concentration of zinc in the stover (0.008%) was recorded with Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}) treatment. on the other hand, the lowest zinc concentration (0.004 %) was found in Zn_0S_0 (No Zn + No S) treatment.

4.6.4 Interaction effect of zinc and sulphur on sulphur content in mungbean stover

Insignificant effect of combined application of different doses of phosphorus and sulphur fertilizers on the sulphur concentration was observed in stover of mungbean (Table 4.9). The highest concentration of sulphur in the stover (0.172 %) was recorded with the Zn_2S_2 treatment (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). On the other hand, the lowest sulphur concentration (0.084 %) was found in Zn_0 S_0 (No Zn + No S) treatment.

4.7 Effect of zinc on nutrient content in mungbean seed

4.7.1 Effect of Zn on nitrogen content in mungbean seed

Application of Zn showed significant variation in the nitrogen concentration in mungbean seed (Table 4.10). The highest nitrogen concentration in seed (7.029 %) was recorded in Zn_2 (8 Kg Zn ha^{-1}). On the other hand, the lowest nitrogen concentration in seed (6.416 %) was recorded in the fu treatment where no Zn was applied. Chanda *et al.* (2002) found significant increase of nitrogen concentration in mungbean seed due to the application of Zn fertilizer.

Table 4.10 Effect of zinc on total N P Zn and S concentrations in mungbean seeds

Treatments	Total N%	P%	Zn%	S%
Zn_0	6.504 bc	0.476 b	0.006	0.337 c
Zn_1	6.521 b	0.517 b	0.007	0.470 ab
Zn_2	7.029 a	0.593 a	0.008	0.522 a

$LSD_{(0.05)}$	0.093	0.054	NS	0.054
CV (%)	0.86	4.47	2.03	6.75

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 Zn on phosphorus content in mungbean seed

Application of Zn increased phosphorus concentration in mungbean plant (Table 4.10). The highest phosphorus concentration in seed (0.593 %) was recorded in Zn_2 (25 Kg ZN ha^{-1}). On the other hand, the lowest phosphorus concentration in seed (0.476 %) was recorded in the Zn_0 treatment where no Zn was applied. Increased P concentration in mungbean seed was also reported by ZnaushiZn *et al.* (1996) found significant increase of phosphorus concentration in mungbean seed due to the application of Zn_2S0_4.

4.7.3 Effect of Zn on zinc content in seed

A statistically significant variations was observed in zinc concentration in seed of mungbean with different doses of Zn (Table 4.10). The highest zinc concentration among the different doses of Zn (0.008 %) was recorded in Zn_2 (25 Kg Zn ha^{-1}) in seed. On the other hand, the lowest zinc concentration in mungbean seed (0.006 %) was recorded in the Zn_0 treatment where no Zn was applied.

4.7.4 Effect of Zn on sulphur content in mungbean seed

Sulphur concentrations in mungbean seed varied significantly with different doses of Zn (Table 4.10). Among the Zn doses the highest sulphur concentration in seed (0.522 %) was recorded in Zn_2 (25 Kg Zn ha^{-1}) treatment. On the other hand, the lowest sulphur concentration in seed (0.337 %) was obtained from having no zinc recorded in the Zn_0 treatment where no Zn was applied.

4. 8 Effect of sulphur on nutrient content in mungbean seed

4.8.1 Effect of sulphur on nitrogen content in mungbean seed

The effect of different doses of sulphur showed statistically significant difference in nitrogen concentration in mungbean seed (Table 4.11). The highest nitrogen concentration among the treatments of sulphur (6.902 %) was observed in S_2 (25Kg S ha^{-1}). The lowest nitrogen concentration (6.329 %) was observed in S_0 (control condition) treatment.

