EFFECT OF MICRONUTRIENTS (B AND Zn) AND SOWING TIME ON WATER RELATIONS AND YIELD OF MUNGBEAN

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DECEMBER, 2014

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Reg. No.: 08-02905

A Thesis

Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE (M.S.)

IN

AGRONOMY

SEMESTER: JULY-DECEMBER, 2014

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CERTIFICATE

This is to certify that thesis entitled, **“*Effect of micronutrients (B and Zn) and sowing time on water relations and yield of mungbean*”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRONOMY,** embodies the result of a piece of *bonafide* research work carried out by **Molla Al- Mamun,Registration No. 08-02905** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed during the course of this investigation has been duly acknowledged and the style of this thesis have been approved and recommended for submission.

Dated-

Dhaka, Bangladesh

….………………………………

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DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to Almighty Allah, the Great, Gracious and Merciful, Whose blessings enabled the author to complete this research work successfully.

The author likes to express his deepest sense of gratitude and sincere appreciation to his respected Supervisor ***Prof.Dr. Md. Shahidul Islam****, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, for his scholastic guidance, support, encouragement and invaluable suggestions and constructive criticism throughout the study period and help in completing the research work and in the preparation of the manuscript writing.*

The author also expresses his gratefulness and best regards to respected Co-supervisor, ***Prof. Dr. Md. Fazlul Karim****, Department of Agronomy, SAU, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.*

The author expresses his sincere respect to ***Prof. Dr. Md. Fazlul Karim****, Chairman, Department of Agronomy, SAU, Dhaka for valuable suggestions and cooperation during the study period. The author also expresses heartfelt thanks to all the teachers of the Department of Agronomy, SAU, for their valuable teaching and encouragement during the period of the study.*

The author expresses his sincere appreciation to his father ***Molla Sakawat Hossen****, mother* ***Nasima Begum****, brothers, sisters, relatives, well-wishers and friends, especially Md Shamsuzzaman, for their inspiration, help and encouragement throughout the study period.*

EFFECT OF MICRONUTRIENTS (B AND Zn) AND SOWING TIME ON WATER RELATIONS AND YIELD OF MUNGBEAN

ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, in the Kharif-II season during the period from August 2013 to January 2014 to study the effect of micronutrients (B and Zn) and sowing time on water relations and yield of mungbaen (*Vigna radiata* L.).The experiment consisted of five levels of micronutrients viz., F_0 = Recommended Fertilizer Dose (RFD) [20.7 kg N/ ha, 48 kg P_2O_5/ha and 34.8 kg K_2O/ha]; F_1 = RFD + 1 kg B/ha; F_2=RFD +2 kg B/ha; F_3= RFD +8.5 kg Zn/ha; F_4 = RFD + 17 kg Zn/ha and three sowing time, viz., (S_1= 24 August, S_2=23 September and S_3=23 October). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The results indicated that increasing micronutrient level reduced number of days to 1^{st} emergence, 80% emergence, 50% flowering and increased exudation rate, relative water content, number of branches plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield and harvest index except B @ 2 kg/ha for exudation rate. Delayed sowing from 24^{th} August to 23^{th} October reversed the effects for all the parameters mentioned above except days to 50% flowering. Highest exudation rate (2352 mg hr^{-1}), relative water content (93.33%), number of branches plant^{-1}(3.00), number of pods plant^{-1} (17.67), longest pod length (10.60 cm) and number of seeds pod^{-1} (11.67), 1000-seed weight (42.83 g), seed yield (1.85 t ha^{-1}) and harvest index (64.24%) were found when mungbean was sown on 24^{th} August and applied recommended NPK with 17 kg Zn ha^{-1}. On the other hand, lowest exudation rate (173.00 mg ha^{-1}), relative water content (78.3%) and pod length (7.50 cm), number of branches plant^{-1} (0.33), pods plant^{-1} (7.00), number seeds pod^{-1} (7.50), 1000-seed weight (28.25 g), seed yield (0.51 t ha^{-1}) and harvest index (12.09%) were found when mungbean was sown on 23 October and applied recommended fertilizer dose(F_0). It was also observed that recommended NPK with 17 kg Zn ha^{-1} gave the highest performance for all the parameters mentioned above under all the three sowing conditions.

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ABBREVIATIONS AND ACRONYMS

%	:	Percentage
@	:	At the rate of
Abstr.	:	Abstract
AEZ	:	Agro-Ecological Zone
Agric.	:	Agriculture
BARC	:	Bangladesh Agricultural Research Council
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BBS	:	Bangladesh Bureau of Statistics
BCR	:	Benefit Cost Ratio
Cm	:	Centimeter
cv.	:	Cultivar
DAS	:	Day After Sowing
et al.	:	et alii (and others)
FAO	:	Food and Agriculture Organization Of the United Nations
Fig.	:	Figure
FW	:	Fresh weight
FYM	:	Farm Yard Manure
G	:	Gram
Hort.	:	Horticulture
i.e.	:	That is
J.	:	Journal

K	:	Potassium
Kg	:	Kilogram
LSD	:	Least Significant Difference
M	:	Meter
MP	:	Muriate of Potash
N	:	Nitrogen
NS	:	Not significant
^{O}C	:	Degree Celsius
P	:	Phosphorus
RCBD	:	Randomized Complete Block Design
Sci.	:	Science
Soc.	:	Society
T	:	Ton
t/ha	:	Ton per hectare
Tk.	:	Taka
TSP	:	Triple Super Phosphate
UK	:	United Kingdom
UNDP	:	United Nations Development Program
Viz.	:	Namely

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Pulse crops belong to seed legume under family Fabaceae. Bangladesh grows various types of pulses. Crops among them lentil, chickpea, cowpea, blackgram, mungbean, fieldpea and grasspea are important. Pulses constitute the main source of protein for the people, particularly the poor sections of Bangladesh. These are also the best source of protein for domestic animals. Besides, the crops have the capability to enrich soils through nitrogen fixation. Pulse protein is rich in lysine that is deficient in rice. According to FAO (2012) recommendation, a minimum percapita intake of pulses should be 80 g day^{-1}, whereas, it is only 10 g day^{-1} in Bangladesh (BBS, 2011). This is because of the fact that national production of the pulses is not adequate to meet up our national demand. Both the acreage and production of the pulses are decreasing in Bangladesh day by day due to increasing acrages of wheat, boro rice and maize in our cropping system with irrigation facilities.

Mungbean (*Vigna radiata* L.) is one of the most important pulse crops in Bangladesh. It holds the 3^{rd} position in protein content and 4^{th} position in both acreage and production in Bangladesh (Sarkar *et al.*, 2012). Its edible seed is characterized by higher digestibility, flavour, high protein content and absence of any flatulence effects (Ahmad *et al.*, 2008). In Bangladesh, total production of pulses is only 0.65 million ton against 2.7 million ton requirement. 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 crop is 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).Mungbean seed contains 1-3% fat, 5.4% carbohydrates, 25.67% protein, 3.5-4.5% fibers and 4.5-5.5% ash, while calcium and phosphorus are 132 and 367 mg 100^{-1} g of seed, respectively (Frauque *et al.*, 2000).

Bangladesh is a developing country. Where population is increasing and land is decreasing day by day, so we have to produce more food from our limited land. To meet up the increased demand of food, farmers are growing more cereal crops. So, at present the cultivation of pulses have gone to marginal land because farmers do not want to use their fertile land in pulse cultivation. Another cause of decreasing pulse cultivation is its low yield. But the agroclimatic conditions of Bangladesh favor mung production almost throughout the year. The farmers of Bangladesh generally produce mungbean by one ploughing and hardly use any fertilizer and irrigation due to its lower productivity and also due to their poor socio-economi condition and lack of proper knowledge. There is an ample scope for increasing the yield of mungbean with improved management practices.

