EFFECTS OF ZINC AND CALCIUM ON GROWTH AND YIELD OF MUNGBEAN(*Vigna radiata* L.)

A Thesis

By

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECTS OF ZINC AND CALCIUM ON GROWTH AND YIELD OF MUNGBEAN(*Vigna radiata* L.)"** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of Master of ScienceinAgricultural Botany, embodies the result of a piece of *bona-fide* research work carried out by**MANAS KUMAR ROY**, Registration No. **11-04252** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh **Prof. A. M. M. Shamsuzzaman**

Supervisor

Department of Agricultural Botany
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Dedicated To

My Beloved Parents

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ABSTRACT

An experiment was carried out at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from March to June 2016 in order to investigate the effects of zinc and calcium on growth and yield of BARI mug 6. Three levels of zinc (0, 1.5 and 3.0 kg ha^{-1}) and four levels of calcium (0,50,75,100 ppm) were applied for the study. BARI mug 6 was used as plant material.The experiment was set up in randomized complete block design with three replications. Almost all the parameters were significantly influenced by different levels of Zn, Ca and their combinations. Considering interaction of Zn and Ca, the highest plant height (67.30 cm), number of flowers $plant^{-1}$ (30.00) and number of nodules $plant^{-1}$ (30.33) were obtained from the treatment combination of Zn_2Ca_3 where the highest number of leaves $plant^{-1}$ (18.30), number of branches $plant^{-1}$ (4.42) and chlorophyll content (Chl-a = 1.057 μg g^{-1}, Chl-b = 1.423 μg g^{-1} and total = 2.48 μg g^{-1}) were obtained from the treatment combination of Zn_2Ca_2.The highest dry weight $plant^{-1}$ (25.71 g), number of pods $plant^{-1}$ (24.25), number of seeds pod^{-1} (12.87), number of fertile seeds pod^{-1} (11.00), pod length (cm) (8.81), weight of 1000 seed (47.50), weight of seeds $plant^{-1}$ (13.70), seed yield (1357 kg ha^{-1}), stover yield (1666 kg ha^{-1}), biological yield (3023 kg ha^{-1}) and harvest index (44.88%) were achieved from the treatment combination of Zn_1Ca_2. In terms of Zn application, the highest dry weight $plant^{-1}$ (23.14 g), number of pods $plant^{-1}$ (17.87), number of seeds pod^{-1} (12.27), number of fertile seeds pod^{-1} (9.98), pod length (cm) (8.12), weight of 1000 seed (45.95), weight of seeds $plant^{-1}$ (9.82), seed yield (1211.75 kg ha^{-1}), stover yield (1585 kg ha^{-1}), biological yield (2797 kg ha^{-1}) and harvest index (43.21%) were obtained from Zn_1 (1.5 kg ha^{-1}).In response of Ca application, the highest number of branches $plant^{-1}$ (4.28 a), dry weight $plant^{-1}$ (23.31 g), chlorophyll content (Chl-a = 0.865 μg g^{-1}, Chl-b = 1.097 μg g^{-1} and total = 1.962 μg g^{-1}), number of pods $plant^{-1}$ (17.63), number of seeds pod^{-1} (12.33), number of fertile seeds pod^{-1} (10.00), pod length (cm) (8.34), weight of 1000 seed (45.94), weight of seeds $plant^{-1}$ (10.00), seed yield (1212 kg ha^{-1}), stover yield (1587 kg ha^{-1}), biological yield (2798 kg ha^{-1}) and harvest index (43.15%) were achieved from Ca_2 (75 ppm).In case of control treatment for both Zn and Ca the results on all the studied parameters were lowest.

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ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Milligram
ml	=	Milliliter
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celsius
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
Mg	=	Microgram

CHAPTER I

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 holds the 3rd position in protein content and 4th in both acreage and production in Bangladesh (Sarkar *et al*., 2012).

In Bangladesh, daily consumption of pulses is only 14.30 g capita^{-1} day^{-1} (BBS, 2010), while World Health Organization (WHO) suggested 45g capita^{-1} day^{-1} for a balanced diet. Mungbean is a 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 25% protein,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 the best of all other pulses (Khan, 1981).

Besides being a rich source of protein, it maintains soil fertility through biological nitrogen fixation in soil and thus plays a vital role in sustainable agriculture (Kannaiyan, 1999). Mungbean fixes 63-342 kg N ha^{-1} per season in soil by biological nitrogen fixation (Kannaiyan, 1999).

In Bangladesh, total production of pulses is only 0.65 million ton against a requirement of 2.7 million ton. This means that the shortage is almost 80% of the total requirement (Rahman and Ali, 2007). The reason is mostly due to low yield (MoA, 2013). At present, the area under pulse cropsare 0.406 million hectare with a production of 0.322 million ton (BBS, 2013), where mungbean is cultivated in the area of 0.108 million ha with production of 0.03 million ton (BBS, 2014).

Salam *et al.* (2005) studied the effect of micronutrients on fertilization and productivity potential of mungbean and urdbean gave the highest dry matter accumulation, pods per plant, seed yield per plant ,seeds per pod,100 seed weight, pod and seed weight per plant, harvest index and production efficiency.

Fertilizer is one of the most important factors that affect crop production. Fertilizer recommendation for soils and crops is a dynamic process and the management of fertilizers is one of the important factors that greatly affect the growth, development and yield of mungbean .

The soils of different parts of Bangladesh are more or less deficient in zinc and molybdenum as well as nitrogen fixing bacteria (Rhizobium sp.) which causes poor yield of mungbean. However, there is a great possibility to increase its production by cultivating HYV with balanced fertilization including micronutrient. Micronutrients play an important role in increasing yield of pulses and oilseed legumes through their effects on the plant itself and on the nitrogen fixing symbiotic process. Deficiencies of these nutrients have been very pronounced under multiple cropping systems due to excess removal by HYV of crops and hence their exogenous supplies are urgently required. Zinc and B deficiency is widespread in the country; much observed in wetland rice soils, light textured soils and calcareous soils (Jahiruddin et al., 1992; Rabman et al. 1993; Islam et al., 1997).

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).

Calcium is part of every plant cell. Much of the Ca in plants is part of the cell walls in a compound called calcium pectate. Without adequate Ca, cell walls would collapse and plants would not remain upright. Calcium is not mobile in plants. It does not easily move from old leaves to young leaves. Deficiency symptoms for Ca are rare in agriculture (Rehm, 1994). Calcium also has a positive effect on soil properties. This nutrient improves soil structure thereby increasing water penetration, and providing a more favorable soil environment for growth of plant roots and soil microorganisms (McLean *et al*., 1983).

The farmers of Bangladesh generally grow mungbean with almost no fertilizer. So, there is an ample scope of increasing the yield of mungbean unit^{-1} area by using balanced fertilizer including zinc and calcium.

Considering the above facts, the present study was therefore, undertaken with the following objectives:

1. To find out the effect of zinc on the growth and yield on BARI mug6.
2. To find out the effect of calcium on the growth and yield on BARI mug6.
3. To find out the appropriate combination of zinc and calcium on the growth and yield on BARI mug6.

CHPTER II

REVIEW OF LITERATURE

Mungbean is one of the important pulse crops in Bangladesh as well as many countries of the world. The crop gets less concentration by the researcher on various aspects because normally it grows with less care and management practices. So, the research as far done in Bangladesh is not adequate and conclusive. In this chapter, an attempt has been made to review the available information in home and abroad regarding the effect of zinc and calcium on the growth and yield of mungbean along with some legumes.

2.1 Effect of zinc (Zn)

Rahman *et al*. (2015) conducted a field experiment to study the effects of phosphorus and zinc on the growth and yield of mungbean (BARI mug 6). Four levels of phosphorus (0, 15, 20 and 25 kg P ha^{-1}) and three levels of zinc (0, 1.5 and 3 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. In case 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 of 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 0 kg Zn ha^{-1}. The maximum significant plant height (52.05 cm), number of branch $plant^{-1}$ (2.87), number of pods $plant^{-1}$ (20.86), number of seeds pod^{-1} (12.65) and weight of 1000-seeds (45.11 g) were also obtained with the treatment of 3 kg Zn ha^{-1}.

Karmakar *et al*. (2015) conducted a field experiment during the *kharif* season of 2014 to study the effects of zinc on the concentrations of N, P, K, S and Zn in mungbean stover and seed (BARI mug6). Three levels of zinc (0, 1.5 and 3 kg ha^{-1}) were used in the study. The results revealed that the N, P, K and S concentration of mungbean plant increased significantly from control to 3 kg Zn ha^{-1} treatment. Application of zinc increase organic carbon, N, P, K and S status of postharvest soil significantly. The treatment also produced highest pods plant^{-1}, seeds pod^{-1} and seed yield ha^{-1}.

Malik *et al*. (2015) conducted an experiment during the years 2011-2012 to study the effect of zinc on plant height (cm), number of productive branches, number of leaves, leaf area (sq.cm.), fresh weight (g), dry weight (g), number of pods per plant, seed yield per plant and 1000seed weight (g) of mungbean (*Vigna radiata* L.). The doses of zinc were 5, 10, 15 and 20 ppm. All the parameters were significantly influenced by Zn and the highest seed yield per plant was attained from 10 ppm of zn.

Ram and Katiyar (2013) conducted a field experiment to evaluate the influence of sulphur and zinc on mungbean for two consecutive summer seasons of 2008-09 and 2009-10. Four levels of sulphur (0, 20, 40 and 60 kg ha^{-1}), four levels of zinc (0, 5, 7.5 and 10 kg ha^{-1}) and the summer mungbean variety "Narendra Moong-1" were used. The results showed that application of 10 kg Zn ha^{-1} significantly increased the plant height, number of branches plant^{-1}, number of nodules plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, seed yield and protein content (%). The control (0 kg Zn ha^{-1}) had the poorest performance in respect of yield and protein content of mungbean seed during both the years. The highest seed yield (14.40 q ha^{-1}) was observed in 10 kg Zn ha^{-1} treatment which was significantly superior over rest of the treatments for both seasons. The minimum seed yield (9.56 and 10.06 q ha^{-1}) was achieved with 5 kg Zn ha^{-1} during both the years.

Samreen *et al*. (2013) conducted an experiment using four varieties of mungbean (Ramazan, Swat mungI, NM92 and KMI) with nutrient solutions with and without Zn. Each variety was applied with Zn solutions at three levels i.e. 0, 1 and 2 μM concentrations. Plant growth, chlorophyll contents, crude proteins and Zn contents were noted to be higher when greater supply of zinc doses was applied. Plant phosphorous contents declined with supply of Zn from 1 μM to 2 μM compared to the control signifying a Zn/P complex foundation possibly in roots of plant, preventing the movement of P to plant. They concluded that zinc application at 2 μM concentration in solution culture turned out to be the best treatment for improving the growth and quality parameters of mungbean.

Quddus *et al*. (2011) carried out an experiment in AEZ 12 of Bangladesh during *kharif* of 2008 and 2009. The objectives were to evaluate the effect of zinc and boron on the yield and yield contributing characters of mungbean (*Vigna radiata* L. Wilczek). There were four levels of zinc (0, 0.75, 1.5, and 3.0 kg/ha) and four levels of boron (0, 0.5, 1.0, and 2 kg/ha). Results showed that the combination of $Zn_{1.5}B_{1.0}$ produced significantly higher yield 3058 kg/ha and 2631 kg/ha, in the year 2008 and 2009, respectively. The lowest yields 2173 kg/ha and 1573 kg/ha, were found in control Zn_0B_0 combination. They also found that combined applications of zinc and boron were superior to their single application in both the years.

Biswas *et al.* (2010) conducted a two-year field experiment during *kharif* season of 2005 and 2006 to study the effect of zinc spray and seed inoculation on nodulation, growth and seed yield of mungbean. The results revealed that two rounds of foliar spray of 0.05% $ZnSO_4$ solution at 25 and 40 days after sowing (DAS) increased seed yield by 9.02% (1236.50 kg ha^{-1}) over water spray (1164.50 kg ha^{-1}).

Ali *et al.* (2002) reported that yield losses of varying magnitude in chickpea, e.g., 22-50% were due to zinc. Genotypic differences in response to application of zn had also been found among mungbean genotypes.

Bharti *et al.* (2002) carried out a field experiment during the winter of 1997-98 to observe the effect of Zn (0, 1.5 and 2.5 kg ha^{-1}) application on the yield and nutrition of mungbean (cv. BG256). They reported that the mean seed yield, pod number plat^{-1} and pod length increased when Zn content increased, whereas stover yield decreased with the increasing rate of Zn.

Abdo (2001) conducted two field experiments during the 1998 and 1999 seasons to study the effect of foliar spray with micronutrients (Zn, Mn or B) on morphological, physiological and anatomical parameters of two mungbean *(Vigna radiata)* cultivars V- 2010 (Giza-1) and VC-1000. Zn (0.2 or 0.4 g/l), Mn (1.5 or 2.0 g/l), B (3.0 or 5.0 g/l) and a mixture of Zn, Mn and B (0.2, 1.5 and 3.0 g/l,
of 5 kg borax + 2 kg $ZnSO_4$. Soil application gave higher yields than foliar or soil + foliar application.

Chowdhury and Narayanan (1992) observed that the tallest plant of mungbean (64.9 cm) was found in plant receiving inoculums alone with Zn and B (both 1 kg ha^{-1}) as compared to all other treatments. They also reported that plant height increased 123% higher in plants receiving inoculums along with Zn (1 kg ha^{-1}) and B (1 kg ha^{-1}) over control.

Pandey and Singh (1981) reported that seed yields of greengram grown with NPK on a sandy loam calcareous soil (pH 8.3) were increased by applying 10 kg ZnSO4 ha^{-1}.

Gupta (1979) reported that Zn is a micronutrient requiring for plant growth relatively to a smaller amount. The total Zn content of soils lies between 20 and 200 ppm with the available Zn fraction ranging from 0.4 to 0.5 ppm.

2.2 Effect of calcium (Ca)

Calcium is the most critical element in growth and development of pulse crop seeds and is the main limiting of the pulse production in many parts of the world and perhaps it can said that calcium is the most important and vital element in the pulse crop production system. Ca helps building block of protein and a key ingredient in the formation of chlorophyll by improving plant growth due to increased supply of calcium ion (Ca^{2+}) and to decrease the damaging effects of salinity in plants (Badr *et al*., 2002).

Kumar *et al*. (2010) conducted an experiment to study the effect of calcium and sulphur on plant height (cm), number of leaves, leaf area (sq. cm.), dry weight, number of pods, yield of seed per plant and 1000 seeds weight of mungbean (*Vigna radiata* L.) var. PDU-54 and PU-44. The doses of calcium were 25, 50, 100 and 200 ppm. The concentrations of sulphur were 25, 50, 75 and 100 ppm. The results were found significant for both the varieties of mungbean. Calcium application at 200 ppm gave the highest plant height (cm), number of leaves, leaf area (sq. cm.), dry weight, number of pods, yield of seed per plant and 1000 seeds weight.