Table 4.11 Effect of sulphur on total N P Zn and S concentrations in mungbean seeds

Treatments	Total N%	P%	Zn%	S%
S_0	6.329 c	0.4817 b	0.004	0.346 c
S_1	6.622 b	0.541 a	0.006	0.456 b
S_2	6.902 a	0.547 a	0.007	0.518 a
S_3	6.808 b	0.491 b	0.006	0.46 b
LSD$_{(0.05)}$	0.093	0.054	NS	0.054
CV (%)	0.86	4.47	2.03	6.75

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NS: Non significant

4.8.2 Effect of S on phosphorus content in mungbean seed

Concentration of P in mungbean seed was affected significant due to the application of different doses of S (Table 4.11). The highest phosphorus concentration among the treatments of S (0.547 %) was observed in S_2 (25 Kg S ha^{-1}). The lowest phosphorus concentration (0.481 %) was found in plants raised without S fertilization. S_0 (0 Kg S ha^{-1}) treatment.

4.8.3 Effect of S on zinc content in mungbean seed

The effect of different doses of S fertilizers showed a statistically significant variation in the zinc concentration in mungbean seed (Table 4.11). The highest zinc concentration in mungbean seed (0.007 %) was recorded in 25 Kg S ha^{-1}. The lowest zinc concentration (0.004 %) in seed was observed in the treatment having no zinc fertilizer was applied.

4.8.4 Effect of S on sulphur content in mungbean seed

The effect of different doses of S fertilizers showed significant variation in sulphur concentration in the seed of mungbean (Table 4.11). The highest sulphur concentration (0.518 %) in seed among different doses of S fertilizer was recorded with S_2 treatment (25 Kg Zn ha^{-1}). The lowest sulphur concentration (0.346 %) in seed was observed in the treatment S_0 where no sulphur fertilizer was applied.

4.9.Interaction of zinc and sulphur on N, P, K, S and Zn concentration in mungbean seeds

4.9.1 Interaction effect of Zn and S on nitrogen concentrations in mungbean seed

Significant effect of combined application of different doses of Zn and S fertilizers on the nitrogen concentration was observed in the seed of mungbean (Table 4.12). The highest concentration of nitrogen in the seed (7.473 %) was recorded with the treatment combination Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). This may be due to the higher supply and subsequent assimilation of this element in the seed. On the other hand, the lowest nitrogen concentration (5.747 %) in seed was found in Zn_0S_0 (No Zn+ No S) treatment combination. Singh *et al.* (1993) found significant increase of nitrogen concentration in mungbean due to the application of increasing level of Zn fertilizer.

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

Treatments	Total N%	P%	Zn%	S%
Zn_0S_0	5.747 h	0.423 f	0.004	0.246 f
Zn_0S_1	6.793 cd	0.473 d-f	0.005	0.340 e
Zn_0S_2	6.973 b	0.533 b-d	0.005	0.426 cd
Zn_0S_3	6.223 f	0.490 c-e	0.006	0.390 de
Zn_1S_0	6.287 f	0.526 b-d	0.006	0.463 c
Zn_1S_1	7.053 b	0.536 bc	0.007	0.556 b
$Zn_1 S_2$	6.757 d	0.516 cd	0.007	0.356 e
Zn_1S_3	6.857 c	0.583 b	0.007	0.560 b
Zn_2S_0	6.590 e	0.496 c-e	0.007	0.393 de
Zn_2S_1	6.550 e	0.583 b	0.006	0.463 c
Zn_2S_2	7.473 a	0.680 a	0.008	0.650 a
Zn_2S_3	6.107 g	0.440 ef	0.005	0.440 cd
LSD$_{(0.05)}$	0.093	0.054	NS	0.054
CV (%)	0.86	4.47	2.03	6.75

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 Zn and S on phosphorus concentrations in mungbean seed

Significant effect of combined application of different doses of Zn and S fertilizers on the phosphorus concentration was observed in mungbean seed (Table 4.12).The highest concentration of phosphorus in the seed (0.680 %)

was recorded with the treatment combinations Zn_2S_2. This may be due to the higher supply and subsequent assimilation of this element in the seed. On the other hand, the lowest phosphorus concentration (0.423 %) in seed was recorded without Zn and S application (Zn_0S_0).