Micronutrients (B, Zn, Mo, Mg etc.) plays a pivotal role for increasing the yield of mungbean. Boron is very important in cell division and in pod as well as seed formation in relation to water uptake. The chlorosis and browning of young leaves, kill during of the growing points, distorted blossom development, lesions in pits and roots are the deficiency symptoms of some boron sensitive crops. The critical level of boron with reference to crops in general was reported to range from 0.3 to 0.8 ppm depending on soil types (Shorrocks, 1984). Zinc is involved in auxin formation, activation of dehydragenase enzymes and stabilization of ribosomal fractions (Aghatise and Tayo, 1994).

Mungbean is generally sown in kharif-I (2^{nd} week of February to 1^{st} week March) and kharif-II (1^{st} week of August to 1^{st} week of September) seasons, respectively in the southern, the north and north-western and the south-western regions of Bangladesh, at though it is cultivated in both summer and winter seasons in many countries of the world. The proper sowing time again depends on the varieties and prevailing environment. Growers tend to manipulate sowing time in order to obtain better growth, good quality and higher yield. The time of sowing is also adjusted so as to synchronize the time of harvest with market demand.

For any improvement programmed selection of superior parents is a prerequisite i.e., possessing better heritability and genetic advance for various traits (Ahmad *et al.*, 2008). Sowing time, a non-monetary input, is an important factor to obtain optimum yield from mungbean (Samanta *et al.*, 1999). So, exploitation of optimum sowing time for mungbean cultivation is inevitable. Optimum time of sowing of mungbean may vary from variety to variety and season to season due to variation in agro ecological conditions. Therefore, there must be a specific sowing dates for specific varieties, especially in the summer season for different varieties to optimize yield. Delayed sowing after March and early sowing before February reduce yield of summer mungbean. Mid February may be considered as the optimum time for summer mungbean (Chovatia *et al.*, 1993). Delayed sowing after September and early sowing before August in Kharif-II season reduce yield of mungbean. Mid-August may be considered as the optimum time for sowing mungbean in Kahrif-II season (Dharmalingam and Basu, 1993).

Delayed sowing after September in Kharif-II season hampers the growth of mungbean plants. It is due to low temperature prevailing during the crop growing period. Micronutrients B and Zn are reported to have the positive effects on the stress tolerance, especially the low temperature tolerance in crop plants. Delayed sowing of mungbean in Kharif-II season faces low temperature stress. Therefore, the micronutrients B and Zn might have the positive effects on low temperature stress tolerance on mungbean under late sowing condition in Kharif-IIseason.

The present study was, therefore, undertaken with the following objectives:

1. To find out the effect of boron and zinc on the performance of mungbean under different sowing dates in Kharif-II season.
2. To identify the suitable date of sowing for mungbean cultivar studied to get higher yield.
3. To study the combined effect of micronutrients and sowing time in relation to water uptake and yield of mungbean.

Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Mungbean is one of the important pulse crops in Bangladesh as well as many countries of the world. The crop has conventional less concentration by the researcher on various aspects because normally it grows with less care and management practices. For that a very few studies related to yield and development of mungbean have been carried out in our country as well as many other countries of the world. 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 micronutrient and sowing time on the yield of mungbean and other legumes.

2.1. Effect of micronutrient

Biswas *et al.* (2010) conducted a two-year field experiment during kharif season of 2005 and 2006 at the Pulse and Oilseeds Research Sub-station, Beldabga, Murshidabad, West Bengal, India 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}). Combined inoculation of seed with Rhizobium + Azotobacter + PSB (1629.00 kg ha^{-1}) and Rhizobium + PSB rermarkbly increased the seed yield due to better nodulation along with improvement in growth and yield. The effect of interaction between foliar spray and inoculation on seed yield was found significant.

Srivastava *et al.* (2005) observed that in absence of applied B, there was no yield as no pods were formed, in comparison to a yield of 300 kg ha^{-1} in the full nutrient treatment. There was yellowing of younger leaves and typical 'little leaf' symptoms when B was omitted. A critical concentration range of 15-20 ppm B was found for the shoot tips of chickpea.

Ali *et al*. (2002) reported that yield losses of varying magnitude in chickpea, e.g., 22-50% due to Zinc (Zn), up to 100% due to boron (B) and 16-30% due to sulphur (S). Genotypic differences in response to application of Fe, B and Zn have also been found among chickpea genotypes.

Bharti *et al.* (2002) carried out a field experiment in Bihar, India during the winter of 1997-98 to observe the effect of B (0, 1.5 and 2.5 kg ha-1) application on the yie;ld and nutrition of chickpea (cv. BG256). They reported that the mean seed yield and seed and stover Zn and B content increased, whereas stover yield decreased with the increasing B and Zn rate.

Abdo (2001) conducted two field experiments at Giza Experimental Station, ARC, Egypt, 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, respectively) in addition to distilled water as control were sprayed once at 35 DAS. The results showed that foliar spray with the adopted conc. of Zn, Mn or B alone or in a mixture increased significantly most of the growth parameters over the control in both seasons. Application of Zn (0.2 g/l) along followed by a mixture of micronutrients results in better morphological and physiological parameters. It was observed that mungbean cv. VC-1000 surpassed cv. V-2010 in all parameters under investigation in both seasons. The effect of spraying with low level of Zn, Mn, B and their mixture on the internal structure of the vegetative growth of mungbean cv. VC-1000 was investigated.

Rizk and Adbo (2001) carried out two field experiments at Giza Experimental Station, ARC, Egypt, during the 1998 and 1999 seasons to investigate the response of mungbean (*Vigna radiata*) to treatment with some micronutrients. Two cultivars of mungbean (V-2010 and VC-1000) were used inthis investigation. Zn (0.2 or 0.4g/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, respectively), in addition to distilled water as control were sprayed once at 35 DAS. The obtained results could be summarized in the following: Generally, cultivar VC-100 surpassed cultivar V-1000 in yield and its components as well as in the chemical composition of seeds with exception in 1000-seed weight and phosphorus percentage in seeds. All treatments increased significant yield and its components especially Zn (0.2 g/l) which showed a highly significant increase in all characters under investigation compared to the control. All adopted treatments increased significantly protein percentage in seeds of the two mungbean cultivars in both seasons. Among all treatments of micronutrients, B gave the highest percentage of crude protein. Seeds mungbean cv. VC-1000 exceeded those in both seasons.

Vrema and Mishra (1999) carried out a pot experiment with mungbean cv. PDM 54; boron was applied by seed treatment, soil application or foliar spraying. Boron increased yield and growth parameters with the best results in terms of seed yield plant^{-1} when the equivalent of 5 kg boron ha^{-1} was applied at flowering.

Wang *et al.* (1999) reported that there is limited risk of B toxicity due to the of boron fertilizer at up to 4 to 8 times recommended rates in rapeseed-rice cropping rotations in southeast china. The low risk of B toxicity can be attributed to relatively high B removal in harvested seed, seed and stubble, the redistribution of fertilizer B by leaching in the 0 to 60 cm layer and to boron sorption.

Verma*et al.* (1988) in a pot experiment with mungbean cv. PDM 54, boron was applied by seed treatment, soil application or foliar spraying. Boron increased yield and growth parameters with the best results in terms in terms of seed yield/plant given when the equivalent of 5 kg borax ha^{-1} was applied at flowering.