Gashti *et al*. (2012) conducted an experiment in order to investigate the effect of calcium and potassium application on yield and yield components of peanut (*Arachis hypogaea* L.). Potassium rates in 4 levels (0, 30, 60 and 90 kg/ha from potassium sulfate) and calcium rates in 4 levels (0, 30, 60 and 90 kg/ha from gypsum) were used. Results showed that the application of calcium had significant effect on pod yield, kernel yield and oil content, So that applying of 90 kg/ha calcium form gypsum performed considerably better than the rest. But applying of these fertilizers had no significant effect on protein content of peanut kernel. The yield of pod and kernel also increased with increasing of calcium application along with potassium. The highest yield of pod (5650 kg/ha) and kernel (4622 kg/ha) were obtained form 90 kg/ha calcium form gypsum. The highest oil content (46.22%) was obtained in 90 kg/ha calcium and 30 kg/ha potassium (interaction effect).

Calcium supply can increase both N use efficiency and hence plant growth as well as Na+ exclusion by plant roots (Aslam *et al*., 2001; Mahmood *et al*., 2009).

Proportion of Ca^{2+} becomes inadequate under saline sodic conditions and may result in reduced yields due mainly to ion imbalance (Aslam *et al*. 2001; Mahmood *et al*., 2010).

Without adequate S and Ca^{2+}, crops cannot reach their full potential regarding yield or protein content (Zhao *et al*., 1999 and Blake-Kalff *et al*., 2000). Ca^{2+} and Sulfur improve K/Na selectivity and increases the action of Ca^2+ in reducing the injurious effects of Na+ in plants (Wilson *et al*., 2000).

Due to synergic effect of Ca^2+ and S in the presence of adequate N, P, K and Zn, their efficiency is enhanced which results in increased crop productivity. The improved Ca^2+ and S nutrition through gypsum application is an economical and practical treatment for suppressing the uptake of toxic elements (Na, Cl, Mg, Mo and Se) which are antagonistic to plant uptake of S and Ca^2+. Thus gypsum ($CaSO_4$) application is useful not only in increasing crop production and quality of produce but also in improving soil conditions for crop growth (Tandon, 1991).

Grichar *et al*. (2002) and Murata (2003) found that enough calcium content in the soil around the peanut pods leads to increased yield, oil content and protein content of the kernel. It decreases decayed pod and increases absorption of other nutritional elements from the soil. Deficit of calcium and low pH are the most important factors in limiting of growth and production of peanut. Calcium increases the growth and survival of the symbiotic bacteria in peanut, especially in acidic soil and thus, has a positive effect on nitrogen fixation. Presence of enough calcium content in the soil leads to prevent of black hallow and cracked pods, decreases of aflatoxin production and consequently decreases decayed pod of peanut. In fact, calcium is one of the most important nutritional elements to gain high yield and high quality of peanut. Law content of calcium leads to production of immature pods, black embryo in seed, weak germination of seeds and decays peanut pod.

It is well established that calcium is a yield-enhancing nutrient in pulse crop and it is needed for both good vegetative growth and normal healthy fruit development (Cheema *et al*., 1991). AOSA (2012) reported that a uniform stand of healthy, vigorous seedlings is also essential if growers are to achieve the yield and quality needed for profitable crop production. Thus, seed quality is also critical to growers.

Ntare *et al*. (2008) found from an experiment that the deficiency of both calcium and phosphorus, particularly calcium, is the possible cause of low yield in groundnut production, and that calcium deficiency leads to a high percentage of aborted seeds (empty pods or pops) and improperly filled pods.

Chen and Dick (2011) conducted a study to determine the effect of two calcium sources i.e. gypsum and dolomitic lime on yield and quality of groundnuts. The application of gypsum as a calcium and sulphur source can contribute immensely to an improvement on groundnut yield and quality, compared to both calcitic lime (CL) and dolomitic lime (DL), especially under rainfed conditions. They further emphasized that gypsum is a multipurpose fertilizer capable of improving both chemical and physical properties of soils.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from March 2016 to June 2016to study the effect of zinc and calcium on the growth and yield of mungbean (BARI mug 6). The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in appendix I.

3.1.2 Soil

The soil belongs to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.1 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in appendix II.

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by 3 distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October. Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in appendix III.

3.2 Test crop and its characteristics

Seeds of BARI mug 6 were collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. After multilocation trials BARI released this variety for general cultivation with a popular name BARI mug 6 in the year 2003. The plant attains a height of 55-65 cm, the leaves look light green and its life duration is about 75-80 days. Seeds are larger than local variety and light brown-yellow in color. Seed contains 20-25% protein. 1000seed weight is 35-40g. Under proper management practices it may give 1.6-2.0 t ha^{-1} seed yield.

3.3 Experimental details

3.3.1 Treatments

The experiment comprised two factors.

Factor A: Zinc (Zn) – Three doses as follows:

1. Zn_0= 0 kg ha^{-1}
2. Zn_1= 1.5 kg ha^{-1}
3. Zn_2= 3 kg ha^{-1}

Factor B: Calcium (Ca) – Four doses as follows:

1. Ca_0= 0 ppm
2. Ca_1= 50 ppm
3. Ca_2= 75 ppm
4. Ca_3= 100 ppm

Treatment combinations: (3×4) = 12

Zn_0Ca_0, Zn_0Ca_1, Zn_0Ca_2, Zn_0Ca_3, Zn_1Ca_0, Zn_1Ca_1, Zn_1Ca_2, Zn_1Ca_3, Zn_2Ca_0, Zn_2Ca_1, Zn_2Ca_2, Zn_2Ca_3.

Zinc and calcium were applied as zinc sulphate ($ZnSO_{4}.7H_2O$) and gypsum ($CaSO_4.2H_2O$) respectively. Zinc sulphate contains 23%Zn and gypsum contains 33% Ca.

3.3.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of doses of Zinc (Zn) and Calcium (Ca). The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot 3.0 m× 1.43 m. The distance between blocks and plots were 0.5 m and 0.25 m respectively. The details were presented in appendix IV.

3.4 Growing of crops

3.4.1 Seed collection

The seeds of the test crop i.e., BARI mug 6was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.4.2 Preparation of the main field

The plot selected for the experiment was opened in the first week of March, 2016 with a power tiller and was exposed to the sun for a week, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for sowing.

3.4.3 Seed Sowing

Seeds are sown on 20 March 2016.

3.4.4 Fertilizers and manure application

The fertilizer N, P and K were applied @ 20.7 kg N/ha, 48 kg P_2O_5/ha, 34.8 kg K_2O/ha in the form of urea, TSP and MOP respectively during final land preparation as basal dose. Zn was applied in the form of $ZnSO_4.7H_2O$ as per treatment during final land preparation. Ca was applied in the form of$CaSO_4.2H_2O$ as per treatment at 30DAS and 45 DAS through foliar spray.

3.4.5 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the mungbean.

3.4.5.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after germination in every alternate day in the evening. Further irrigation was done when needed. Stagnant water was effectively drained out at the time of heavy rains.

3.4.5.2 Weeding

Several weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. First weeding was done at 20 days after sowing (DAS), 2nd and 3rd weeding was done at 35 and 50 DAS, respectively.

3.4.5.3 Plant protection

At early stage of growth few hairy caterpillar and virus vectors (jassid) attacked the young plants and at later stage of growth pod borer attacked the plant. Hairy caterpillar and pod borer were successfully controlled by the application of Diazinon 50 EC and Ripcord @ 1 L ha^{-1} on the time of 50% pod formation stage.

3.5 Harvesting, threshing and cleaning

The crop was harvested at full maturity from 8th May, 2016. Harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of mungbean seed. Fresh weight of seed and stover were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The stover was sun dried and the yields of seed and stover plot^{-1} were recorded and converted to t ha^{-1}.

3.6 Data Collection and Recording

Ten plants were selected randomly from each unit plot for recording data on crop parameters and the yield of grain and straw were taken plot wise. The following parameters were recorded during the study:

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}
4. Leaf area index
5. Dry weight plant^{-1} (g)
6. Days to first flowering
7. Number of flowers plant^{-1}
8. Days to 100% maturity
9. Number of nodules plant^{-1}
10. Chlorophyll content
11. Number of pods plant^{-1}
12. Number of seeds plant^{-1}
13. Number of fertile seeds plant^{-1}
14. Pod length (cm)
15. 1000 seed weight (g)
16. Weight of seeds plant^{-1} (g)
17. Seed yield (kg ha^{-1})
18. Stover yield (kg ha^{-1})
19. Biological yield (kg ha^{-1})
20. Harvest index (%)

3.7 Procedure of recording data

3.7.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at different days after sowing of crop duration. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves.

3.7.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at different days after sowing of crop duration. Leaves number plant^{-1} was recorded from pre selected 10 plants by counting all leaves from each plot and mean was calculated.

3.7.3 Number of branches plant^{-1}

The branches were counted from the 10 randomly selected plant at harvest time and mean value was determined.

3.7.4 Leaf area index

Leaf area index was determined by counting number of leaves/plant, leaf length and breadth & then multiplying leaf area per m^2. The leaf area index (LAI) was worked out by using the following formula.

$$LAI = \frac{\text{Total leaf area m}^{-2}}{\text{Ground area (1 m}^2\text{)}}$$

3.7.5 Dry weight plant^{-1} (g)

Five sample plants in each plot were selected at random in the sample rows outside the central 1 m^2 of effective harvesting area and cut close to the ground surface at different days of crop duration. They were first air dried for one hour, then oven dried at 80(±5) °C till a constant weight was attained. Mean dry weight was expressed as per plant basis.

3.7.6 Days to first flowering

Days to 1st flowering was measured from the date of sowing when 1st of the mungbean plants flowered.

3.7.7 Number of flowers plant^{-1}

Number of flowers plant^{-1} was calculated from pre selected 10 plants at a certain duration from 1st flowering to harvest an mean was calculated per plant basis.

3.7.8 Days to 100% maturity

Days to 100% maturity was measured from the date of sowing when at least 90% of the mungbean pods was matured. It was measured at harvest from pre selected 10 plants from each plot.

3.7.9 Chlorophyll content (mg g^{-1})

The leaves of the mungbean plants were extracted with 80% acetone. The leaf extract was centrifuged and the supernatant was collected.Chlorophyll content was estimated using the method described by Witham *et al.* (1986). The absorbance of the supernatant was recorded at 645 and 663 ɳm for chlorophyll 'a' and 'b' contents respectively. Theamount of chlorophylls was expressed as µg g^{-1} fresh weight.

3.7.10 Number of nodules plant^{-1}

Number of nodules plant^{-1} was collected from pre selected uprooted 10 plants at harvest. Number of total nodules of ten plants from each plot was noted and the mean number was expressed per plant basis.

3.7.11 Number of pods plant^{-1}

Number of total pods of 10 plants from each plot was noted and the mean number was expressed per plant basis.

3.7.12 Number of seeds plant^{-1}

Number of total seeds of ten plants from each plot was noted and the mean number was expressed per plant basis.

3.7.13 Number of fertile seeds plant^{-1}

Number of fertile seeds of ten plants from each plot was noted and the mean number was expressed per plant basis.

3.7.14 Pod length (cm)

Length of 10 pods of 10 selected plants from each plot was noted and the mean number was expressed per pod basis.

3.7.15 Weight of 1000 seeds (g)

One thousand cleaned and dried seeds were counted randomly form 1m^2 area and weight by using a digital electric balance and the weight was expressed in gram.

3.7.16 Weight of seeds plant^{-1} (g)

Sees weight of ten plants from each plot was noted and the mean weight was expressed per plant basis.

3.7.17 Seed yield (kg ha^{-1})

The plants of the central 1.0 m^2 from the plot were harvested for taking grain yield. The grains were threshed from the plants, cleaned, dried and then weighed. The yield of grain in kg plot^{-1} was adjusted at 12% moisture content of grain and then it was converted to t ha^{-1}.

3.7.18 Stover yield (kg ha^{-1})

The stover of the harvested crop in each plot was sun dried to a constant weight. Then the stovers were weighted and thus the stover yield plot^{-1} was determined. The yield of stover in kg plot^{-1} was converted to kg ha^{-1}.

3.7.19 Biological yield (kg ha^{-1})

Grain yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Stover yield.

3.7.20 Harvest index (%)

Harvest index was calculated from the ratio of grain yield to biological yield and expressed in percentage. It was calculated by using the following formula.

$$\text{HI (\%)} = \frac{\text{Seed yield}}{\text{Biological yield (Seed yield + Stover yield)}} \times 100$$

3.8 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Deferent Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to investigate the effects of zinc and calcium on the growth and yield of mungbean (BARI mug 6). The results obtained from the study have been presented, discussed and compared in this chapter . The analyses of variance of data in respect of all the parameters have been shown in appendix IV-XII. The results have been presented and discussed with the help of tables and graphs and possible interpretation has been given under different subheadings.

4.1 Plant height

4.1.1 Effect of Zn

Different levels of Zn treatment exhibited significant influence on plant height of mungbean at different days after sowing (Fig. 1 and appendix V). Results revealed that the highest plant height (32.98, 63.06 and 65.77 cm at 25, 40 DAS and at harvest, respectively) was obtained from Zn_2 (3 kgZn ha^{-1}) which was statistically identical with Zn_1 (1.5 kg Zn ha^{-1}) at harvest. The lowest plant height (29.91, 57.75 and 62.28 cm at 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Zn_0).