4.9.3 Interaction effect of Zn and S on zinc content in mungbean seed

Significant effect of combined application of different doses of Zn and S fertilizers on the zinc concentration was observed in seed of mungbean (Table 4.12). The highest concentration of zinc in the seed (0.008 %) was recorded with the treatment combination of Zn_2S_2 which may be due to the higher supply and subsequent assimilation of this element in the seed. On the other hand, the lowest zinc concentration (0.004 %) in seed was found in Zn_0S_0 treatment combination.

4.9.4 Interaction effect of Zn and S on sulphur content in mungbean seed

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

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

Combined application of Zn and S fertilizers affected sulphur concentration in mungbean seed (Table 4.12). The highest concentration of sulphur in seed (0.650 %) was recorded with the higher dose of Zn and S fertilizers which may be due to the higher supply and subsequent assimilation of these elements in the seed. The lowest sulphur concentration (0.246 %) in seed was found in Zn_0S_0 treatment combination.

4.10 Effect of zinc on nutrient content in the post harvest soil of mungbean field

44.10.1 Effect of zinc on total nitrogen content in the post harvest soil of mungbean field

A statistically insignificant variation was observed in nitrogen concentration in post harvest soil of mungbean field with different doses of Zn (Table 4.13). Considering the different doses of Zn the highest nitrogen concentration in soil (0.095 %) was recorded in Zn_2 (8 Kg Zn ha^{-1}). The lowest nitrogen concentration in soil (0.078 %) was recorded in the Zn_0 treatment with no Zn was applied.

Table 4.13 Effect of zinc on total N, available P, available Zn and available S contents of the post harvest soil of mungbean field

Treatments	Total N%	Available P (ppm)	Available Zn (ppm)	Available S (ppm)
Zn_0	0.078	16.14 c	0.53 c	19.38 d
Zn_1	0.083	17.93 b	0.74 b	20.39 c
Zn_2	0.095	19.99 a	1.07 a	23.17 b
LSD $_{(0.05)}$	NS	0.675	0.031	0.054
CV (%)	3.05	2.15	1.06	1.15

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

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

Significant variation was observed in phosphorus concentration in postharvest soil with different doses of Zn (Table 4.13). Considering the different doses of Zn the highest phosphorus concentration in soil (19.99 ppm) was recorded in Zn_2 (25 Kg Zn ha^{-1}). The lowest phosphorus concentration in soil (16.14 ppm) was found in Zn_0 treatment which was statistically similar to Zn_0 where no Zn was applied.

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

Zinc concentration in postharvest soil of mungbean with different doses of Zn was found significant (Table 4.13). The highest zinc concentration in soil (1.07 ppm) was recorded in Zn_2 (25 Kg Zn ha^{-1} and the lowest zinc concentration in soil (0.53 ppm) zinc concentration was recorded in Zn_0 treatment. Prasad *et al.* (2000) found significant increase of zinc concentration in the post harvest soil of summer mungbean field due to the application of 20- 30 Kg Zn ha^{-1}.

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

A statistically significant variation was observed in sulphur concentration in the post harvest soil of mungbean with different doses of Zn (Table 4.13). Considering the different doses of Zn the highest sulphur concentration in soil (23.52 ppm) was recorded in Zn_2 (25 Kg Zn ha^{-1}) treatment. The lowest sulphur concentration in soil (19.38 ppm) was recorded in the Zn_0 treatment where no Zn was applied.

4.11 Effect of sulphur on nutrient content in in the post harvest soil of mungbean field

4.11.1 Effect of S on total nitrogen content in the post harvest soil of mungbean field

The effect of different doses of S fertilizers did not show significant variation in the nitrogen concentration in post harvest soil (Table 4.14).

4.11.2 Effect of S on available phosphorus content in the post harvest soil of mungbean field

Significant variation in phosphorus concentration in the soil of mungbean field (Table 4.14) was observed due to S application. Among the different treatments S_2 (25 Kg S ha^{-1}) showed the highest phosphorus concentration (20.70 ppm). But S1 and S2 has no significant difference. The lowest phosphorus concentration (14.72 ppm) in soil was observed in the treatment S_0 where no S fertilizer was applied.