Mishra and Masood (1998) in afield study at Kanpur, Uttar Pradesh, mungbean (*Vigna radiata*) cv. K-851 were given 0, 25 or 50 kg P2O5 ha-1 and 0, 2, 4 or 6 g Mo kg-1 seed by seed pelleting. Seed yields were 422, 624 and 714 kg ha-1 with the P rates as listed and 486, 583, 649 and 628 kg from seed pelleting with increasing Mo rates. Nodule numbers were not significantly affected by treatment. Yield component data are tabulated.

Chowdhury and Narayanan (1992) observed that the tallest plant heightof 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.

Mandal *et al.* (1998) noted that most of alluvial acidic soils in North Bengal, India may response to the application of B fertilizer thus increasing the yield of pulse crops in the area.

Patra (1998) observed significant yield increase if soybean by the application of Zn (5 kg ha^{-1}).

Rahman and Alam (1998) observed that application of B (1.5 kg ha^{-1}) produced significant 10.17% higher branches $plant^{-1}$ over control in groundnut.

Yang and Zhang (1998) observed that the addition of Zn promoted elongation of epicotyls and hypocotyls of mungbean and increased seedling height and dry weight. High concentration of Zn decreased soluble protein.

Bonilla *et al.* (1997) suggested that B is an obligatory requirement for normal determinate nodule development and functioning in case of bean. Boron deficiency in pea caused a decrease in the number of nodules and an alteration of indeterminate nodule development. Moreover, B plays an important role in mediating cell surface interactions that lead to endocytosis of rhizobia by hoist cells and hence to the cporrect establishment of the symbiosis between pea and rhizobium (Bolanos *et al.*, 1994) .

Talashikar and Chavan (1996) reported a significant increase of pod yield and haulm of groundnut due to application of boron of groundnut cultivation.

Saha *et al.* (1996) conducted a field experiment in pre-khraif seasons of 1993-94 at Pundibari, India, Yellow season was given 0, 2.5or 5.0 kg borax and 0, 1 or 2 kg $ZnSO_4$ ha^{-1} applied as soil, 66% soil + 33% foliar or foliar applications and the residual effects were studied on summer greengram. In both years green gram seed yield was highest with a combination of 5 kg borax + 2 kg $ZnSO_4$. Soil application gave higher yields than foliar or soil + foliar application.

Srivastava *et al.* (1996) conducted a field experiment in Nepal with chickpea in Boron deficient soil and observed the highest flower abortion and no seed production in the treatment with any B addition.

Zaman *et al.* (1996a) conducted an experiment on mungbean and observed that application of B (2.0 kg ha^{-1}) produced 23.37% higher 1000 seed weight over control.

Zaman *et al.* (1996b) conducted an experiment on mungbean and observed that the application of Zn (1 kg ha^{-1}) with B (2 kg ha^{-1}) produced maximum plant height (35.03 cm) compared to control (21.53 cm). They also reported that the application of Zn (1 kg ha^{-1}) either alone or in combination with B (1 or 2 kg ha^{-1}) appreciable increased root length of mungbean over the control. They also reported that plant received 1 kg Mo ha^{-1} with 2 kg ha^{-1} produced 50.31 and 40.21% higher root length of mungbean over control.

Zaman *et al.* (1996c) observed that application of B (2 kg ha^{-1}) significant increased 23.57% higher plant height of mungbean over control. They also observed that application of B (2 kg ha^{-1}) produced 23.18% and 20.49% higher root length over control in 1989 and 1990, respectively.

Bolanos *et al.* (1994) suggested that Zn is required for normal development and function of nodules in case of pea. In the absence of Zn, the number, size and weight of nodules decreased and nodules development changed leading to an inhibition of nitrogenase activity.

Mahajan *et al.* (1994) found that soil application of B (0.5 kg ha^{-1}) increased pod yield and harvest index significantly of groundnut.

Wu *et al.* (1994) observed that plant dry weights of different organs in soybean were positively correlated with Zn concentration.

Gupta and Gupta (1993) reported that in the a pot experiment in soil containing 0.4 mg kg^{-1} available B, chickpea or lentils were grown following application of 0-6 mg B kg^{-1} soil and also reported that lentil was more susceptible to boron than chickpea. Boron conc. In both crops was lower in the seeds than in the straw and was increased at higher B rates.

Islam and Sarkar (1993) found higher number of seed $pod^{-1}$of mustard due to application of B @ 1.5 kg ha^{-1} above and below which seed set was hampered.

Bell *et al.* (1990) observed that leaf elongation was inhibited by interruption of the B supply 5 days late the appearance of B deficiency symptoms in the roots as observed in greengram.

Buzetti *et al.* (1990) observed that plant zinc concentration increased or decreased with increasing or decreasing rate of applied zinc of soybean.

Dwivedi *et al.* (1990) observed that under acute B stress flowering and seed formation of pulse, oil and cereal crops were drastically reduced.

Marschner (1990) reported that the deficiency symptoms of some boron sensitive crops like legumes, Brassica, beets, celery, grapes and fruit trees showed chllorosis and browning of young leaves, killed growing points, distorted blossom development, lesions in pit and roots and plants, burning of the tips of the leaves and restricted root growth are the boron toxicity symptoms in most crops.

Sakal and Sinha (1990) carried out field trials at 7 sites in North Bihar, India. They observed the seed yield of chickpea increased from 1.4 t/ha with no B to 1.76 t/ha with 3 kg B/ha. The yield response to B application was grater on low

B soils. It was conclude the on soils <0.35 ppm B, 3 kg B/ha was optimum and on soils >0.35 ppm B, 2kg B/ha was optimum.

Kulkarny *et al.* (1989) reported that the zinc application increased nodule weight, nodule number and dry weight of groundnut.

Yang *et al.* (1989) reported that combined application of N, K, Zn and B increased seed yield in rapeseed. Application of B along with N, K and Zn promoted CO_2 assimilation, nitrate reduced activity in leaves and dry matter accumulation. Seed glucosinolate and erucic acid content varies among cultivars and generally decreased with increasing K, Zn and B while seed oil content increased.

Sakal *et al.* (1988) reported that on a coarse textured highly calcareous soil, application of 2.0 and 2.5 kg B ha^{-1}increased seed yields of blackgram and chickpea by 63 and 38%, respectively.

Schon and Blevins (1987) obtained increased chickpea yields with increasing levels of b from 0 to 2.5 kg ha^{-1}. Similar results were also observed by Rerkasem *et al.* (1987) in blackgram and greengram.

Rerkasem *et al.* (1987) observed that 10 kg borax ha^{-1} increased the number of nodes $plant^{-1}$ in greengram.

Salins *et al.* (1985) reported that Zn application increased the weight of aerial parts and roots of peas.

Dutta *et al.* (1984) stated that application of B (1 kg ha^{-1}) in mungbean increased leaf area ratio, leaf area index, crop growth rate, number of branches $plant^{-1}$, no. of pod $plant^{-1}$, weight of seed pod^{-1} and a decrease in chlorophyll content and net assimilation rate but the relative growth rate, total dry matter and seed yield and some of other growth attributes were unaffected.

Singh and Singh (1984) observed that the toxicity symptoms of boron in lentil plants started appearing first in the 8 ppm level. Most important symptoms were the yellowing of the leaflets of lower leaf followed by browning and scorching.

Oliveria and Kato (1983) observed that foliar N, P and K contents of bean were unaffected by B and Zn fertilization.

Agarwala *et al.* (1981) found that direct effects of Zn are reflected by the close relationship between Zn supply and pollen production capacity of the anthers as well as the viability of the pollen grains of chickpea.

Franco and Munns (1981) reported that seed yield shoot weight in bean due to Zn application.

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 $ZnSO_4$ ha^{-1}.

Chakavarty *et al.* (1979) stated that boron concentration in legume crops increased significantly with increasing level of applied boron.