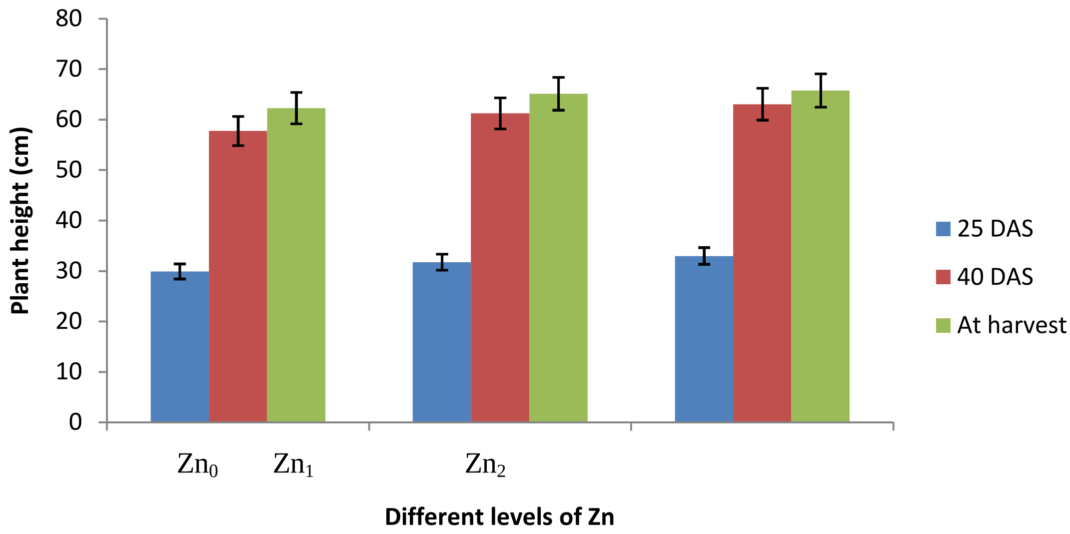

Fig. 1. Plant height of mungbean affected by different levels of Zn

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}

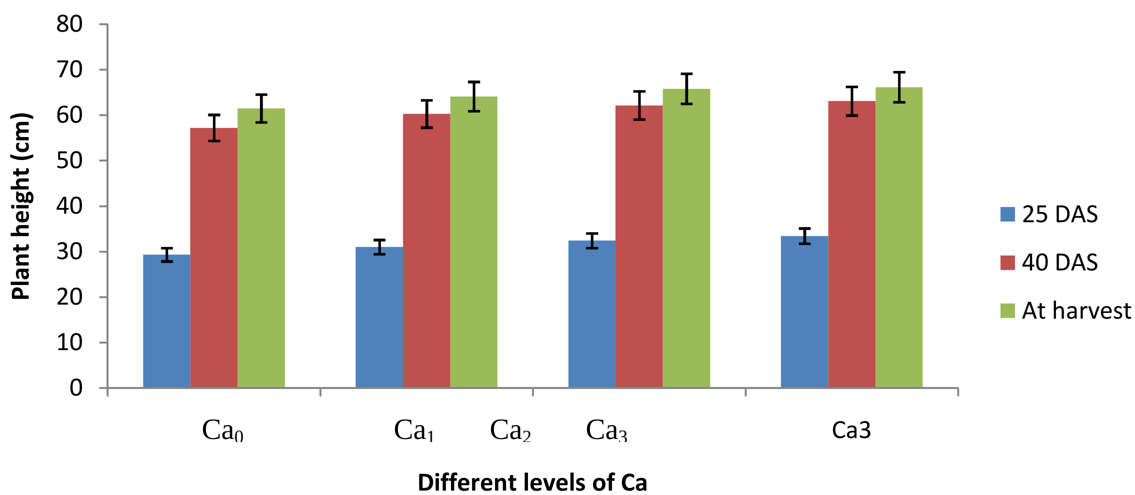

Fig. 2. Plant height of mungbean affected by different levels of Ca

Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.1.2 Effect of Ca

The data on plant height (cm) of mungbean at different growth stages as influenced by Ca was significant (Fig. 2 and Appendix V). Results revealed that the highest plant height (33.43, 63.08 and 66.17 cm at 25, 40 DAS and at harvest, respectively) was obtained from Ca_3 (100 ppm Ca) which was statistically identical with Ca_2 (75 ppm Ca) at all growth stages where the lowest plant height (29.31, 57.22 and 61.49 cm at 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Ca_0). Ca helps as a key ingredient in the formation of chlorophyll by improving plant growth due to increased supply of calcium ion (Ca^{2+}) (Badr *et al*., 2002). Kumar *et al*. (2010) also found significant effect on plant height affected by Ca application.

4.1.3 Combined effect of Zn and Ca

Significant variation was found on plant height of mungbean influenced by combined effect of Zn and Ca at all growth stages (Table 1 and Appendix V). It seems from the results that combination of Zn_2Ca_3 showed the highest plant height (35.37, 65.87 and 67.30 cm at 25, 40 DAS and at harvest, respectively) which was statistically identical with Zn_2Ca_2 and statistically similar with Zn_1Ca_2 and Zn_1Ca_3 at harvest. The lowest plant height (27.37, 53.03 and 58.77 cm at 25, 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_0Ca_0 which was immediate lower than the treatment combination of Zn_0Ca_1.

Table 1. Interaction effect of Zn and Ca on plant height

Treatment	Plant height (cm)		
	25 DAS	40 DAS	At harvest
Zn_0Ca_0	27.37 g	53.03 e	58.77 g
Zn_0Ca_1	29.50 f	58.17 d	61.50 f
Zn_0Ca_2	31.37 de	59.60 cd	64.30 d
Zn_0Ca_3	31.40 de	60.20 c	64.53 d
Zn_1Ca_0	29.77 ef	59.03 cd	62.63 e
Zn_1Ca_1	31.60 d	60.22 c	65.07 cd
Zn_1Ca_2	32.07 cd	62.57 b	66.20 ab
Zn_1Ca_3	33.53 bc	63.17 b	66.67 ab
Zn_2Ca_0	30.80 def	59.67 cd	63.07 e
Zn_2Ca_1	31.93 d	62.47 b	65.77 bc
Zn_2Ca_2	33.80 b	64.30 ab	66.93 a
Zn_2Ca_3	35.37 a	65.87 a	67.30 a
$LSD_{0.05}$	1.507	1.777	1.033
CV (%)	8.268	10.522	11.314

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.2 Number of leaves plant^{-1}

4.2.1 Effect of Zn

Number of leaves plant^{-1} at different growth stages of mungbean was significantly influenced by different doses of Zn (Fig. 3 and Appendix VI). It was found that the highest number of leaves plant^{-1} (5.930, 10.79 and 16.62 at 25, 40 DAS and at harvest, respectively) was obtained from Zn_2 (3 kg Zn ha^{-1}) which was statistically identical with Zn_1 (1.5 kg Zn ha^{-1}) where the lowest number of leaves plant^{-1} (4.970, 9.180 and 14.79 at 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Zn_0). Malik *et al*. (2015) also found that Zn had significant influence on number of leaves per plant which supports the present study.

4.2.2 Effect of Ca

Different levels of Ca application had significant effect on number of leaves plant^{1} at different growth stages of mungbean (Fig. 4 and Appendix VI). Results revealed that the highest number of leaves plant^{-1} (6.00, 11.19 and 17.02 at 25, 40 DAS and at harvest, respectively) was obtained from Ca_2 (75 ppm Ca) followed by Ca_3 (100 ppm Ca) and Ca_1 (50 ppm Ca) where the lowest number of leaves plant^{-1} (5.40, 9.810 and 15.32 at 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Ca_0). Similar result was also observed by Kumar *et al*. (2010). Calcium application had significant effect on number of leaves plant^{-1} and at 200 ppm gave the highest number of leaves Kumar *et al*. (2010).

4.2.3 Combined effect of Zn and Ca

Significant variation was observed on number of leaves plant^{-1} influenced by combined effect of Ca and Zn (Table 2 and Appendix VI). Results showed that the highest number of leaves plant^{-1} (6.37, 12.50 and 18.30 at 25, 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_2Ca_2 followed by Zn_1Ca_3, Zn_2Ca_1 and Zn_2Ca_2. The lowest number of leaves plant^{-1} (4.70, 8.570 and 13.97 at 25, 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_0Ca_0 which was statistically similar with Zn_0Ca_1.

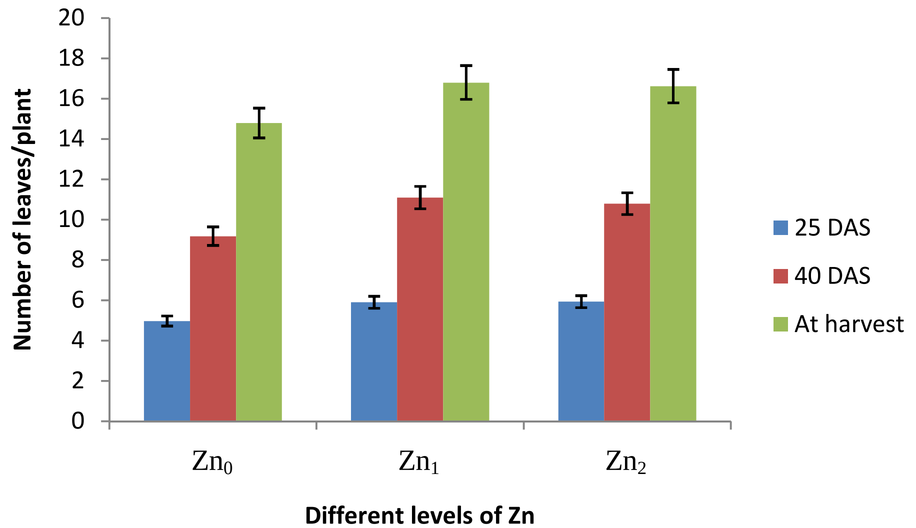

Fig. 3. Number of leaves plant^{-1}of mungbean affected by different levels of Zn

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}

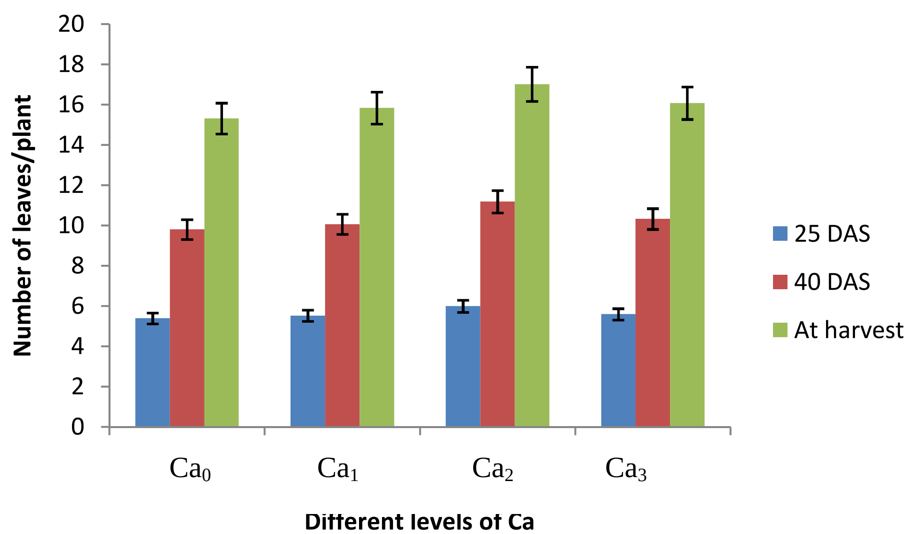

Fig. 4. Number of leaves plant^{-1}of mungbean affected by different levels of Ca

Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

Table 2. Interaction effect of Zn and Ca on number of leaves $plant^{-1}$

Treatment	Number of leaves $plant^{-1}$		
	25 DAS	40 DAS	At harvest
Zn_0Ca_0	4.70 d	8.570 g	13.97 g
Zn_0Ca_1	5.00 cd	8.770 g	14.57 fg
Zn_0Ca_2	5.33 c	9.900 ef	15.47 de
Zn_0Ca_3	5.13 c	9.470 f	15.13 ef
Zn_1Ca_0	5.73 b	10.37 de	15.87 cd
Zn_1Ca_1	5.77 b	10.57 cd	16.13 c
Zn_1Ca_2	6.37 a	12.50 a	18.30 a
Zn_1Ca_3	5.87 b	10.93 bc	16.90 b
Zn_2Ca_0	5.77 b	10.50 cd	16.13 c
Zn_2Ca_1	5.83 b	10.87 b-d	16.83 b
Zn_2Ca_2	6.30 a	11.17 b	17.30 b
Zn_2Ca_3	5.80 b	10.60 cd	16.20 c
$LSD_{0.05}$	0.382	0.4908	0.6082
CV (%)	4.276	5.344	7.112

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.3 Number of branches plant^{-1}

4.3.1 Effect of Zn

Number of branches plant^{-1} at different growth stages of mungbean was significantly influenced by different levels of Zn application (Fig. 5 and Appendix VII). It was observed that Zn_2 (3 kg Zn ha^{-1}) gave the highest number of branches plant^{-1} (2.23 and 4.24 at 40 DAS and at harvest, respectively) which was statistically identical with Zn_1 (1.5 kg Zn ha^{-1}) where the lowest number of branches plant^{-1} (1.52 and 3.91 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Zn_0). Rahman *et al*. (2015) found significantly increased number of branch plant^{-1} (2.87) from the treatment of Zn_2 (3 kg Zn ha^{-1}). Malik *et al*. (2015) and Ram and Katiyar (2013) also found that Zn had significant influence on number of branches per plant.

4.3.2 Effect of Ca

Different levels of Ca application had significant effect on number of branches plant^{-1} at different growth stages of mungbean (Fig. 6 and Appendix VII). Results exhibited that the highest number of branches plant^{-1} (2.25 and 4.28 at 40 DAS and at harvest, respectively) was obtained from Ca_2 (75 ppm Ca) followed by Ca_3 (100 ppm Ca).the lowest number of branches plant^{-1} (1.66 and 3.95 at 40 DAS and at harvest, respectively) was obtained from control treatment (Ca_0) which was statistically similar with Ca_1 (50 ppm Ca).

4.3.3 Combined effect of Zn and Ca

Significant variation at different growth stages of mungbean was observed on number of branches plant^{-1} influenced by combined effect of Zn and Ca (Table 3 and Appendix VII). It was observed that the the highest number of branches plant^{-1} (2.60 and 4.42 at 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_2Ca_2 which was statistically identical with Zn_1Ca_2 and Zn_2Ca_3 and statistically similar with Zn_1Ca_3. The lowest number of branches plant^{-}

[1](1.27 and 3.80 at 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_0Ca_0 which was statistically identical with Zn_0Ca_3 and statistically similar with Zn_0Ca_1at harvest.

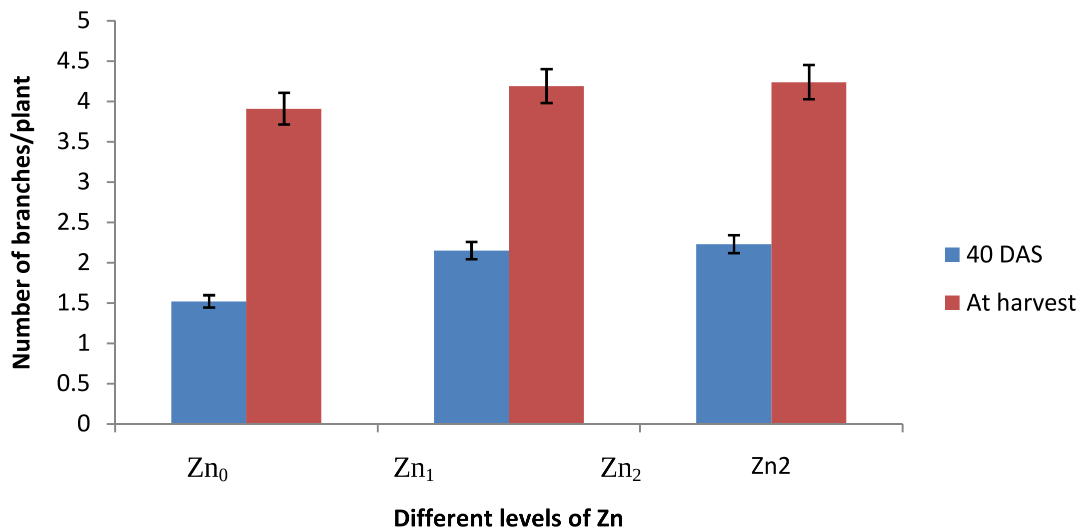

Fig. 5. Number of branches plant^{-1} of mungbean affected by different levels of Zn