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

Treatments	Total N%	Available P (ppm)	Available Zn (ppm)	Available S (ppm)
S_0	0.079	14.72 b	0.43 c	20.11 c
S_1	0.087	20.10 a	0.67 b	21.15 b
S_2	0.086	20.70 a	1.01 a	23.60 a
S_3	0.082	20.63 a	0.54 b	23.54 a
LSD$_{(0.05)}$	NS	0.675	1.692	0.054
CV (%)	3.05	2.15	1.79	1.15

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

The effect of different doses of S fertilizers produced significant differences in the zinc concentration in soil of mungbean field (Table 4.14). Among the different doses of S fertilizers, S_1 (15 Kg S ha^{-1}) gave the highest zinc concentration (1.01 ppm) in soil. The lowest zinc concentration (0.43 ppm) in soil was observed in the S_0 treatment where no S fertilizer was applied.

4.11.4 Effect of S on available sulphur content in the post harvest soil of mungbean field

The effect of different doses of S fertilizers showed a statistically significant difference in the sulphur concentration in soil of mungbean field (Table 4.14). Among the different treatments of fertilizer doses, S_2 (25 Kg S ha^{-1}) showed the highest sulphur concentration (23.60 ppm) in soil. The lowest sulphur concentration (20.11 ppm) in soil was observed in the treatment S_0 where no S fertilizer was applied.

4.12.l Interaction effect of zinc and sulphur on total nitrogen and phosphorus content of 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 Zn and S fertilizers (Table 4.15). But there was a significant effect on available phosphorus was observed in postharvest soil due to combined application of Zn and S fertilizers. The highest phosphorus concentration (22.50 ppm) was recorded in the treatment combination with Zn_2S_2 (8 Kg ZN ha^{-1}+ 25 Kg S ha^{-1}). On the other hand, the lowest phosphorus concentration (12.30 ppm) in soil was found in Zn_0S_0 treatment combination.

4.12.2 Interaction effect of zinc and sulphur on available zinc and sulphur content of the post harvest soil of mungbean field

Significant effect of combined application of different doses of Zn and S fertilizers on the zinc and sulphur concentration was observed in soil of mungbean field (Table 4.15). The highest zinc concentration (1.21 ppm) and sulphur concentration (27.16 ppm) was recorded in the treatment combination of Zn_2S_2 (8 kg Zn ha^{-1}+ 25kg S ha^{-1}). On the other hand, the lowest zinc concentration (0.42 ppm) and sulphur concentration (17.25 ppm)in the post harvest soil was found in ZN_0S_0 (control condition) treatment.

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

Treatments	Total N%	Available P (ppm)	Available Zn (ppm)	Available S (ppm)
Zn_0S_0	0.07367	12.30 j	0.42 f	17.25 g
Zn_0S_1	0.07867	18.58 f	0.56 e	19.16 f
Zn_0S_2	0.08567	19.93 de	0.61 de	21.74 d
Zn_0S_3	0.07867	13.80 i	1.16 ab	19.16 f
Zn_1S_0	0.08567	19.45 e	0.46 ef	20.28 e
Zn_1S_1	0.08867	20.55 cd	0.68 f	21.74 d
Zn_1 S_2	0.08200	15.80 h	1.04 c	20.28 e
Zn_1S_3	0.09400	21.36 b	1.17 ab	22.07 d
Zn_2S_0	0.08467	16.97 g	0.86 d	23.75 b
Zn_2S_1	0.09067	21.03 bc	1.06 be	23.07 c
Zn_2S_2	0.1073	22.50 a	1.21 a	27.16 a
Zn_2S_3	0.06333	19.81 e	1.15 b	23.75 b
LSD$_{(0.05)}$	NS	0.6752	0.162	0.4216
CV (%)	3.05	2.15	1.79	1.15