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.

Santos (1979) found a positive of legumes to Zn which increases symbiotic N fixation and the effectiveness of nitrate reductase.

Howeler *et al.* (1978) observed that yield of mungbean was nearly doubled with the application of 1 kg Zn ha^{-1}.

Novoselova and Ryabov (1977) observed that Zn slowed down the vegetative growth and increased the development of reproductive organs of tetraploid red clove.

Gerath *et al.* (1975) reported an increasing in yield of winter rape through application of boron fertilizer and recommended an application of 1 to 2 kg B ha^{-1} for increased yield.

2.2. Effect of sowing time

Islam (2008) conducted two experiments in kharif-I and khiarif-II seasons of 2006 with BARI mung-2 under well-watered and water-stress conditions with growth regulators. He observed water content and exudation rate varied with the growing season due to different sowing date.

Number of branches plant^{-1} of short-season lentil varied significant for different sowing time. Hanaln *et al.* (2006) observed that highest canopy traits such as rapid growth, light interception of lentil.

Lal *et al.* (2006) found maximum disease intensity (52%) which was recorded from 15 October sown on lentil while maximum seed yield (730 kg ha^{-1}) was obtained in lentil crop sown on 5 November.

Hossain *et al.* (2006) reported that lentil aphid appeared in the field in the first week of January. The crop sown in November received less aphid infestation and consequently produced higher yield than the crop sown in December.

Inderjit *et al.* (2005) conducted a field experiment on sandy-loam soil of Gurdaspur, Panjab, India, during the 1998-2000 winter season (rabi) to study the effect of different sowing dates, row spacing and seed rates on the productivity of lentil (Lens culinaris cv. LG 308) and reported significant effect for emergence of seedling for different sowing date. Mungbean sown on 10 November produced flowering and attain maturity the crop sown on 25 November and 10 December by a margin of 8.85 and 11.5%, respectively. Significantly higher mean seed yield was obtained in lentil sown on 10 November at 20 cm row spacing (15.7 q/ha) and that sown on 10 November using 37.5 kg seed/ha (15.9 q/ha).

Turk *et al.* (2003) reported significant effect regarding seedling emergence for different sowing time. The sowing time and rate optimum for the growth and yield of the large-seeded lentil cv. Diskiai and the small-seeded cv. Smelinukai were investigated by Kazemekas (2001) on a light loamy soil in Lithuania from 1998 to 2000 and reported that sowing time significantly influenced seedling germination. The high yields were obtained foe early sowing (1 January), high plant density (120 plant m^{-2}) for highest number of branches $plant^{-1}$.The early sowing (1 January) ensured high plant density (120 plants m^{-2}). The performance of lentil cv. Giza 9 were investigated by Allam (2002) under various sowing date and reported that sowing on 1 November gave higher number of pod $plant^{-1}$, number of seed pod^{-1} and seed yield $plant^{-1}$. Harvest index was higher when sowing conducted on 1 and 15 November.

Anwar *et al.* (2003) conducted an experiment with kabuli chickpea in cool temperature sub-humid climate under different dates of sowing and found that relative water content and exudation rate were significantly influenced by sowing date.

Brand *et al.* (2003) found that the optimum sowing dates for mungbean cultivars in 2000 were mid June to early July and in 2001 mid May to mid June. The effects of sowing date, plant density phosphorus level and ethephon application were investigated in the semiarid region in the north of Jorden by Turk *et al.* (2003) and observed that yields were obtained for early sowing (1 January).

Field experiments were conducted by Ahmed *et al.* (2002) found that the control options were sowing dates (mid-November, mid-December and mid-January), host plant resistance cultivars ILL 5883(highly resistant), ILL 5722 (moderately resistant) and ILL 2130 (highly susceptible) and fungicide seed treatment on mungbean crops.

Al-Hussien *et al.* (2002) reported that different sowing dates (early and late) significantly affect number of branches $plant^{-1}$ of lentil.

Allam (2002) found under various sowing date (1 November, 15 November and 1 December) that the sowing on 1 November gave taller plants with higher number of branches $plant^{-1}$of lentil.

In mungbean number of branches plant^{-1}, number of pods plant^{-1}, number of seed pod^{-1}, 1000 seed weight and seed yield were significantly influenced by the dates of sowing (Mian *et al.*, 2002).

The highest yield was obtained when seeds were sown on 25 January followed by 05 February and 15 January and the lowest in 5 march planting. The lowest yield obtained from early and delay planting. The lower seed yield plant^{-1} at the last sowing was due to significant decrease in the number of seeds pod^{-1} and 1000 seed weight of chickpea (Siddique *et al.*, 2002).

Kazemekas (2001) found that the earliest sowing date were optimum for the optimum flowering and maturity of greengram.

Andrews *et al.* (2001a) in Canterbury, New Zealand carried out an experiment to assess the potential of mungbean as a seed legume crop in the UK. The model was validated using five sowing dates at Durham, UK in 1999. Predicted time to flowering was within 7 days of actual time to flowering and predicted seed yields were within 9% of actual yields. Time to flowering generally decreased along the transect from North West to South East UK ranging from 28 June to 9 July and from 20 May to 14 June with the May and October sowings, respectively.

Andrews *et al.* (2001b) predicted time to flowering was within 7 days of actual time i.e. 15 September to flowering and predicted seed yields of lentil were within 9% of actual yield and actual yields range from 1.40 to 1.65 t ha^{-1}.

Seed yield in mungbean is a function of number of pods plant^{-1}, number of seed pod^{-1}, 1000 seed weight and seed size of mungbean (Nag *et al.*, 2000).

Siddique *et al.* (1998a) observed sowing in late April or early May allowed a longer period for vegetative and reproductive growth, rapid canopy development, more water use and hence, greater vegetative growth and number of branches of lentil.

Siddique *et al.* (1998b) reported that sowing in late September or early October allowed a longer period for vegetative and reproductive growth. Early-sown lentils began flowering earlier in the growing season, at a time when vapour in the post-flowering period when compared with those treatments where sowing was delayed.

Rahman and Sarkar (1997a) reported that high-yielding cultivars also had more leaves and petioles at both vegetative and reproductive phases and number of branches plant^{-1} of lentil.

Rahman and Sarkar (1997b) reported the highest (1.85 t ha^{-1}) and the lowest (0.75 t ha^{-1}) seed yields of mungbean were obtained from cultivars ILX 87052 and Utfala, respectively. Higher seed yields were achieved through the contribution of higher total dry matter, more pods per plants and bigger seeds.

El-Nagar and Galal (1997) in 1993-95 at Assuit, Egypt, lentils were sown 1 or 15 November or 1 December and were harvested at physiological maturity or one or two weeks late and reported that delaying harvesting by one or two weeks after physiological maturity decreased seed yield by 19.7% and 33.6%, respectively. The delaying sowing decreased seed yield.

Yield potentiality is an inherent character of crop cultivars. The productivity of a crop is governed by such inherent genetic makeup and physiological expression under certain growth environment (Baset *et al.*, 1996).

Gurung *et al.* (1996a) carried out a field experiment in 1991-94 at Dhankuta, Nepal to determine the appropriate sowing date for lentils and reported that October sowing were associated with early good crop vigor with highest percentage of seedling germination.

Gurung *et al.* (1996b) reported reduced number of branches plant^{-1}from November and December sowings for chickpea were mainly due to the adverse effect of the air temperatures at the early vegetative growth period and shorter total crop growth period. Mishra *et al.* (1996) also reported similar findings.

Gurung *et al.* (1996c) reported that warmer air temperatures during vegetative growth period and longer total growth period, seed yield from September sowing was low. This was mainly due to excess rainfall during early vegetative growth stage which had adverse effects on mungbean establishment.