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}

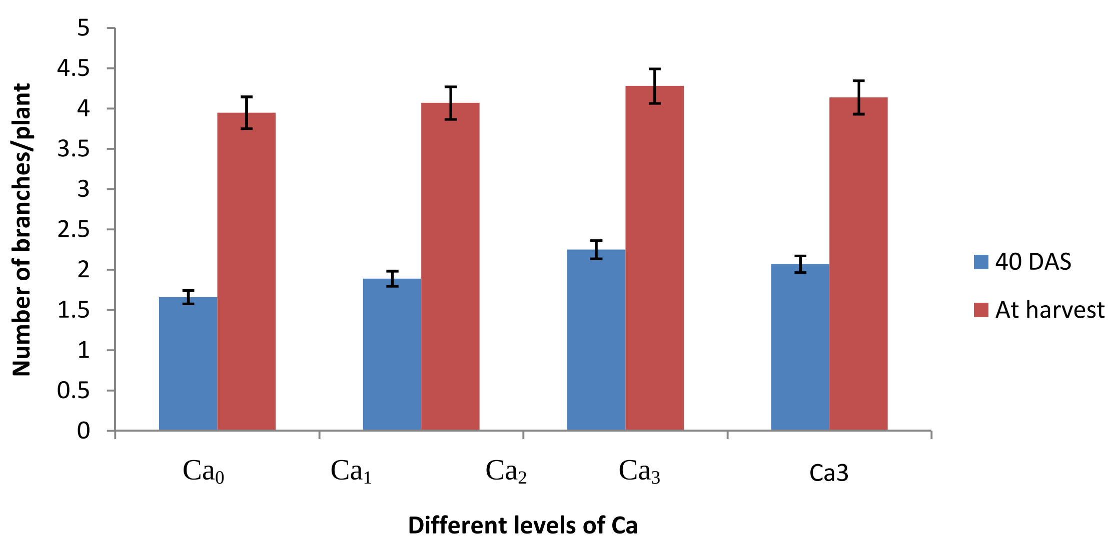

Fig. 6. Number of branches plant^{-1} of mungbean affected by different levels of Ca

Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

Table 3. Interaction effect of Zn and Ca on number of branches $plant^{-1}$

Treatment	Number of branches $plant^{-1}$	
	40 DAS	At harvest
Zn_0Ca_0	1.270 e	3.800 f
Zn_0Ca_1	1.700 d	3.870 ef
Zn_0Ca_2	1.700 d	4.130 bc
Zn_0Ca_3	1.400 e	3.830 f
Zn_1Ca_0	1.830 cd	3.970 de
Zn_1Ca_1	1.970 c	4.170 bc
Zn_1Ca_2	2.570 a	4.370 a
Zn_1Ca_3	2.230 b	4.230 ab
Zn_2Ca_0	1.870 cd	4.070 cd
Zn_2Ca_1	2.000 c	4.170 bc
Zn_2Ca_2	2.600 a	4.420 a
Zn_2Ca_3	2.470 a	4.330 a
$LSD_{0.05}$	0.1855	0.1312
CV (%)	4.117	5.236

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.4 Leaf area index

4.4.1 Effect of Zn

Leaf area index of mungbean at different growth stages as influenced by different doses of Zn was significant (Fig. 7 and Appendix VIII). It was examined that the highest leaf area index (4.65, 8.53 and 14.23 at 25, 40 DAS and at harvest, respectively) was obtained from Zn_2 (3 kg Zn ha^{-1}) which was statistically identical with Zn_1 (1.5 kg Zn ha^{-1}) where the lowest leaf area index (3.58, 7.85 and 12.85 at 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Zn_0). Similar result was also observed by Malik *et al*. (2015) and found that Zn had significant influence on leaf area per square cm.

4.4.2 Effect of Ca

At different crop duration of mungbean, different levels of Ca application exhibited significant influence on leaf area index(Fig. 8 and Appendix VIII). Results exposed that the highest leaf area index (4.68, 8.56 and 16.62 at 25, 40 DAS and at harvest, respectively) was obtained from Ca_3 (100 ppm Ca) followed by Ca_2 (75 ppm Ca) and Ca_1 (50 ppm Ca). The lowest leaf area index (3.74, 7.94 and 13.03 at 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Ca_0). Kumar *et al*. (2010) also found similar result with the present study and found that calcium application at 200 ppm gave the highest leaf area.

4.4.3 Combined effect of Zn and Ca

Leaf area index of mungbean was found significant due to different treatment combination of Zn and Ca (Table 4 and Appendix VIII). Results revealed that the highest leaf area index (5.00, 9.13 and 15.00 at 25, 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_2Ca_3followed by Zn_1Ca_2. The lowest leaf area index (2.67, 7.40 and 11.33 at 25, 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_0Ca_0 that was immediately lower than Zn_0Ca_1 but significantly different.

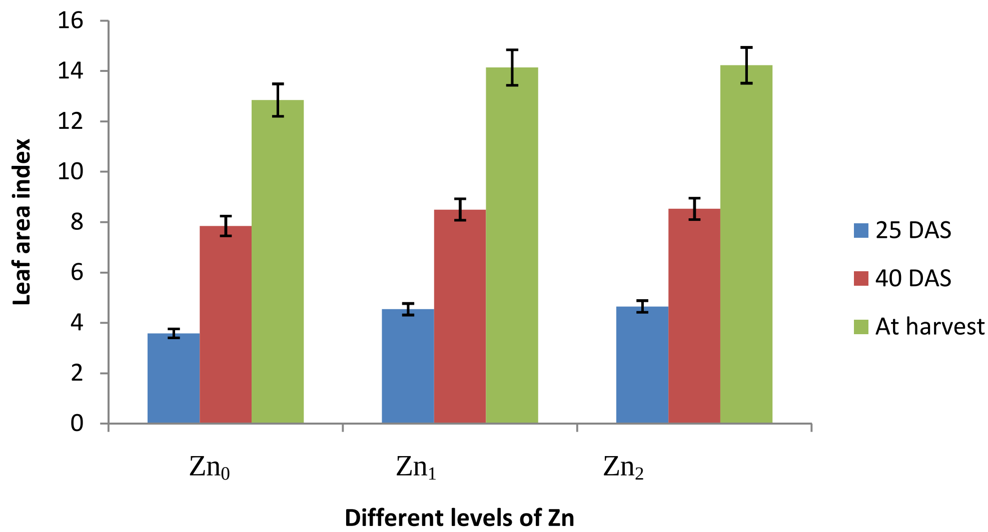

Fig. 7. Leaf area index of mungbean affected by different levels of Zn

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}

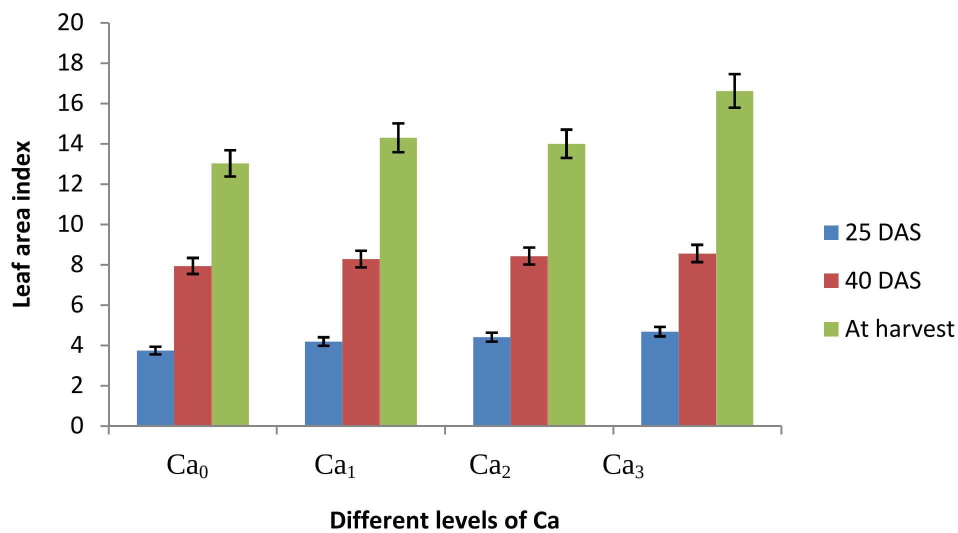

Fig. 8. Leaf area index of mungbean affected by different levels of Ca

Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

Table 4. Interaction effect of Zn and Ca on leaf area index

Treatment	Leaf area index		
	25 DAS	40 DAS	At harvest
Zn_0Ca_0	2.67 e	7.40 d	11.33 f
Zn_0Ca_1	3.80 d	8.07 bc	12.93 e
Zn_0Ca_2	4.13 c	8.13 bc	13.80 c
Zn_0Ca_3	3.70 d	7.80 c	13.33 d
Zn_1Ca_0	4.23 c	8.20 bc	13.87 c
Zn_1Ca_1	4.37 bc	8.37 b	13.93 c
Zn_1Ca_2	4.97 a	9.07 a	14.57 b
Zn_1Ca_3	4.57 b	8.43 b	14.10 c
Zn_2Ca_0	4.33 bc	8.23 bc	13.90 c
Zn_2Ca_1	4.40 bc	8.40 b	14.00 c
Zn_2Ca_2	4.90 a	8.43 b	14.10 c
Zn_2Ca_3	5.00 a	9.13 a	15.00 a
$LSD_{0.05}$	0.308	0.394	0.3470
CV (%)	3.758	6.218	6.527

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.5 Dry weight plant^{-1}

4.5.1 Effect of Zn

Significant variation was observed on dry weight plant^{-1} at different crop duration influenced by different doses of Zn (Fig. 9 and Appendix IX). It was examined that the highest dry weight plant^{-1} (7.47, 16.27 and 23.14 g at 25, 40 DAS and at harvest, respectively) was obtained from Zn_1 (1.5 kg Zn ha^{-1}) which was statistically identical with Zn_2 (3 kg Zn ha^{-1}) where the lowest dry weight plant^{-1} (5.95, 13.01 and 19.27 g at 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Zn_0). Malik *et al*. (2015) and Yang and Zhang (1998) also found similar result and observed that Zn had significant influence on dry weight per plant. Kulkarny *et al.* (1989) reported that the zinc application increased dry weight of groundnut.

4.5.2 Effect of Ca

Dry weight plant^{-1}of mungbean at different growth stages as influenced by different levels of Ca application was significant (Fig. 10 and Appendix IX). It was examined that the highest dry weight plant^{-1} (7.50, 16.26 and 23.31 g at 25, 40 DAS and at harvest, respectively) was obtained from Ca_2 (75 ppm Ca) followed by Ca_3 (100 ppm Ca) and Ca_1 (50 ppm Ca). The lowest dry weight plant^{-1} (6.25, 13.76 and 19.97 g at 25, 40 DAS and at harvest, respectively) was obtained from control treatment (Ca_0). Kumar *et al*. (2010) obtained similar result with the present study and found that calcium application at 200 ppm gave the highest dry weight.

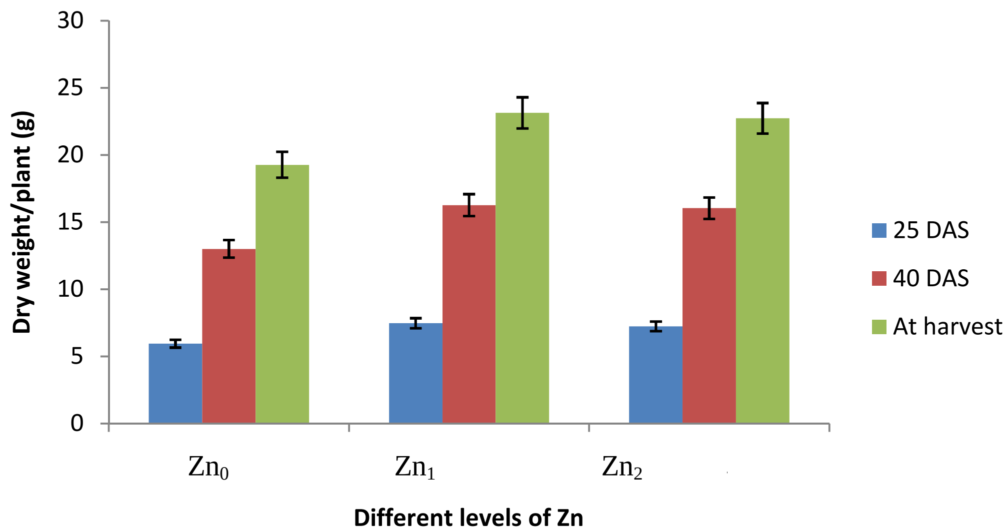

Fig. 9. Dry weight plant^{-1} of mungbean affected by different levels of Zn

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}

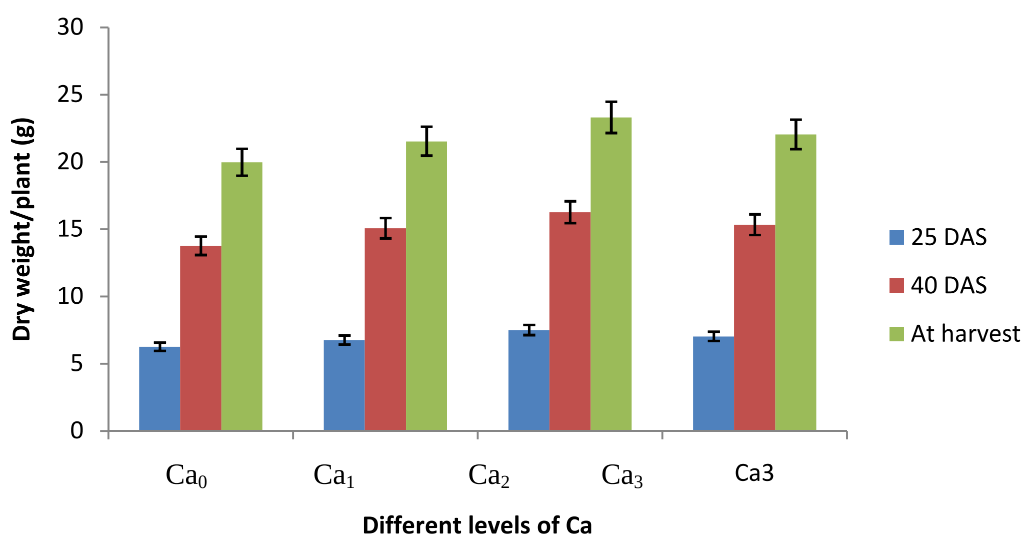

Fig. 10. Dry weight plant^{-1} of mungbean affected by different levels of Ca

Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.5.3 Combined effect of Zn and Ca

Combined effect of Zn and Ca had significant effect on dry weight plant^{-1} at different growth stages of mungbean (Table 5 and Appendix IX). It was found that the highest dry weight plant^{-1} (8.62, 17.85 and 25.71 g at 25, 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_1Ca_2 followed by Zn_1Ca_3 and Zn_2Ca_2. The lowest dry weight plant^{-1} (5.80, 11.48 and 17.67 g at 25, 40 DAS and at harvest, respectively) was obtained from the treatment combination of Zn_0Ca_0 which was nearest to the treatment combinations of Zn_0Ca_3 but significantly different to each other.