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

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 2013, to study the "Effect of zinc and sulphur 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%. Three levels of zinc (0, 4 and 8 kg Zn ha^{-1}) and four levels of sulfur (0, 15, 25 and 35 kg S ha^{-1}) and 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 P(20 kg N from urea, 30 kg K from MOP and 80 kg TSP, respectively) were applied. The whole amounts of Urea, MOP and TSP fertilizer were applied as basal dose during final land preparation. The required amounts of Zn (from zinc oxide) and S (from Gypsum) 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 14th September 2013 and the crop was harvested on 14th December 2013. 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 Zn and S. Plant height increased with increasing levels of Zn and S individually. The individual application of Zn @ 8 kg ha^{-1} (Zn_2) produced the tallest plant (53.92 cm) whereas application of S @ 25 kg ha^{-1} produced the tallest plant height (53.55

cm). The tallest plant (57.20 cm) was found in Zn_2S_2 treatment combination which was higher over control treatment. The individual application of Zn and S 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 Zn and S up to Zn_2S_2 (8 kg Zn ha^{-1}+ 25 kg Zn ha^{-1}).

Like all other plant characters, seed yield of mungbean was influenced significantly due to application of Zn and S. Seed yield increased with increasing levels of Zn and S up to certain level. The highest seed yield (2.417 t ha^{-1}) was found in plants receiving Zn @ 8 kg ha^{-1} and the lowest grain yield (2.223 t ha^{-1}) was recorded in Zn_0 treatment. The individual application of S @ 25 kg ha^{-1} produced the highest amount of seed yield (2.468 t ha^{-1}). The combined application of Zn and S had positive effect on seed yield of mungbean. The highest seed yield (2.657 t ha^{-1}) of mungbean was recorded in Zn_2S_2 treatment. The lowest seed yield (2.043 t ha^{-1}) was recorded in Zn_0S_0 treatment. Combined application of Zn @ 8 kg ha^{-1} and S @ 25 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 Zn and S fertilization. The interaction effect of Zn and S was also found remarkable. The N, P, K, S and Zn concentration in stover varied from 0.5310 % N in Zn_0S_0 treatment to 0.8210 % N in Zn_1S_2 treatment, 0.3443 % P in Zn_0S_0 treatment to 0.6743 % P in Zn_2S_2 treatment, 0.65 % K in Zn_0S_0 treatment to 1.471 % K in Zn_2S_2 treatment, 0.084% S in Zn_0S_0 treatment to 0.162 % S in Zn_2S_2 and 0.004 % Zn in Zn_0S_0 to 0.008 % Zn in Zn_1S_3 treatment, respectively. Nitrogen (N), P, K, S and Zn concentration in stover increased with increasing levels of Zn and S up to certain level.

Nutrient concentration (N, P, K, S and Zn) in seeds were positively affected due to Zn and S fertilization. The interaction effect of Zn and S was also found remarkable. The N, P, K, S and Zn concentration in seeds varied from 5.74% N in Zn_0S_0 treatment to 7.46% N in Zn_2S_2 treatment, 0.42 % P in Zn_0S_0 treatment to 0.69% P in Zn_2S_2 treatment, 1.16 % K in Zn_0S_0 treatment to 2.21 % K in Zn_2S_2 treatment, 0.246% S in Zn_0S_0 treatment to 0.65 % S in Zn_2S_2 and 0.004% Zn in Zn_0S_0 to 0.008% Zn in Zn_2S_2 treatment, respectively. The N, P, K, S and Zn concentration in seeds also increased with increasing level of Zn and S 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 Zn and S at different levels. The addition of Zn and S 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 zinc and sulfur fertilizers @ 8 kg Zn ha^{-1} and 25 kg S ha^{-1} respectively.

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

Application of zinc and sulfur fertilizers @ 8 kg Zn ha^{-1} and 25 kg S 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, 2013 to July, 2013

Name of the **Months**	**Air temperature (^0C)**		**Relative humidity**	**Rainfall (mm)**
	Maximum	**Minimum**		
March, 2013	32	20	45	61
April, 2013	34	23	55	137
May, 2013	33	24	72	245
June, 2013	32	26	79	315
July, 2013	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