Gurung *et al.* (1996d) found that average seed yields of blackgram crops sown on 10 and 25 October were 1274 and 1591 kg/ha, respectively which were significantly higher than other sowing dates. Blackgram seed yield was greatly reduced if sowing was advanced from 10 October to 25 September (533 kg/ha) or delayed from 25 October to 9 November (597 kg/ha). The straw yields of lentil were also higher from October sowings.

Mishra *et al.* (1996) reported that seed yield decreased with delay in sowing date after 23 October and the weed-free control gave the highest seed yield of lentil.

Greengram (*Vigna radiate* L. Wilczek) harvested from early showed best quality than that of late sowing. Late sowing crop was harvested under humidity (>70%) and high air temperature (25-35°C) conditions which respond was for poor germination and vigor of the harvested greengram seed (Yadav and Nagarajan, 1995).

Sekhon *et al.* (1994) reported that sowing rates had no significant effect on seed yields and seed yields of lentil range from 2.04 t ha^{-1} and the lowest rate 1.20 t ha^{-1}.

Time of sowing had no effect on germination of the pea seeds and there were no differences between in seed quality harvested in either January to February (Castillo *et al.*, 1994; Batra *et al.*, 1992).

Delay in sowing caused a significant reduction in seed yield. The highest seed yield was recorded in 16 November sowing of chickpea (Dixit *et al.*, 1993).

Bukhtiar *et al.* (1991a) observed that the higher harvest index (HI) of 42.3% in lentil cv. AARIL344 and 41.4% in lentil cv. AARIL337 was obtained from 23

November sowing. The lower HI (25.1%) was recorded in lentil cv. AARIL355 sown on 26 September. The last week of October was found better with an optimum range from the end of September to 2^{nd} week of November.

Bukhtiar *et al.* (1991b) found that the last week of October proved the better sowing date at which blackgram cv. AARIL496 (1694 and 6125 kg ha^{-1}) sowing in the 2^{nd} week of November blackgram cv. AARIL344 (1427 and 1365 kg ha^{-1}). The overall mean seed yield for cultivars was higher (1236.5 kg ha^{-1}) in 9-6 followed by blackgram cv. AARIL496 (1225.4 kg ha^{-1}) and blackgram cv. AARIL344 (1222.4 kg ha^{-1}). The lowest mean yield (493.2 kg ha^{-1}) was recorded in blackgram cv. AARIL355.

In case of groundnut, yield recorded from 5 February and 20 February did not differ markedly, but produced significant higher yield that of crop sown earlier on 20 January (Patel *et al.*, 1983).

The seed yield of greengram was significant influenced by different date of sowing. Greengram sown on 30 October gave highest yield. Delay in sowing beyond 30 October reduced the seed yield (Saxena and Yadav, 1975).

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at theSher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from August 2013 to January 2014 to study the effect of micronutrients (B and Zn) and sowing time on water relations and yield of mungbaen**.** 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 Mung-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 Mung-6 in the year 2003. The plant attains a height of 35-40 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. 1000 seeds weight is 35-40 g. 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: **Doses of Micronutrient (B and Zn)**

i. F_0= Recommended fertilizer dose (RFD) [20.7 kg N/ha, 48 kg P_2O_5/ha and 34.8 kg K_2O/ha (BARI, 1998)]
ii. F_1= RFD + 1.0 kg B ha^{-1}
iii. F_2= RFD + 2.0 kg B ha^{-1}
iv. F_3= RFD + 8.5 kg Zn ha^{-1}
v. F_4 =RFD + 17.0 kg Zn ha^{-1}

Factor B: **Sowing time**

i. S_1= 24 August
ii. S_2 = 23 September
iii. S_3= 23 October

There were 15 (5 × 3) treatment combinations viz., F_0S_1, F_0S_2, F_0S_3, F_1S_1, F_1S_2, F_1S_3, F_2S_1, F_2S_2, F_2S_3, F_3S_1, F_3S_2, F_3S_3, F_4S_1, F_4S_2 and F_4S_3.

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 micronutrients and sowing time. The 15 treatment combinations of the experiment were assigned at random into 15 plots of each replication. The size of each unit plot 3.0m× 2.0 m. The spacing between blocks and plots were 0.5 m and 0.25 m.

3.4. Growing of crops

3.4.1.1. Seed collection

The seeds of the test crop i.e., BARI Mung-6 were 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 August, 2013 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 24 August, 23 september and 23 october.

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. B and Zn were applied respectively from boric acid and $ZnSO_4$ as per treatment during final land preparation.

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), 2^{nd} and 3^{rd} 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 November and harvesting was completed in January, 2014. 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 recording

3.6.1. Days to 1st emergence

Days to 1st emergence was counted from the date of sowing seeds for BARI Mung-6 variety.

3.6.2. Days to 80% emergence

Days to 80% emergence was counted from the date of sowing seeds for BARI Mung-6 variety.

3.6.3. Days to 50% flowering

Days to 50% flowering was measured from the date of sowing when 50 % of the mungbean plants flowered.

3.6.4. Relative water content

Relative water content (RWC) was measured at first flowering. The third leaves with petioles for each sample were cut with a sharp knife and were put in a polyethylene bag. The bags were kept on a tray containing little water and were warp pod with a moist towel to avoid light and desiccation. Then the samples were brought in the laboratory and their fresh weights were recorded without any delay. The leaf samples were then dipped in water for 24 hours and their turgid weights were recorded after soaking the leaf surface water by paper towel. The samples were then over-dried to constant weight at 70^{0}c in 3 days. The relative water content was measured using the following formula:

Relative Water Content (RWC %) = [(Fresh weight – Dry weight) / (Turgid weight- Dry weight)] × 100

3.6.5. Exudation Rate

Exudation rate was measured on 30 days after sowing before sunshine from the stem at about 5 cm above from the ground. At first, dry cotton was weighed. A slanting cut on the stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exudation of the sap was collected from the stem for 1 hour at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was calculated by deducting cotton weight from the sap containing cotton weight was expressed hour^{-1} basis as follows:

Exudation Rate (ER) = [(Weight of cotton + Sap) – (Weight of cotton)] / Time

3.6.6. Number of branches plant^{-1}

The branches were counted from the 3 randomly selected plants at 50 days after sowing and mean value was determined.

3.6.7. Number of pods plant^{-1}

Number of total pods of 3 plants from each plot was noted and the mean number was expressed per plant basis.

3.6.8. Pod length plant^{-1}

Length of 10 pods of 3 selected plants from each plot was noted and the mean number was expressed per pod basis.

3.6.9. Number of seeds pod^{-1}

Number of total seeds from ten randomly selected pods of 3 plants from each plot was noted and the mean number was expressed per pod basis.

3.6.10. Weight of 1000 seeds

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.

3.6.11. Seed yield

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

3.6.12. Stover yield

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 was converted to t ha^{-1}.

3.6.13. Biological yield

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula and was expressed in t ha^{-1}.

Biological yield = Seed yield + Stover yield.

3.6.14. Harvest index

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

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

3.7. 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 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to evaluate the effect of sowing date and micronutrient on water relation and yield of mungbean. The results obtained from the study have been presented, discussed and compared in this chapter through different tables, figures and appendices. The analyses of variance of data in respect of all the parameters have been shown in Appendices IV-VII. The results have been presented and discussed with the help of tables and graphs and possible interpretations have been given under the following headings.