Table 5. Interaction effect of Zn and Ca on dry weight plant^{-1}

Treatment	Dry weight plant^{-1} (g)		
	25 DAS	40 DAS	At harvest
Zn_0Ca_0	5.80 h	11.48 i	17.67 i
Zn_0Ca_1	5.97 h	13.45 h	19.74 gh
Zn_0Ca_2	6.10 gh	14.18 g	20.48 fg
Zn_0Ca_3	5.91 h	12.92 h	19.19 h
Zn_1Ca_0	6.33 fg	14.72 fg	20.88 ef
Zn_1Ca_1	6.88 de	15.32 ef	21.62 e
Zn_1Ca_2	8.62 a	17.85 a	25.71 a
Zn_1Ca_3	8.04 b	17.18 b	24.36 b
Zn_2Ca_0	6.62 ef	15.07 f	21.36 ef
Zn_2Ca_1	7.42 c	16.43 cd	23.22 cd
Zn_2Ca_2	7.78 b	16.76 bc	23.74 bc
Zn_2Ca_3	7.15 cd	15.88 de	22.58 d
$LSD_{0.05}$	0.334	0.6152	0.9321
CV (%)	4.826	8.334	8.249

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.6 Chlorophyll content

4.6.1 Effect of Zn

Significant variation was found for total chlorophyll content of mungbean recorded at 45 DAS affected by (Table 6 and Appendix X). Total chlorophyll content is a sum of 'chlorophyll-a' and 'chlorophyll-b'. 'Chlorophyll-a' and 'chlorophyll-b' were also significantly affected by different doses of Zn (Table 6 and Appendix X). Results revealed that the highest chlorophyll-a and chlorophyll-b content of leaves (0.846 and 1.092 µg g^{-1}, respectively) were obtained from Zn_2 (3 kg Zn ha^{-1}) treatment which was statistically different from all other Zn treatments where the lowest chlorophyll-a and chlorophyll-b content of leave (0.511 and 0.651 µg g^{-1}, respectively) were obtained from control treatment (Zn_0). Accordingly, the highest total chlorophyll content of leaves (1.938 µg g^{-1}) was also obtained from Zn_2 (3 kg Zn ha^{-1})and the lowest total chlorophyll content of leaves (1.162 µg g^{-1}, respectively) was obtained from control treatment (Zn_0).Khalil *et al*. (1998) studies reflected that zinc deficient leaves appeared light green due to the low concentration of chlorophyll. Hisamitsu *et al*. (2001) investigated that zinc deficiency disrupted the chlorophyll synthesis. Increased chlorophyll contents are due to zinc which acts as a structural and catalytic component of proteins, enzymes and as co-factor for normal development of pigment biosynthesis (Balashouri, 1995).

4.6.2 Effect of Ca

Chlorophyll contentof mungbean leaves (chlorophyll-a, chlorophyll-b and total chlorophyll) recorded at 45 DAS affected by different levels of Ca application was significant (Table 6 and Appendix X). Results indicated that the highest chlorophyll-aand chlorophyll-b content of leaves (0.824 and 1.096 µg g^{-1}, respectively) were obtained fromCa_2 (75 ppm Ca) treatment which was statistically identical with Ca_3 (100 ppm Ca)where the lowest chlorophyll-a and chlorophyll-b content of leaves (0.498 and 0.612 μg g^{-1}, respectively) were obtained from control treatment (Ca_0).Similarly, the highest total chlorophyll content of leaves (1.921 μg g^{-1}) was also obtained from Ca_2 (75 ppm Ca) which was statistically identical with Ca_3 (100 ppm Caand the lowest total chlorophyll content of leaves (1.111μg g^{-1}) was obtained from control treatment (Ca_0).Similar effect was also obtained by Badr *et al*., (2002). Ca helps as a key ingredient in the formation of chlorophyll by improving plant growth (Badr *et al*., 2002).

4.6.3 Combined effect of Zn and Ca

Treatment combination of Zn and Ca showed significant variation on chlorophyll contentof mungbean recorded at 45 DAS (Table 6 and Appendix X). Results signified that the highest chlorophyll-a and chlorophyll-b content of leaves (1.057 and 1.423 μg g^{-1}, respectively) were obtained from the treatment combination of Zn_2Ca_2 which was statistically identical with Zn_2Ca_3. The lowest chlorophyll-a and chlorophyll-b content (0.410 and 0.482 μg g^{-1}, respectively) was obtained from the treatment combination of Zn_0Ca_0 which was statistically identical with Zn_0Ca_1in terms of chlorophyll-a. Regarding total chlorophyll content of leaves the highest (2.480 μg g^{-1}) was also obtained from the treatment combination of Zn_2Ca_2 which was statistically identical with Zn_2Ca_3 and closely followed by Zn_1Ca_2. The lowest total chlorophyll content of leaves (0.892 μg g^{-1}) was obtained from the treatment combination of Zn_0Ca_0 which was statistically identical with Zn_0Ca_1.

Table 6. Chlorophyll content of mungbean affected by zinc and calcium and their interaction

Treatment	Chlorophyll (Chl) content at 45 DAS (µg g^{-1})		
	Chl-a	Chl-b	Total
Effect of Zn			
Zn_0	0.511 c	0.651 c	1.162 c
Zn_1	0.737 b	0.901 b	1.638 b
Zn_2	0.846 a	1.092 a	1.938 a
$LSD_{0.05}$	0.214	0.236	0.276
CV (%)	2.304	2.567	3.152
Effect of Ca			
Ca_0	0.498 c	0.612 c	1.111 c
Ca_1	0.603 b	0.720 b	1.323 b
Ca_2	0.865 a	1.097 a	1.962 a
Ca_3	0.824 a	1.096 a	1.921 a
$LSD_{0.05}$	0.211	0.196	0.207
CV (%)	2.304	2.567	3.152
Combined effect of Zn and Ca			
Zn_0Ca_0	0.410 g	0.482 g	0.892 g
Zn_0Ca_1	0.436 g	0.522 f	0.958 g
Zn_0Ca_2	0.460 fg	0.680 de	1.140 e
Zn_0Ca_3	0.736 c	0.921 c	1.657 c
Zn_1Ca_0	0.520 f	0.600 e	1.120 ef
Zn_1Ca_1	0.652 d	0.778 c	1.430 d
Zn_1Ca_2	0.956 b	1.186 b	2.142 ab
Zn_1Ca_3	0.820 b	1.040 b	1.860 bc
Zn_2Ca_0	0.565 ef	0.755 cd	1.320 d
Zn_2Ca_1	0.721 cd	0.860 c	1.581 cd
Zn_2Ca_2	1.057 a	1.423 a	2.480 a
Zn_2Ca_3	1.039 a	1.330 a	2.369 a
$LSD_{0.05}$	0.108	0.233	0.362
CV (%)	2.304	2.567	3.152

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.7 Days to first flowering

4.7.1 Effect of Zn

Significant variation was found for days to 1^{st} flowering of mungbean due to different doses of Zn (Table 7 and Appendix XI). Results revealed that the highest days to first flowering (37.67) was obtained from Zn_2 (3 kg Zn ha^{-1}) followed by Zn_1 (1.5 kg Zn ha^{-1}) where the lowest days to first flowering(36.00) was obtained from control treatment (Zn_0).

4.7.2 Effect of Ca

Days to 1^{st} flowering of mungbean affected by different levels of Ca application was significant (Table 7 and Appendix XI). Results exposed that the highest days to first flowering (37.11) was obtained from Ca_3 (100 ppm Ca) which was statistically identical with Ca_2 (75 ppm Ca) where the lowest days to first flowering (35.56) was obtained from control treatment (Ca_0). According to Kamara (2010), adequate amounts of calcium should be present in the soil from early flowering stage up to pod filling in order to get good yield.

4.7.3 Combined effect of Zn and Ca

Treatment combination of Zn and Ca showed significant variation on days to 1^{st} flowering of mungbean (Table 7 and Appendix XI). Results indicated that the highest days to first flowering (38.00) was obtained from the treatment combination of Zn_2Ca_3 followed by Zn_2Ca_2. The lowest days to first flowering (35.00) was obtained from the treatment combination of Zn_0Ca_0 followed by Zn_0Ca_3 and Zn_2Ca_0.

4.8 Number of flowers plant^{-1}

4.8.1 Effect of Zn

Number of flowers plant^{-1}was significantly influenced by different doses of Zn of mungbean (Table 7 and Appendix XI). The highest number of flowers plant^{-1} (23.11) was obtained from Zn_2 (3 kg Zn ha^{-1}) which was statistically identical with Zn_1 (1.5 kg Zn ha^{-1}). The lowest number of flowers plant^{-1} (20.85) was obtained from control treatment (Zn_0).

4.8.2 Effect of Ca

Number of flowers plant^{-1} was significantly influenced by different levels of Ca application (Table 7 and Appendix XI). The highest number of flowers plant^{-1} (24.05) was obtained from Ca_3 (100 ppm Ca) followed by Ca_1 (50 ppm Ca) and Ca_2 (75 ppm Ca) where the lowest number of flowers plant^{-1} (19.88) was obtained from control treatment (Ca_0).

4.8.3 Combined effect of Zn and Ca

Significant variation was observed on number of flowers plant^{-1} influenced by combined effect of Zn and Ca (Table 7 and Appendix XI). Results showed that the highest number of flowers plant^{-1} (30.00) was obtained from the treatment combination of Zn_2Ca_3 followed by Zn_1Ca_2. The lowest number of flowers plant^{-1} (18.50) was obtained from the treatment combination of Zn_0Ca_0 which was statistically similar with Zn_0Ca_1.

4.9 Days to 100% maturity

4.9.1 Effect of Zn

Days to 100% maturitywas significant due to different doses of Zn of mungbean (Table 6 and Appendix X). The highest days to 100% maturity (55.33) was obtained from Zn_2 (3 kg Zn ha^{-1}) which was statistically identical with Zn_1 (1.5

kgZn ha^{-1}). The lowest days to 100% maturity (52.13) was obtained from control treatment (Zn_0).

4.9.2 Effect of Ca

Days to 100% maturityinfluenced by different levels of Ca application of mungbean was significant (Table 7 and Appendix XI). The highest days to 100% maturity (54.97) was obtained from Ca_3 (100 ppm Ca) which was statistically similar with Ca_2 (75 ppm Ca). The lowest days to 100% maturity (53.27) was obtained from control treatment (Ca_0). Grichar *et al*. (2002) and Murata (2003) found that law content of calcium leads to production of immature pods, black embryo in seed, weak germination of seeds and decays peanut pod.

4.9.3 Combined effect of Zn and Ca

Days to 100% maturityof mungbean at harvest was found Significant due to different treatment combination of Zn and Ca (Table 7 and Appendix XI). The highest days to 100% maturity (56.30) was obtained from the treatment combination of Zn_2Ca_3 which was statistically identical with Zn_1Ca_3 and which was statistically similar with Zn_2Ca_2. The lowest days to 100% maturity (51.40) was obtained from the treatment combination of Zn_0Ca_0 which was immediate lower than Zn_0Ca_1, Zn_0Ca_2 and Zn_0Ca_3 but significantly different.

4.10 Number of nodules $plant^{-1}$

4.10.1 Effect of Zn

Significant variation was found for number of nodules $plant^{-1}$ of mungbean due to different doses of Zn (Table 7 and Appendix XI). It was found that the highest number of nodules $plant^{-1}$ (28.17) was obtained from Zn_2 (3 kg Zn ha^{-1}) which was statistically identical with Zn_1 (1.5 kg Zn ha^{-1}) where the lowest number of nodules $plant^{-1}$ (16.92) was obtained from control treatment (Zn_0). Ram and Katiyar (2013) also found significant influence on number of nodules. Bolanos *et* *al.* (1994) suggested that Zn is required for normal development and function of nodules. Kulkarny *et al.* (1989) reported that the zinc application increased nodule weight and nodule number.

4.10.2 Effect of Ca

Number of nodules plant^{-1} of mungbean affected by different levels of Ca application was significant (Table 7 and Appendix XI). Results revealed that the highest number of nodules plant^{-1} (27.22) was obtained from Ca_3 (100 ppm Ca) which was statistically identical with Ca_2 (75 ppm Ca). The lowest number of nodules plant^{-1} (18.89) was obtained from control treatment (Ca_0).

4.10.3 Combined effect of Zn and Ca

Treatment combination of Zn and Ca showed significant variation on number of nodules plant^{-1} of mungbean (Table 7 and Appendix XI). The highest number of nodules plant^{-1} (30.33) was obtained from the treatment combination of Zn_2Ca_3 which was statistically similar with Zn_2Ca_2. The lowest number of nodules plant^{-1} (11.33) was obtained from the treatment combination of Zn_0Ca_0 which was nearest to Zn_0Ca_1 but significantly different.

Table 7. Yield contributing parameters of mungbean showing days to first flowering, number of flowersplant^{-1}, days to 100% maturity and number of nodules plant^{-1}affected by zinc and calcium and their interaction

Treatment	Yield contributing parameters			
	Days to first flowering	Number of flowers plant^{-1}	Days to 100% maturity	Number of nodules plant^{-1}
Effect of Zn				
Zn_0	36.00 c	20.85 b	52.13 b	16.92 b
Zn_1	36.58 b	23.00 a	55.30 a	26.00 a
Zn_2	37.67 a	23.11 a	55.33 a	28.17 a
$LSD_{0.05}$	0.4043	0.5328	0.6358	2.949
CV (%)	9.376	7.291	8.553	10.419
Effect of Ca				
Ca_0	35.56 c	19.88 c	53.27 c	18.89 c
Ca_1	36.55 b	22.61 b	54.23 b	23.00 b
Ca_2	36.89 a	22.74 b	54.50 ab	25.67 a
Ca_3	37.11 a	24.05 a	54.97 a	27.22 a
$LSD_{0.05}$	0.2782	0.9946	0.5792	2.157
CV (%)	9.376	7.291	8.553	10.419
Combined effect of Zn and Ca				
Zn_0Ca_0	35.00 e	18.50 g	51.40 h	11.33 i
Zn_0Ca_1	36.33 c	19.34 fg	52.30 g	15.00 h
Zn_0Ca_2	37.00 b	20.81 ef	52.60 g	19.33 g
Zn_0Ca_3	35.67 d	20.67 ef	52.20 g	22.00 f
Zn_1Ca_0	36.00 cd	21.65 de	54.00 f	21.67 f
Zn_1Ca_1	36.33 c	22.80 d	54.80 de	25.00 d
Zn_1Ca_2	37.00 b	27.08 b	55.20 cd	28.00 c
Zn_1Ca_3	37.00 b	20.47 ef	56.10 a	29.33 b
Zn_2Ca_0	35.67 d	25.22 c	54.40 ef	23.67 e
Zn_2Ca_1	37.00 b	20.33 ef	55.60 bc	29.00 b
Zn_2Ca_2	37.33 b	20.95 e	56.00 ab	29.67 ab
Zn_2Ca_3	38.00 a	30.00 a	56.30 a	30.33 a
$LSD_{0.05}$	0.3710	1.357	0.4544	0.9458
CV (%)	9.376	7.291	8.553	10.419

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.11 Number of pods plant^{-1}

4.11.1 Effect of Zn

Number of pods plant^{-1} of mungbean was significantly influenced by different doses of Zn (Table 8 and Appendix XII). Results exposed that the highest number of pods plant^{-1} (17.87) was obtained from Zn_1 (1.5 kg Zn ha^{-1}) which was statistically identical with Zn_2 (3 kg Zn ha^{-1}). The lowest number of pods plant^{-1} (14.36) was obtained from control treatment (Zn_0). Rahman *et al*. (2015) and Karmakar *et al*. (2015) found similar results from different experiments and observed that that maximum number of pods plant^{-1} of mungbean was obtained from the treatment of Zn_2 (3 kg Zn ha^{-1}).

4.11.2 Effect of Ca

Number of pods plant^{-1} was significantly influenced by different levels of Ca application (Table 8 and Appendix XII). Results signified that the highest number of pods plant^{-1} (17.63) was obtained from Ca_2 (75 ppm Ca) which was statistically identical with Ca_1 (50 ppm Ca) and Ca_3 (100 ppm Ca). The lowest number of pods plant^{-1} (13.33) was obtained from control treatment (Ca_0). Similar result was observed by Kumar *et al*. (2010). Gashti *et al*. (2012) showed that the application of calcium had significant effect on pod yield. Kumar *et al*. (2010) also found that calcium application at 200 ppm gave the highest number of pods per plant.

4.11.3 Combined effect of Zn and Ca

Significant variation was observed on number of pods plant^{-1} influenced by combined effect of Zn and Ca (Table 8 and Appendix XII). Results showed that the highest number of pods plant^{-1} (24.25) was obtained from the treatment combination of Zn_1Ca_2 which was significantly different from all other treatment combinations. The lowest number of pods plant^{-1} (12.27) was obtained from the treatment combination of Zn_0Ca_0 which was statistically similar with Zn_2Ca_0.

4.12 Number of seeds pod^{-1}

4.12.1 Effect of Zn

Number of seeds pod^{-1} was significant due to different doses of Zn (Table 8 and Appendix XII). Results indicated that the highest number of seeds pod^{-1} (12.27) was obtained from Zn_1 (1.5 kg Zn ha^{-1}) which was statistically identical with Zn_2 (3 kg Zn ha^{-1}) where control treatment (Zn_0) showed lowest number of seeds pod^{-1} (11.10). Similar result was also observed by Rahman *et al*. (2015), Karmakar *et al*. (2015) and Ram and Katiyar (2013). Rahman *et al*. (2015) found highest number of seeds pod^{-1} (12.65) from Zn_2 (3 kg Zn ha^{-1}). Karmakar *et al*. (2015) also found maximum number of seeds pod^{-1} with the same Zn treatment.

4.12.2 Effect of Ca

Number of seeds pod^{-1} influenced by different levels of Ca application of mungbean was significant (Table 8 and Appendix XII). It was found that the highest number of seeds pod^{-1} (12.33) was obtained from Ca_2 (75 ppm Ca) followed by Ca_1 (50 ppm Ca) and Ca_3 (100 ppm Ca). The lowest number of seeds pod^{-1} (11.20) was obtained from control treatment (Ca_0).

4.12.3 Combined effect of Zn and Ca

Number of seeds pod^{-1} of mungbean at harvest was found Significant due to different treatment combination of Zn and Ca (Table 8 and Appendix XII). Results indicated that the highest number of seeds pod^{-1} (12.87) was obtained from the treatment combination of Zn_1Ca_2 which was statistically identical with Zn_1Ca_3 and Zn_2Ca_2. The lowest number of seeds pod^{-1} (10.20) was obtained from the treatment combination of Zn_0Ca_0 which was nearest to Zn_0Ca_1 but significantly different.

4.13 Number of fertile seeds pod^{-1}

4.13.1 Effect of Zn

Significant variation was found for number of fertile seeds pod^{-1} of mungbean due to different doses of Zn (Table 8 and Appendix XII). Results verified that the highest number of fertile seeds pod^{-1} (9.98) was obtained from Zn_1 (1.5 kg Zn ha^{-1}) which was statistically identical with Zn_2 (3 kg Zn ha^{-1}) where the lowest number of fertile seeds pod^{-1} (8.56) was obtained from control treatment (Zn_0). Similar result was also observed by Karmakar *et al*. (2015) and Ram and Katiyar (2013).

4.13.2 Effect of Ca

Number of fertile seeds pod^{-1} of mungbean affected by different levels of Ca application (Table 8 and Appendix XII). Results revealed that the highest number of fertile seeds pod^{-1} (10.00) was obtained from Ca_2 (75 ppm Ca) followed by Ca_1 (50 ppm Ca) and Ca_3 (100 ppm Ca). The lowest number of fertile seeds pod^{-1} (8.85) was obtained from control treatment (Ca_0).

4.13.3 Combined effect of Zn and Ca

Treatment combination of Zn and Ca showed significant variation on number of fertile seeds pod^{-1} of mungbean (Table 8 and Appendix XII). The highest number of fertile seeds pod^{-1} (11.00) was obtained from the treatment combination of Zn_1Ca_2 which was significantly different from all other treatment combinations followed by Zn_1Ca_3, Zn_2Ca_1 and Zn_2Ca_2. The lowest number of fertile seeds pod^{-1} (8.260) was obtained from the treatment combination of Zn_0Ca_0 which was statistically similar with Zn_0Ca_1.

4.14 Pod length (cm)

4.14.1 Effect of Zn

Pod lengthof mungbean was not significantly influenced by different doses of Zn (Table 8 and Appendix XII). The highest pod length (cm) (8.12) was obtained from Zn_1 (1.5 kg Zn ha^{-1}) where the lowest pod length (cm) (8.03) was obtained from control treatment (Zn_0). Bharti *et al.* (2002) also reported similar result and found that pod length increased when Zn content increased.

4.14.2 Effect of Ca

Pod length was significantly influenced by different levels of Ca application (Table 8 and Appendix XII). It was examined that the highest pod length (cm) (8.34) was obtained from Ca_2 (75 ppm Ca) which was statistically identical with Ca_3 (100 ppm Ca) where the lowest pod length (cm) (7.85) was obtained from control treatment (Ca_0) which was also statistically identical with Ca_1 (50 ppm Ca).

4.14.3 Combined effect of Zn and Ca

Significant variation was observed on pod length influenced by combined effect of Zn and Ca (Table 8 and Appendix XII). Results verified that the highest pod length (cm) (8.81) was obtained from the treatment combination of Zn_1Ca_2 followed by Zn_1Ca_3 and Zn_0Ca_2. The lowest pod length (cm) (7.80) was obtained from the treatment combination of Zn_0Ca_0 which was statistically identical with Zn_0Ca_1, Zn_0Ca_3, Zn_1Ca_0 and Zn_1Ca_1.

4.15 Weight of 1000 seed

4.15.1 Effect of Zn

Weight of 1000 seedof mungbean was significant due to different doses of Zn (Table 8 and Appendix XII). It was observed that the highest weight of 1000 seed(45.95 g) was achieved from Zn_1 (1.5 kg Zn ha^{-1}) which was statistically identical with Zn_2 (3 kg Zn ha^{-1}) where the lowest weight of 1000 seed(43.97 g) was obtained from control treatment (Zn_0). Similar results also observed by Rahman *et al*. (2015), Malik *et al*. (2015) and Abdo (2001). Rahman *et al*. (2015) found that the maximum significant weight of 1000-seeds (45.11 g) was obtained from Zn_2 (3 kg Zn ha^{-1}).

4.15.2 Effect of Ca

Weight of 1000 seed of mungbean influenced by different levels of Ca application was significant (Table 8 and Appendix XII). It was verified that the highest weight of 1000 seed(45.94 g) was obtained from Ca_2 (75 ppm Ca) Ca_1 (50 ppm Ca) and Ca_3 (100 ppm Ca) where the lowest weight of 1000 seed(44.33 g) was obtained from control treatment (Ca_0). Kumar *et al*. (2010) also found highest 1000 seeds weight with calcium application at 200 ppm which was similar with the present study.

4.15.3 Combined effect of Zn and Ca

Weight of 1000 seed of mungbean was found significant due to different treatment combination of Zn and Ca (Table 8 and Appendix XII). Results signified that the highest weight of 1000 seed(47.50 g) was obtained from the treatment combination of Zn_1Ca_2 followed by Zn_1Ca_3. The lowest weight of 1000 seed(43.53 g) was obtained from the treatment combination of Zn_0Ca_0 which was statistically similar with Zn_0Ca_3.

4.16 Weight of seeds plant^{-1}

4.16.1Effect of Zn

Significant variation was observed on seed weight plant^{-1} of mungbean influenced by different doses of Zn (Table 8 and Appendix XII). The highest weight of seeds plant^{-1} (9.82) was obtained from Zn_1 (1.5 kg Zn ha^{-1}) followed by Zn_2 (3 kg Zn ha$^-$

^{1}). The lowest weight of seeds plant^{-1} (7.90) was obtained from control treatment (Zn_0). Similar results was also observed by Malik *et al*. (2015) and found significant influence on seed yield plant^{-1} with Zn application.

4.16.3 Effect of Ca

Different levels of Ca application showed significant influence regarding seed weight plant^{-1} (Table 8 and Appendix XII). Results indicated that the highest weight of seeds plant^{-1} (10.00) was obtained from Ca_2 (75 ppm Ca) which was significantly different from all other treatment combinations. The lowest weight of seeds plant^{-1} (6.80) was obtained from control treatment (Ca_0). Kumar *et al*. (2010) also obtained similar result on seed yield per plant with the present study and found that calcium application at 200 ppm gave the highest yield of seed per plant.

4.16.3 Combined effect of Zn and Ca

Combined effect of Zn and Ca exposed significant variation on seed weight plant^{-1} (Table 8 and Appendix XII). It was found that the highest weight of seeds plant^{-1} (13.70) was obtained from the treatment combination of Zn_1Ca_2 followed by Zn_0Ca_1 and Zn_1Ca_3. The lowest weight of seeds plant^{-1} (6.37) was obtained from the treatment combination of Zn_0Ca_0 which was significantly different from all other treatment combinations.

Table 8. Yield contributing parameters of mungbean showing number of pods plant^{-1}, number of seedspod^{-1}, number of fertile seedspod^{-1}, pod length (cm), 1000 seed weight (g) and weight of seeds plant^{-1} (g) affected by zinc and calcium and their interaction

Treatment	Yield contributing parameters					
	Number of pods plant^{-1}	Number of seeds pod^{-1}	Number of fertile seeds pod^{-1}	Pod length (cm)	1000 seed weight (g)	Weight of seeds plant^{-1} (g)
Effect of Zn						
Zn_0	14.36 b	11.10 b	8.560 b	8.030	43.97 b	7.900 c
Zn_1	17.87 a	12.27 a	9.980 a	8.120	45.95 a	9.820 a
Zn_2	17.13 a	12.03 a	9.720 a	8.110	45.64 a	8.920 b
$LSD_{0.05}$	2.127	0.5408	0.6082	NS	1.033	0.8191
CV (%)	7.228	5.429	6.371	4.217	8.392	6.274
Effect of Ca						
Ca_0	13.33 b	11.20 c	8.850 c	7.850 b	44.33 c	6.800 c
Ca_1	17.47 a	11.71 b	9.380 b	7.970 b	45.17 b	9.230 b
Ca_2	17.63 a	12.33 a	10.00 a	8.340 a	45.94 a	10.00 a
Ca_3	17.38 a	11.96 b	9.400 b	8.190 a	45.30 b	9.460 b
$LSD_{0.05}$	0.6011	0.3470	0.3710	0.1855	0.3824	0.4250
CV (%)	7.228	5.429	6.371	4.217	8.392	6.274
Combined effect of Zn and Ca						
Zn_0Ca_0	12.27 g	10.20 e	8.260 e	7.800 e	43.53 g	6.370 e
Zn_0Ca_1	22.45 b	11.33 cd	8.750 de	7.830 e	44.20 f	12.10 b
Zn_0Ca_2	14.73 e	11.60 b-d	8.940 d	8.270 bc	44.33 ef	7.570 d
Zn_0Ca_3	17.88 d	11.27 d	8.270 e	7.910 e	43.83 fg	8.830 c
Zn_1Ca_0	14.60 e	11.67 bc	9.020 d	7.850 e	44.50 ef	7.120 de
Zn_1Ca_1	14.09 ef	11.80 b	9.600 bc	7.900 e	45.40 d	7.550 d
Zn_1Ca_2	24.25 a	12.87 a	11.00 a	8.810 a	47.50 a	13.70 a
Zn_1Ca_3	19.72 c	12.73 a	10.00 b	8.460 b	46.40 b	11.70 b
Zn_2Ca_0	13.12 fg	11.73 b	9.260 cd	7.880 e	44.97 de	6.920 de
Zn_2Ca_1	14.54 e	12.00 b	9.790 b	8.170 cd	45.90 bc	8.010 cd
Zn_2Ca_2	15.24 e	12.53 a	10.10 b	7.940 de	46.00 bc	8.780 c
Zn_2Ca_3	14.55 e	11.87 b	9.730 bc	8.190 cd	45.67 c	7.890 cd
$LSD_{0.05}$	1.045	0.3592	0.4819	0.2454	0.6358	1.020
CV (%)	7.228	5.429	6.371	4.217	8.392	6.274

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

4.17 Seed yield (kg ha^{-1})

4.17.1 Effect of Zn

Significant variation was found for seed yield affected by different doses of Zn (Table 9 and Appendix XIII). Results signified that the highest seed yield (1211.75 kg ha^{-1}) was from Zn_1 (1.5 kg Zn ha^{-1}) next highest yield was obtained from Zn_2 (3 kg Zn ha^{-1}) but significantly different. The lowest seed yield (928.70 kg ha^{-1}) was achieved from control treatment (Zn_0). The results on seed yield found from the present study was conformity with the findings of Rahman *et al*. (2015), Karmakar *et al*. (2015) and Ram and Katiyar (2013). Rahman *et al*. (2015) obtained highest seed yield (1.45 t ha^{-1}) with Zn_2 (3 kg Zn ha^{-1}) where Karmakar *et al*. (2015) also found highest seed yield with the same doses of Zn.

4.17.2 Effect of Ca

Data obtained on seed yield affected by different levels of Ca application was significant (Table 9 and Appendix XIII). Results indicated that the highest seed yield (1212 kg ha^{-1}) was obtained from Ca_2 (75 ppm Ca) where 2nd highest yield was found from Ca_3 (100 ppm Ca). The lowest seed yield (988.30 kg ha^{-1}) was obtained from control treatment (Ca_0). Under the present study, the highest yield with this treatment might be due to cause of higher production of pod yield per plant, grains per pod and 1000 seed weight. It is well established that calcium is a yield-enhancing nutrient in pulse crop and it is needed for both good vegetative growth and normal healthy fruit development (Cheema *et al*., 1991). It can said that calcium is the most important and vital element in the pulse crop production system, (Safarzadeh Vishkaee, 1999). Kumar *et al*. (2010) also obtained the highest yield of pod (5650 kg/ha) form 90 kg ha^{-1} calcium form gypsum. Similar results was also obtained by Mahmood *et al*. (2010) and Blake-Kalff *et al*. (2000).

4.17.3 Combined effect of Zn and Ca

Combined effect of Zn and Ca designated significant variation on seed yield of mungbean (Table 9 and Appendix XIII). Results indicated that the highest seed yield (1357 kg ha^{-1}) was obtained from the treatment combination of Zn_1Ca_2 followed by (second highest seed yield) (1319 kg ha^{-1}) the treatment combination of Zn_1Ca_3. The lowest seed yield (857.20 kg ha^{-1}) was obtained from the treatment combination of Zn_0Ca_0 where second lowest seed yield (908.40 kg ha^{-1}) was from the treatment combination of Zn_0Ca_3. All the treatment combinations under the present study on seed yield were significantly different to each other.