4.1. Day to first emergence

Days to first emergence was significantly influenced by the different micronutrient levels. Results revealed that the days required for first emergence decreased gradually with the increasing levels of micronutrients up to F_4 level (Appendix IV and Figure 1). The control treatment (F_0) took the maximum days (2.90days) for first emergence whereas, the minimum days (2.17days) was taken by F_4 (17.0 kg Zn ha^{-1}) treatment, which was statistically similar (2.37days) with F_3 (8.5 kg Zn ha^{-1}) treatment.

A significant variation of days to emergence was found due to different sowing time (Appendix IV and Figure 2). The minimum days to first emergence (2.14 days) was required in S_1 (24 August) treatment, which was statistically similar (2.26 days) with S_2 (23 September) treatment and the maximum (3.10 days) was recorded in S_3 (23 October) treatment. These results indicated that delayed sowing increased number of days required to first emergence. This might be due to decreasing level of soil moisture with the delayed seed sowing accompanied by the fall in temperature with the onset of winter.

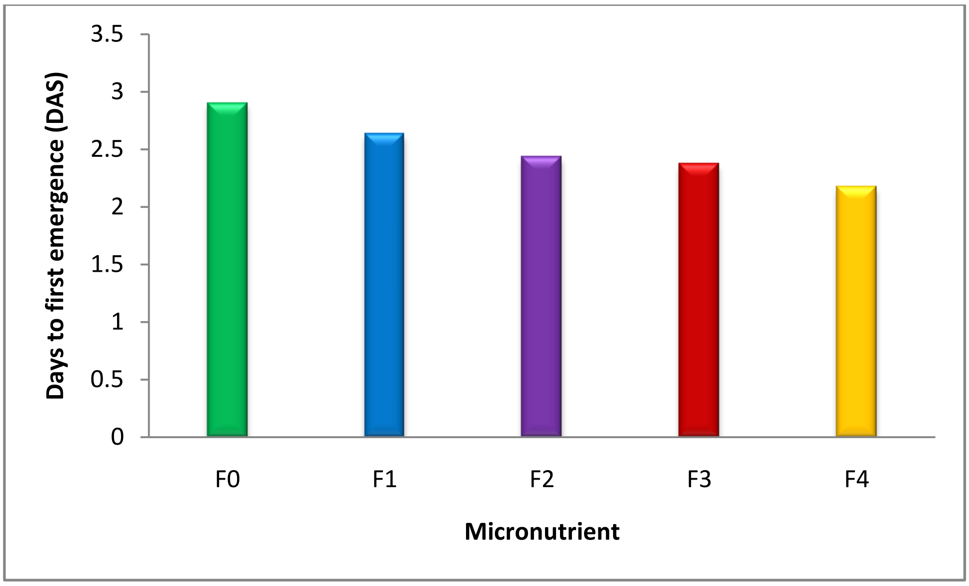

Figure 1. Effect of micronutrients on days to first emergence of mungbean [LSD value = 0.22; F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2=RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn ha^{-1}and F_4 = RFD +17kg Zn ha^{-1}.]

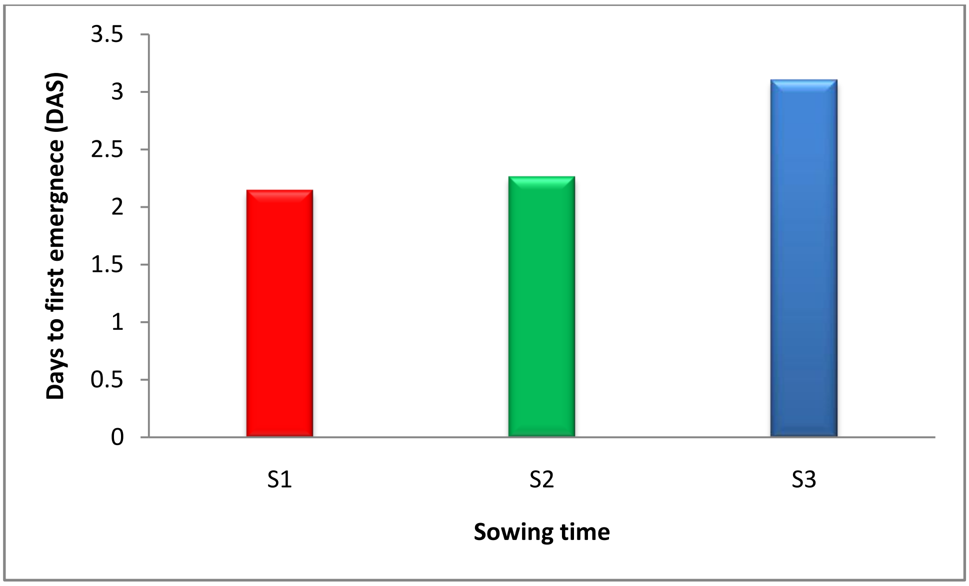

Figure 2. Effect of sowing time on days to first emergence of mungbean [LSD value = 0.17; S_1=24 August, S_2=23 September and S_3=23 October.]

Interaction effect of micronutrient and sowing time on days to first emergence of mungbean was significant (Appendix IV and Table 1). The minimum days required for first emergence (1.80 days) was recorded from the combination of 17.0kg Zn ha^{-1} and seeds sowing on 24 August (F_4S_1) whereas, the maximum days (3.60 days) was recorded from the combination of no micronutrient ha^{-1} when seeds sowing on 23 October (F_0S_3).

4.2. Days to 80% emergence

Days to 80% emergence was significantly influenced due to different levels of micronutrient. Results revealed that, the days required for 80% emergence decreased gradually with increasing the rate of micronutrient (Appendix IV and Figure 3). The minimum days to 80% emergence (3.63 days) was required for F_4 (17 kg Zn ha^{-1}) treatment, which was statistically similar (3.83 days) with F_2 (2 kg B ha^{-1}) treatment and the maximum (5 days) was recorded in F_0 (control treatment). These results indicated that increasing micronutrient rates decreased days required for 80% emergence, where decreasing rate was more for B compared to Zn.

Days to 80% emergence was significantly influenced by the different sowing time (Appendix IV and Figure 4). Results revealed that S_3 (23 October) treatment took the maximum days (4.94 days) for 80% emergence whereas, the minimum days (3.84 days) was taken by S_1 (24 August) treatment, which was statistically similar (3.98 days) with S_2 (23 September) treatment. These results indicated that delayed sowing increased days required to 80% emergence might be due to decreasing trend of soil moisture.

Interaction effect of micronutrient and sowing time significantly influenced the days taken to 80% emergence of mungbean (Appendix IV and Table 1). The minimum days required for 80% emergence (3 days) was recorded from the treatment combination of 17kg Zn $ha^{-1}$and 24 August sowing (F_4S_1). The maximum days required for 80% emergence (5.7 days) was recorded from the combination of no micronutrient and 23 October sowing (F_0S_3) treatment.