4.18 Stover yield (kg ha^{-1})

4.18.1 Effect of Zn

Different doses of Zn had significant variation on stover yield of mungbean (Table 9 and Appendix XIII). It was examined that the Zn level, Zn_1 (1.5 kg Zn ha^{-1}) gave highest stover yield (1585 kg ha^{-1}) followed by Zn_2 (3 kg Zn ha^{-1}) where the lowest stover yield (1407 kg ha^{-1}) was obtained from control treatment (Zn_0). The results on stover yield obtained Rahman *et al*. (2015) and Karmakar *et al*. (2015) was similar with the present study.

4.18.2 Effect of Ca

Significant variation was observed due to different levels of Ca application for stover yield of mungbean (Table 9 and Appendix XIII). Ca application at 75 ppm (Ca_2) showed the highest stover yield (1587 kg ha^{-1}) followed by Ca_3 (100 ppm Ca). The lowest stover yield (1448 kg ha^{-1}) was obtained from control treatment (Ca_0).

4.18.3 Combined effect of Zn and Ca

Combined effect of Zn and Ca demonstrated significant influence on stover yield of mungbean (Table 9 and Appendix XIII). It was observed that the highest stover yield (1666 kg ha^{-1}) was obtained from the treatment combination of Zn_1Ca_2 followed by Zn_1Ca_3 where the lowest stover yield (1353 kg ha^{-1}) was obtained from the treatment combination of Zn_0Ca_0 that was nearest to the treatment combination of Zn_0Ca_3 but significantly different.

4.19 Biological yield (kg ha^{-1})

4.19.1 Effect of Zn

Significant difference was recorded for different doses of Zn on biological yield of mungbean (Table 9 and Appendix XIII). It was found that the highest biological yield (2797 kg ha^{-1}) was obtained from Zn_1 (1.5 kg Zn ha^{-1}) followed by Zn_2 (3 kg Zn ha^{-1}). The lowest biological yield (2336 ha^{-1}) was obtained from control treatment (Zn_0).

4.19.2 Effect of Ca

Biological yield of mungbean was significantly affected by different levels of Ca application (Table 9 and Appendix XIII). Results revealed that Ca_2 (75 ppm Ca) gave the highest biological yield (2798 kg ha^{-1}) followed by Ca_3 (100 ppm Ca) where the lowest biological yield (2436 kg ha^{-1}) was obtained from control treatment (Ca_0).

4.19.3 Combined effect of Zn and Ca

Significant difference was also recorded for the combined effect of Zn and Ca in terms of biological yield of mungbean (Table 9 and Appendix XIII). The highest biological yield (3023 kg ha^{-1}) was obtained from the treatment combination of Zn_1Ca_2 followed by Zn_1Ca_3. The lowest biological yield (2210 kg ha^{-1}) was obtained from the treatment combination of Zn_0Ca_0 which was nearest to the treatment combination of Zn_0Ca_3 but significantly different.

4.20 Harvest index (%)

4.20.1 Effect of Zn

Harvest index was significantly varied due to different doses of Zn of mungbean (Table 9 and Appendix XIII). Results indicated that the highest harvest index(43.21%) was obtained from Zn_1 (1.5 kg Zn ha^{-1}) which was statistically identical with Zn_2 (3 kg Zn ha^{-1}) Zn_2 (3 kg Zn ha^{-1}) where the lowest harvest index(39.73%) was obtained from control treatment (Zn_0). Wu *et al.* (1994) also found similar result on harvest index and found that harvest index was positively correlated with Zn concentration.

4.20.2 Effect of Ca

Significant variation was found on harvest index of mungbean influenced by different levels of Ca application (Table 9 and Appendix XIII). The highest harvest index(43.15%) was obtained from Ca_2 (75 ppm Ca) followed by Ca_1 (50 ppm Ca) and Ca_3 (100 ppm Ca). The lowest harvest index(40.49%) was obtained from control treatment (Ca_0).

4.20.3 Combined effect of Zn and Ca

Combined effect of Zn and Ca recorded significant influence on harvest index of mungbean (Table 9 and Appendix XIII). Results indicated that the highest harvest index(44.88%) was obtained from the treatment combination of Zn_1Ca_2 which was statistically similar with Zn_1Ca_3. The lowest harvest index(38.79%) was obtained from the treatment combination of Zn_0Ca_0 which was immediate lower than Zn_0Ca_3 but significantly different.

Table 9. Yield parameters of mungbean affected by zinc and calcium and their interaction

Treatment	Yield parameters			
	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Effect of Zn				
Zn_0	928.70 c	1407.0 c	2336.0 c	39.73 b
Zn_1	1211.75 a	1585.0 a	2797.0 a	43.21 a
Zn_2	1191.00 b	1573.0 b	2764.0 b	43.06 a
$LSD_{0.05}$	10.79	11.59	11.86	1.357
CV (%)	13.569	16.274	12.394	9.356
Effect of Ca				
Ca_0	988.30 d	1448.0 d	2436.0 d	40.49 c
Ca_1	1106.00 c	1515.0 c	2621.0 c	42.08 b
Ca_2	1212.00 a	1587.0 a	2798.0 a	43.15 a
Ca_3	1136.00 b	1537.0 b	2673.0 b	42.29 b
$LSD_{0.05}$	10.52	11.04	11.82	0.6358
CV (%)	13.569	16.274	12.394	9.356
Combined effect of Zn and Ca				
Zn_0Ca_0	857.20 l	1353.0 l	2210.0 l	38.79 h
Zn_0Ca_1	946.70 j	1425.0 j	2372.0 j	39.91 fg
Zn_0Ca_2	1003.00 i	1465.0 i	2467.0 i	40.63 ef
Zn_0Ca_3	908.40 k	1386.0 k	2294.0 k	39.60 g
Zn_1Ca_0	1032.00 h	1488.0 h	2520.0 h	40.96 de
Zn_1Ca_1	1139.00 f	1533.0 f	2672.0 f	42.62 c
Zn_1Ca_2	1357.00 a	1666.0 a	3023.0 a	44.88 a
Zn_1Ca_3	1319.00 b	1653.0 b	2972.0 b	44.37 ab
Zn_2Ca_0	1075.00 g	1503.0 g	2578.0 g	41.71 d
Zn_2Ca_1	1232.00 d	1588.0 d	2820.0 d	43.70 b
Zn_2Ca_2	1276.00 c	1629.0 c	2905.0 c	43.94 b
Zn_2Ca_3	1180.00 e	1572.0 e	2752.0 e	42.89 c
$LSD_{0.05}$	10.23	11.09	11.77	0.8085
CV (%)	13.569	16.274	12.394	9.356

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

Zn_0= 0 kg Zn ha^{-1}, Zn_1= 1.5 kg Zn ha^{-1}, Zn_2= 3 kg Zn ha^{-1}
Ca_0= 0 ppm Ca, Ca_1= 50 ppm Ca, Ca_2= 75 ppm Ca, Ca_3= 100 ppm Ca

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka in order to explore the effects of zinc and calcium on growth and yield of mungbean (BARI mug 6). The experiment comprised two different factors; (1) three Zn levels *viz*. Zn_0= 0 kg ha^{-1}, Zn_1= 1.5 kg ha^{-1}, Zn_2= 3 kg ha^{-1} and (2) four Ca levels *viz*. Ca_0= 0 ppm , Ca_1= 50 ppm , Ca_2= 75 ppm , and Ca_3= 100 ppm . The experiment was set up in randomized complete block designwith three replications. There were 12 treatment combinations and 3 replication arranged in 36 plots. Data on different growth, yield and yield parameters were recorded and analyzed statistically. Three effects have been considered to evaluate the experiment such as (i) Effect of Zn, (ii) Effect of Ca and (iii) Combined effect of Zn and Ca. Considerable effect was observed on growth, yield attributes and yield of mungbean by different doses of Zn and Ca and their combinations.

All the parameters with Zn application showed significant effect except pod length. Results indicated that the highest plant height (32.98, 63.06 and 65.77 cm 25, 40 DAS and at harvest, respectively), number of leaves plant^{-1} (5.930, 10.79 and 16.62 at 25, 40 DAS and at harvest, respectively), number of branches plant^{-1} (2.23 and 4.24 at 40 DAS and at harvest, respectively), leaf area index (4.65, 8.53 and 14.23 at 25, 40 DAS and at harvest, respectively), number of flowers plant^{-1} (23.11), number of nodules plant^{-1} (28.17), days to first flowering (37.67), days to 100% maturity (55.33) and chlorophyll content (Chl-a = 0.846 µg g^{-1}, Chl-b =1.092 µg g^{-1} and total = 1.938 µg g^{-1}) were obtained from Zn_2 (3 kg ha^{-1}). But the highest dry weight plant^{-1} (7.47, 16.27 and 23.14 g at 25, 40 DAS and at harvest, respectively), number of pods plant^{-1} (17.87), number of seeds pod^{-1} (12.27), number of fertile seeds pod^{-1} (9.98), pod length (cm) (8.12), weight of 1000 seed (45.95), weight of seeds plant^{-1} (9.82), seed yield (1211.75 kg ha^{-1}), stover yield

(1585 kg ha^{-1}), biological yield (2797 kg ha^{-1}) and harvest index (43.21%) were obtained from Zn_1 (1.5 kg ha^{-1}). All the studied parameters were significantly lowest with control treatment (Zn_0). The lowest plant height (29.91, 57.75 and 62.28 cm 25, 40 DAS and at harvest, respectively) number of leaves $plant^{-1}$ (4.970, 9.180 and 14.79 at 25, 40 DAS and at harvest, respectively),number of branches $plant^{-1}$ (1.52 and 3.91 25, 40 DAS and at harvest, respectively), The lowest leaf area index (3.58, 7.85 and 12.85 at 25, 40 DAS and at harvest, respectively), dry weight $plant^{-1}$ (5.95, 13.01 and 19.27 g at 25, 40 DAS and at harvest, respectively), days to first flowering(36.00), number of flowers $plant^{-1}$ (20.85), days to 100% maturity (52.13), number of nodules $plant^{-1}$ (16.92), chlorophyll content (Chl-a = 0.511 μg g^{-1}, Chl-b = 0.651 μg g^{-1} and total = 1.162 μg g^{-1}), number of pods $plant^{-1}$ (14.36), number of seeds pod^{-1} (11.10), number of fertile seeds pod^{-1} (8.56), pod length (cm) (8.03), weight of 1000 seed (43.97), weight of seeds $plant^{-1}$ (7.90), seed yield (928.70 kg ha^{-1}), stover yield (1407 kg ha^{-1}), biological yield (2336 ha^{-1}) and harvest index (39.73%) were obtained from control treatment (Zn_0).

Considering the performance of Ca application, all the studied parameters were significantly varied with different doses of Ca application. The highest plant height (33.43, 63.08 and 66.17 cm 25, 40 DAS and at harvest, respectively), leaf area index (4.68, 8.56 and 14.30 at 25, 40 DAS and at harvest, respectively), days to first flowering (37.11), number of flowers $plant^{-1}$ (24.05), days to 100% maturity (54.97), number of nodules $plant^{-1}$ (27.22) and chlorophyll content (Chl-a = 0.865 μg g^{-1}, Chl-b = 1.097 μg g^{-1} and total = 1.962 μg g^{-1}) were found from Ca_3 (100 ppm Ca). But the highest number of leaves $plant^{-1}$ (6.00 , 11.19 and 17.02 at 25, 40 DAS and at harvest, respectively), number of branches $plant^{-1}$ (2.25 and 4.28 at 40 DAS and at harvest, respectively), dry weight $plant^{-1}$ (7.50, 16.26 and 23.31 g at 25, 40 DAS and at harvest, respectively), number of pods $plant^{-1}$ (17.63), number of seeds pod^{-1} (12.33), number of fertile seeds pod^{-1} (10.00), pod length (cm) (8.34), weight of 1000 seed (45.94), weight of seeds plant^{-1} (10.00), seed yield (1212 kg ha^{-1}), stover yield (1587 kg ha^{-1}), biological yield (2798 kg ha^{-1}) and harvest index (43.15%) were achieved from Ca_2 (75 ppm Ca). On the other hand, The lowest plant height (29.31, 57.22 and 61.49 cm 25, 40 DAS and at harvest, respectively), number of leaves plant^{-1} (5.40, 9.810 and 15.32 at 25, 40 DAS and at harvest, respectively), number of branches plant^{-1} (1.66 and 3.95 at 40 DAS and at harvest, respectively), leaf area index (3.74, 7.94 and 13.03 at 25, 40 DAS and at harvest, respectively), dry weight plant^{-1} (6.25, 13.76 and 19.97 g at 25, 40 DAS and at harvest, respectively), days to first flowering (35.56), number of flowers plant^{-1} (19.88), days to 100% maturity (53.27), number of nodules plant^{-1} (18.89), chlorophyll content (Chl-a = 0.498 μg g^{-1}, Chl-b = 0.612 μg g^{-1} and total = 1.111 μg g^{-1}), number of pods plant^{-1} (13.33), number of seeds pod^{-1} (11.20), number of fertile seeds pod^{-1} (8.85), pod length (cm) (7.85), weight of 1000 seed (44.33), weight of seeds plant^{-1} (6.80), seed yield (988.30 kg ha^{-1}), stover yield (1448 kg ha^{-1}), biological yield (2436 kg ha^{-1}) and harvest index (40.49%) were obtained from control treatment (Ca_0).

Considering interaction of Zn and Ca; all growth, yield attributes and yield parameters were significantly influenced. Results revealed that the highest plant height (35.37, 65.87 and 67.30 cm at 25, 40 DAS and at harvest, respectively), leaf area index (5.00, 9.13 and 15.00 at 25, 40 DAS and at harvest, respectively), days to first flowering (38.00), number of flowers plant^{-1} (30.00), days to 100% maturity (56.30) and number of nodules plant^{-1} (30.33) were obtained from the treatment combination of Zn_2Ca_3 where the highest number of leaves plant^{-1} (6.37, 12.50 and 18.30 at 25, 40 DAS and at harvest, respectively), number of branches plant^{-1} (2.60 and 4.42 at 40 DAS and at harvest, respectively) and chlorophyll content (Chl-a = 1.057 μg g^{-1}, Chl-b = 1.423 μg g^{-1} and total = 2.48 μg g^{-1}) were obtained from the treatment combination of Zn_2Ca_2. Again, the highest dry weight plant^{-1} (8.62, 17.85 and 25.71 g at 25, 40 DAS and at harvest, respectively), number of pods plant^{-1} (24.25), number of seeds pod^{-1} (12.87), number of fertile seeds pod^{-1} (11.00), pod length (cm) (8.81), weight of 1000 seed (47.50), weight of seeds plant^{-1} (13.70), seed yield (1357 kg ha^{-1}), stover yield (1666 kg ha^{-1}), biological yield (3023 kg ha^{-1}) and harvest index (44.88%) were achieved from the treatment combination of Zn_1Ca_2. On the contrary, the lowest plant height (27.37, 53.03 and 58.77 cm at 25, 40 DAS and at harvest, respectively), number of leaves plant^{-1} (4.70, 8.570 and 13.97 at 25, 40 DAS and at harvest, respectively), number of branches plant^{-1} (1.27 and 3.80 at 40 DAS and at harvest, respectively), leaf area index (2.67, 7.40 and 11.33 at 25, 40 DAS and at harvest, respectively), dry weight plant^{-1} (5.80, 11.48 and 17.67 g at 25, 40 DAS and at harvest, respectively), days to first flowering (35.00), number of flowers plant^{-1} (18.50), days to 100% maturity (51.40), number of nodules plant^{-1} (11.33), chlorophyll content (Chl-a = 0.41 µg g^{-1}, Chl-b = 0.482 µg g^{-1} and total = 0.892 µg g^{-1}), number of pods plant^{-1} (12.27), number of seeds pod^{-1} (10.20), number of fertile seeds pod^{-1} (8.260), pod length (cm) (7.80), weight of 1000 seed (43.53), weight of seeds plant^{-1} (6.37), seed yield (857.20 kg ha^{-1}), stover yield (1353 kg ha^{-1}), biological yield (2210 kg ha^{-1}) and harvest index (38.79%) were obtained from the treatment combination of Zn_0Ca_0.

From the above results, it may be concluded that Zn and Ca application is promising for higher yield. Based on the experimental results, it may be concluded that-

1. The effect of Zn had fabulous effect on growth, yield attributes and yield of mungbean.
2. The Zn level of (1.5 kg ha^{-1}) was the best regarding growth and yield performance compared to 0 kg or 3 kg of added zinc per hector.
3. Ca application in mungbean cultivation observed higher yield potentiality with the doses of Ca_2 (75 ppm Ca) compare to Ca_0 (0 ppm Ca), Ca_1 (50 ppm Ca) and Ca_3 (100 ppm Ca).

4. The application of Zn at 1.5 kg Zn ha^{-1} combination with Ca at 75 ppm Ca was found as the best treatment combination regarding yield attributes and yield of mungbean.
5. Considering growth performance, application of Zn at 3 kg Zn ha^{-1} combination with Ca at 100 ppm Ca showed the best results.

However, to reach a specific conclusion and recommendation, more research work on growing mungbean varieties using more different doses Zn and Ca with proper agronomic practices should be done over different Agro-ecological zones.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

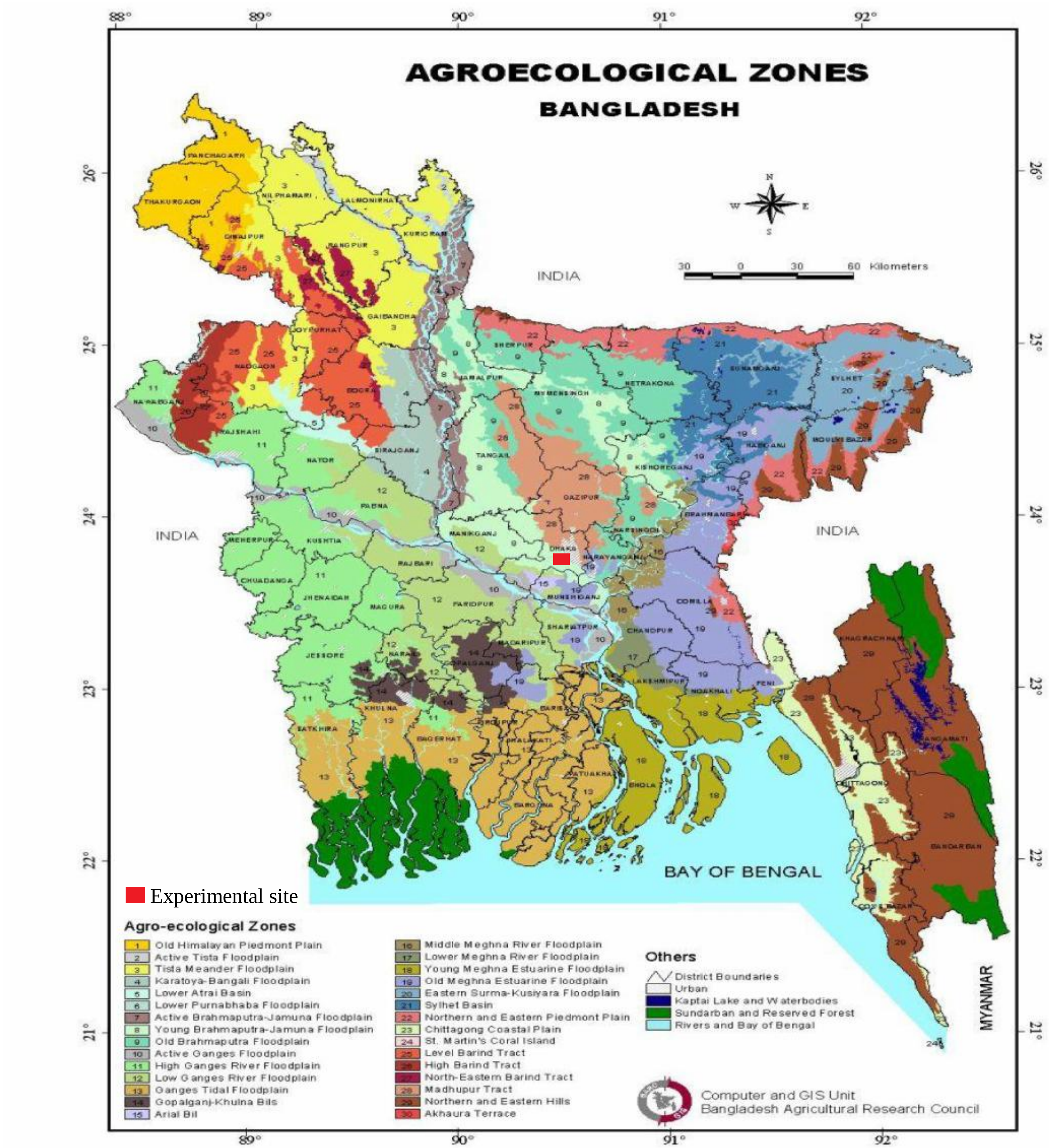


Fig. 11. Experimental site

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from March to June, 2016

Month	RH (%)	Air temperature (C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
March	52.44	35.20	21.00	28.10	0
April	65.40	34.70	24.60	29.65	165
May	68.30	32.64	23.85	28.25	182
June	71.28	27.40	23.44	25.42	190

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

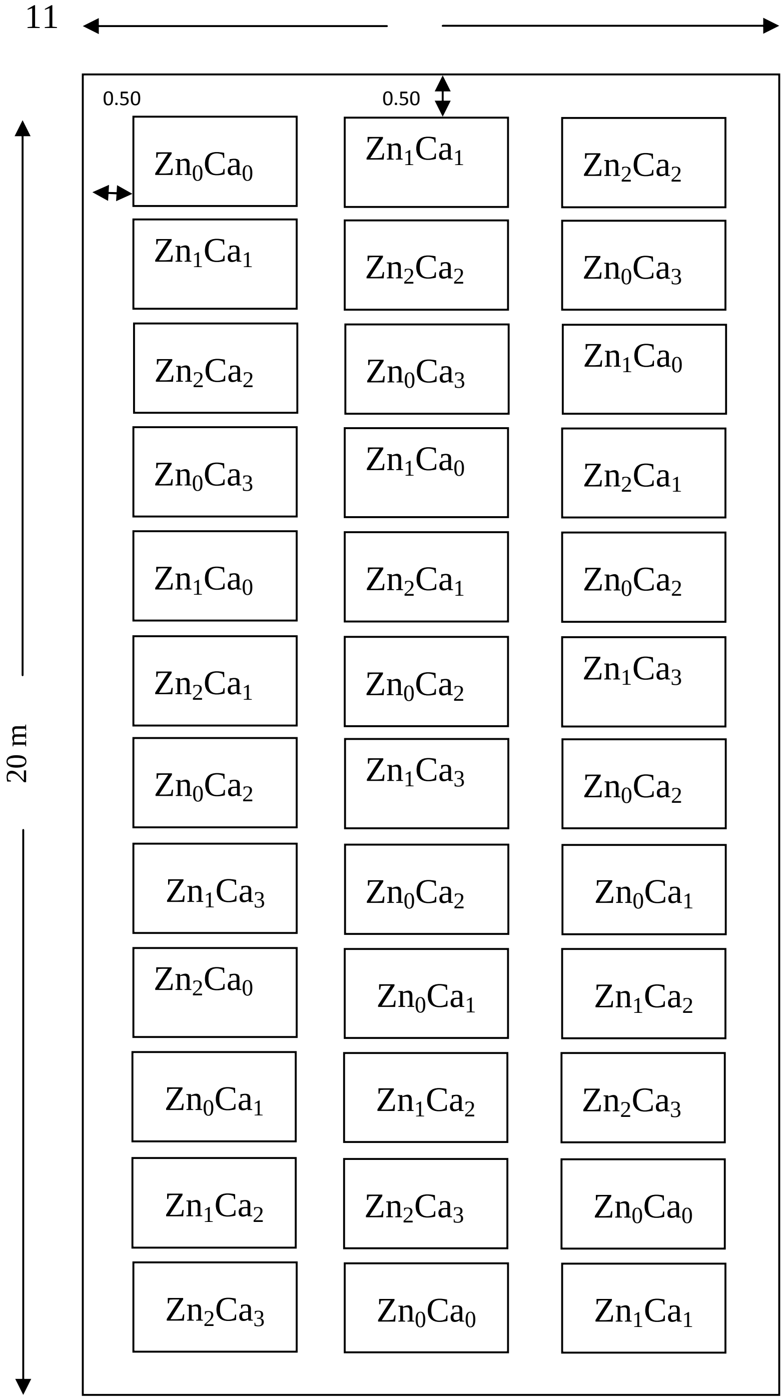
Source: Soil Resource Development Institute (SRDI)

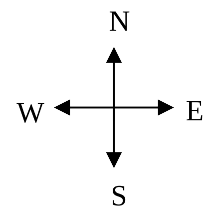
B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
Ph	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experimental field





Plot size: 3.00 m × 1.43 m

Plot spacing: 0.25 m

Between block: 0.50 m

Factor A: Zinc (Zn) – Three doses as follows

1. Zn_0= 0 kg Zn ha^{-1}
2. Zn_1= 1.5 kg Zn ha^{-1}
3. Zn_2= 3 kg Zn ha^{-1}

Factor B: Calcium (Ca) – Four doses as follows

1. Ca_0= 0 ppm Ca
2. Ca_1= 50 ppm Ca
3. Ca_2= 75 ppm Ca
4. Ca_3= 100 ppm Ca

Fig. 12. Layout of the experiment field

Appendix V. Interaction effect of Zn and Ca on plant height of mungbean

Sources of variation	Degrees of freedom	Mean square of plant height (cm) at		
		25 DAS	40 DAS	At harvest
Replication	2	0.586	0.509	0.817
Factor A	2	8.28**	17.80*	21.417*
Factor B	3	13.58*	23.51*	27.463*
AB	6	5.62**	8.28**	10.246**
Error	22	1.273	2.186	2.728

Appendix VI. Interaction effect of Zn and Ca on number of leavesplant^{-1}

Sources of variation	Degrees of freedom	Mean square of umber of leaves/plant at		
		25 DAS	40 DAS	At harvest
Replication	2	0.487	0.611	0.562
Factor A	2	5.381*	9.283**	10.158*
Factor B	3	8.275*	15.622*	18.227*
AB	6	3.182**	7.494**	8.416**
Error	22	0.382	1.192	1.624

Appendix VII. Interaction effect of Zn and Ca on number of branchesplant^{-1}

Sources of variation	Degrees of freedom	Mean square of number of branches/plant at	
		40 DAS	At harvest
Replication	2	0.016	0.144
Factor A	2	3.426**	5.441**
Factor B	3	5.242**	6.452*
AB	6	1.323**	2.272**
Error	22	0.115	0.314

Appendix VIII. Interaction effect of Zn and Ca on leaf area index

Sources of variation	Degrees of freedom	Mean square of leaf area index at		
		25 DAS	40 DAS	At harvest
Replication	2	0.127	0.167	0.221
Factor A	2	6.211**	5.379**	7.271**
Factor B	3	6.264**	8.522*	9.266**
AB	6	2.311**	2.414**	3.381**
Error	22	0.264	0.301	0.514

Table IX. Interaction effect of Zn and Ca on dry weight/plant

Sources of variation	Degrees of freedom	Mean square of dry weight/plant (g) at		
		25 DAS	40 DAS	At harvest
Replication	2	0.002	0.857	1.038
Factor A	2	8.482*	8.349*	14.541*
Factor B	3	7.684*	15.584*	23.657*
AB	6	2.262**	6.552.272**	8.279**
Error	22	0.237	1.314	1.347

Appendix X. Chlorophyll content of mungbean affected by zinc and calcium and their interaction

Sources of variation	Degrees of freedom	Mean square of chlorophyll (Chl) content of leaves at 45 DAS		
		Chl-a	Chl-b	Total
Replication	2	0.001	0.004	0.012
Factor A	2	2.736**	2.149*	3.524**
Factor B	3	3.112**	4.703**	5.314*
AB	6	5.066**	7.312*	8.376*
Error	22	0.112	0.204	0.257

Appendix XI. Yield contributing parameters of mungbean showing days to first flowering, number of flowers plant^{-1}, days to 100% maturity and number of nodules plant^{-1} affected by zinc and calcium and their interaction

Sources of variation	Degrees of freedom	Mean square of			
		Days to first flowering	Number of flowers/plant	Days to 100% maturity	Number of nodules/plant
Replication	2	0.421	1.482	0.316	1.247
Factor A	2	6.426*	7.288**	7.802*	11.436*
Factor B	3	13.473*	10.581*	15.511*	23.325*
AB	6	4.231*	5.625**	6.283**	8.276**
Error	22	1.341	2.104	2.251	2.784

Appendix XII. Yield contributing parameters of mungbean showing number of pods plant^{-1}, number of seeds pod^{-1}, number of fertile seeds pod^{-1}, pod length (cm), 1000 seed weight (g) and weight of seeds plant^{-1} (g) affected by zinc and calcium and their interaction

Sources of variation	Degrees of freedom	Mean square of					
		Number of pods/plant	Number of seeds/pod	Number of fertile seeds/pod	Pod length (cm)	1000 seed weight (g)	Weight of seeds/plant (g)
Replication	2	0.621	0.518	0.258	1.144	0.026	0.251
Factor A	2	7.482*	8.906*	11.216*	NS	3.211**	5.223*
Factor B	3	13.843*	17.711*	18.406*	21.54*	5.226*	8.414*
AB	6	6.792*	4.402**	8.114*	8.288*	2.203*	3.262**
Error	22	2.302	2.216	2.021	1.144	0.207	1.054

Appendix XIII. Yield parameters of mungbean affected by zinc and calcium and their combination

Sources of variation	Degrees of freedom	Mean square of			
		Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Replication	2	6.510	7.461	9.171	2.036
Factor A	2	55.884*	62.427*	68.433*	12.114*
Factor B	3	208.52*	316.443*	383.44*	23.52*
AB	6	21.215*	27.239*	24.26**	2.41**
Error	22	13.011	15.318	16.774	1.813