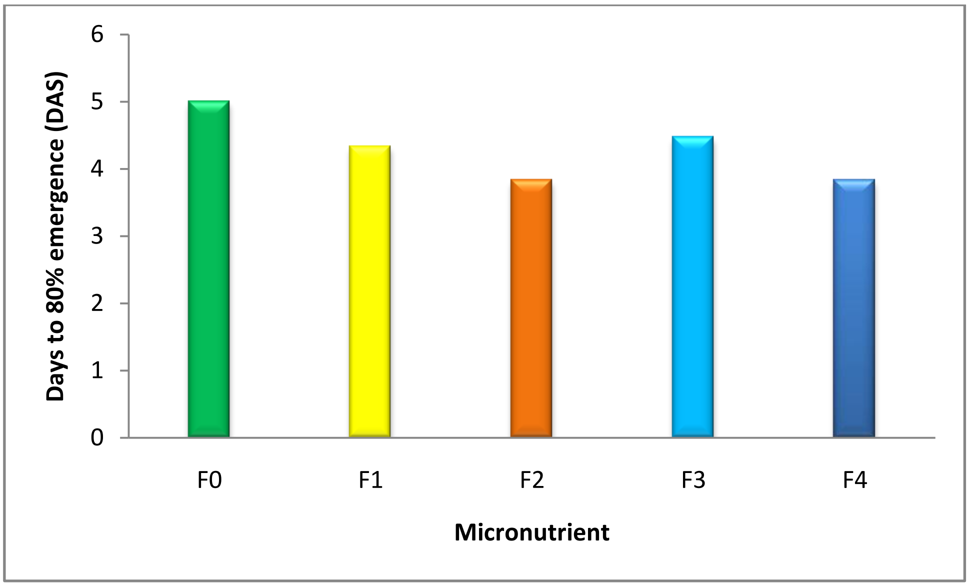

Figure 3. Effect of micronutrients on days to 80% emergence of mungbean [LSD value = 0.22; F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2= RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn $ha^{-1}$and F_4 -=RFD +17kg Zn ha^{-1}]

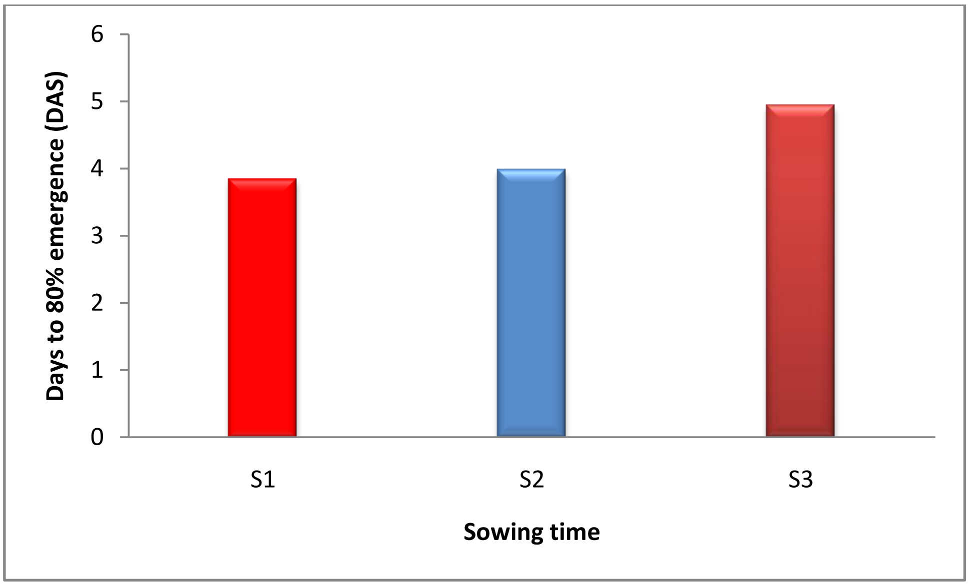

Figure 4. Effect of sowing time on days to 80% emergence of mungbean [LSD value = 0.17; S_1=24 August, S_2=23 September and S_3=23 October.]

Table 1. Interaction effect of micronutrients and sowing time on days to first emergence, 80 % emergence and 50 % flowering of mungbean

Treatments	1^{st} emergence (DAS)	80 % emergence (DAS)	50 % flowering (DAS)
F_0S_1	2.40 fg	4.50 de	37.80 b
F_0S_2	2.70 de	4.80 bc	38.10 ab
F_0S_3	3.60 a	5.70 a	39.00 a
F_1S_1	2.20 gh	3.90 g	36.00 d
F_1S_2	2.50 ef	4.20 f	36.30 cd
F_1S_3	3.20 b	4.90 b	37.33 bc
F_2S_1	2.10 h	3.40 h	33.70 ef
F_2S_2	2.10 h	3.50 h	33.70 ef
F_2S_3	3.10 bc	4.50 de	34.70 e
F_3S_1	2.20 gh	4.30 ef	32.40 gh
F_3S_2	2.00 hi	4.10 fg	32.20 gh
F_3S_3	2.90 cd	5.00 b	33.10 fg
F_4S_1	1.80 i	3.00 i	31.30 h
F_4S_2	2.00 hi	3.30 h	31.50 h
F_4S_3	2.70 de	4.60 cd	32.20 gh
$LSD_{(0.05)}$	0.22	0.22	1.20
CV (%)	5.19	3.05	2.07

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability.
F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2=RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn $ha^{-1}$and F_4 = RFD +17kg Zn ha^{-1}.].
S_1=24 August, S_2=23 September and S_3= 23 October.

4.3. Days to 50% flowering

Significant variation was observed in days to 50% flowering due to micronutrient (Appendix IV and Figure 5). The maximum (38.30 days) days required for 50% flowering was observed in F_0 (no micronutrient) treatment whereas, the minimum (31.67 days) days required for 50% flowering was observed in F_4 (17 kg Zn ha^{-1}) treatment, which was statistically similar (32.57days) with F_3 (8.5 kg Zn ha^{-1}) treatment. These results indicated that micronutrient decreased the days required for 50% flowering with their increasing rate. It was also observed that Zn decreased the days required for 50% flowering more compared to B under the condition of the experiment.

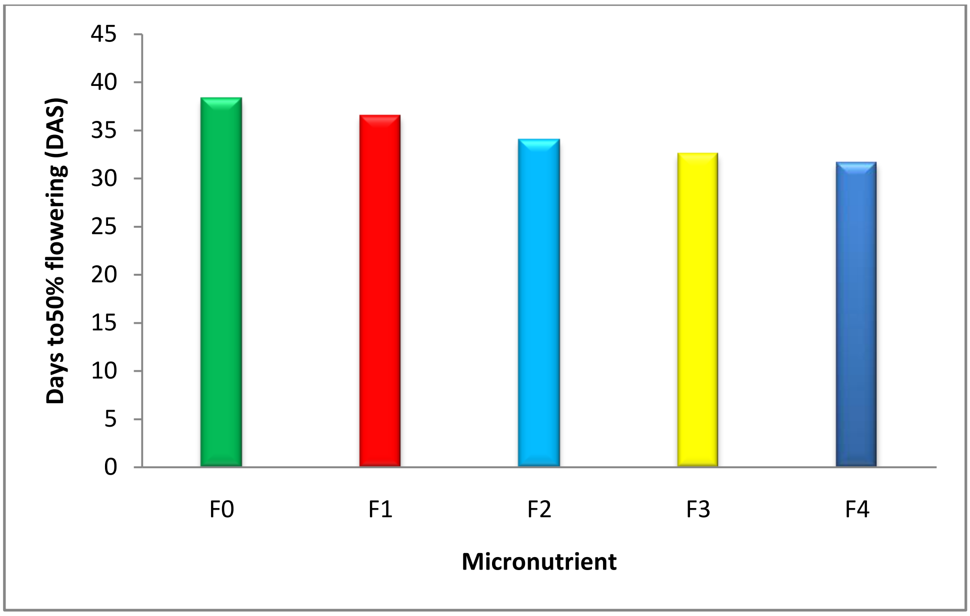

Figure 5. Effect of micronutrients on days to 50% flowering of mungbean [LSD value = 1.20F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2=RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn ha^{-1}and F_4 = RFD +17kg Zn ha^{-1}]

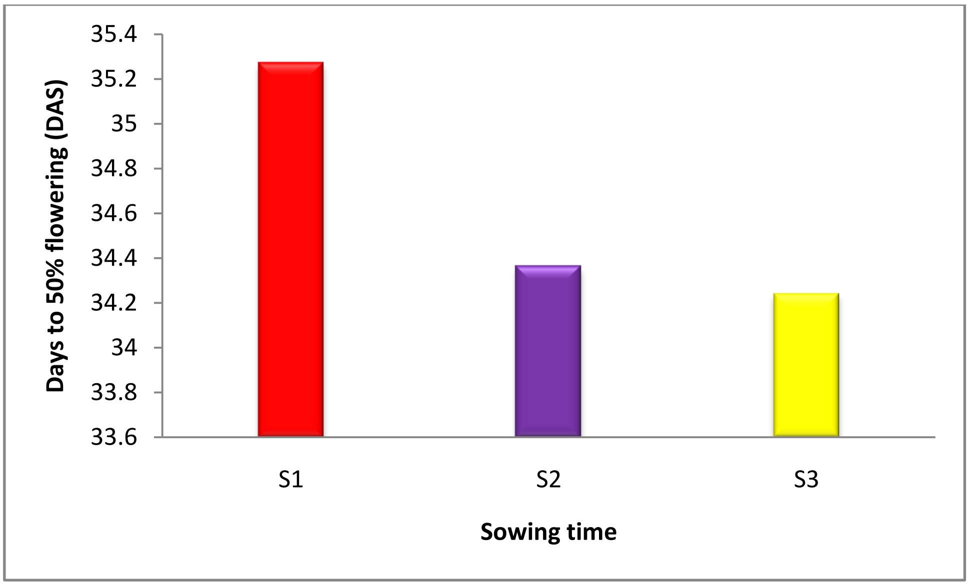

Figure 6. Effect of sowing time on days to 50%flowering of mungbean [LSD value = 0.93; S_1=24 August, S_2=23 September and S_3=23 October.]

Significant variation was observed in days required for 50% flowering due to sowing time in mungbean (Appendix IV and Figure 6).The maximum days required for 50% flowering (35.27 days) was observed in S_1 (24 August) treatment whereas, the minimum days of 50% flowering (34.24 days) was observed in S_3(23 October) treatment, which was statistically similar (34.36days) with S_2 (23 September) treatment.

Combined effect of micronutrient and sowing time showed significant variation in days to 50% flowering (Appendix IV and Table 1). The highest days for 50% flowering (39 days) was recorded from the treatment combination of no micronutrient and 23 October sowing (F_0S_3), which was statistically similar (38.10days) with F_0S_2 (no micronutrient and 23 September sowing) whereas, the lowest days to 50% flowering (31.30 days) was observed from the treatment combination of 17 kg Zn ha^{-1} and 24 August sowing (F_4S_1), which was statistically similar F_3S_1, F_3S_2, F_4S_2 and F_4S_3. The lowest number of days for 50% flowering was observed on 17 kg Zn ha^{-1} and 23 October sowing.

4.4. Exudation rate

Exudation rate is known as the flow of sap from cut end of stem against the gravitational force. The highest exudation rate (1244 mg hr^{-1}) was obtained from F_4 (17 kg Zn ha^{-1}) and the lowest (1006 mg hr^{-1}) in F_2 (2 kg B ha^{-1}), which was statistically similar (1034 mg hr^{-1}) with F_0 (control treatment) (Appendix V and Figure 7). Morpho-physiological differences in mungbean plants due to different micronutrient might influenced the water uptake as well as transpiration stream and thereby influenced exudation rate. These results indicated that B application at the rate of 2 kg ha^{-1} had negative effect on exudation rate. Variations in exudation rate due to micronutrients were also observed by Omae *et al.* (2005) in snapbean.

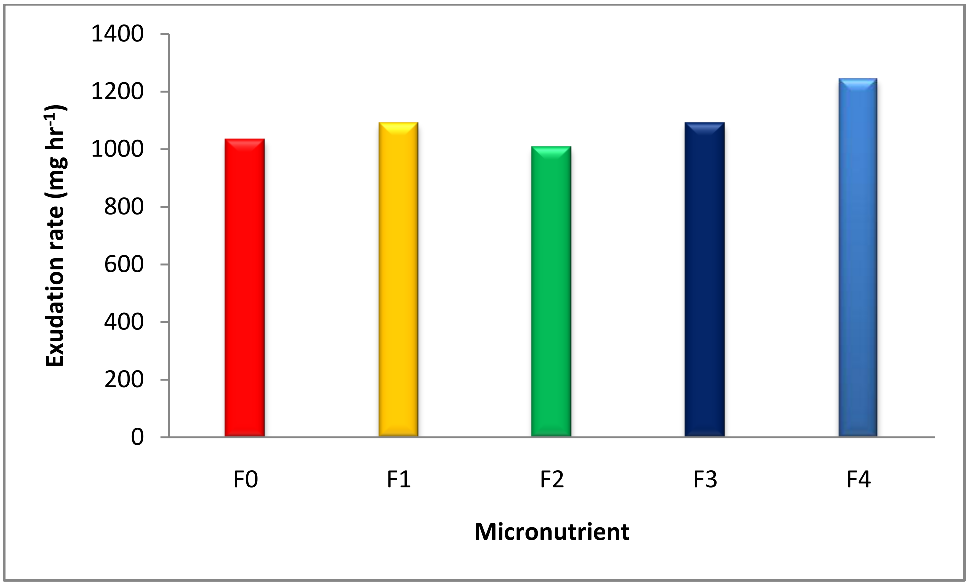

Figure 7. Effect of micronutrients on exudation rate of mungbean [LSD value = 34.55;F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2=RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn $ha^{-1}$and F_4 =RFD +17kg Zn ha^{-1}.]

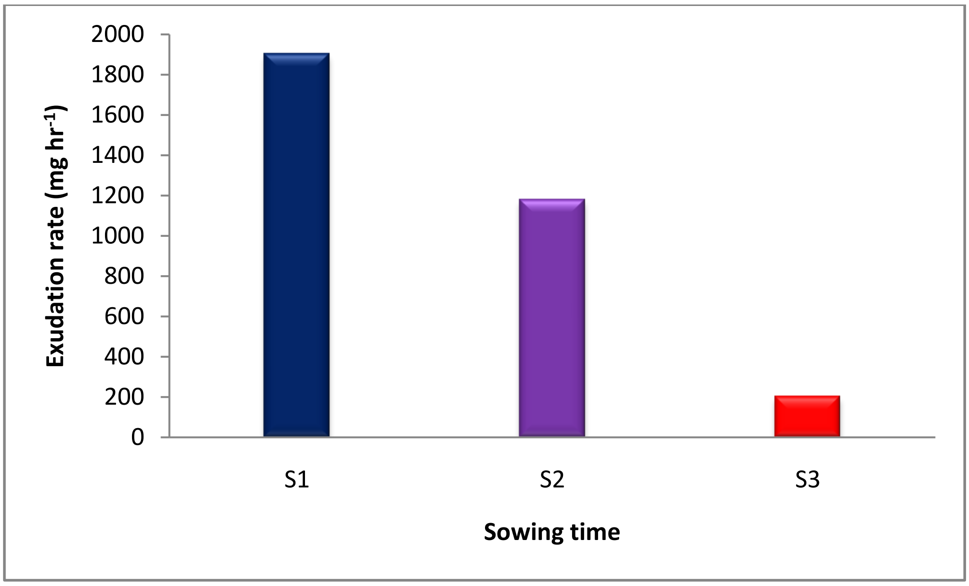

Figure 8. Effect of sowing time on exudation rate of mungbean [LSD value = 26.76; S_1=24 August, S_2=23 September and S_3= 23 October]

Exudation rate was significantly influenced by sowing time (Appendix V and Figure 8). However, the highest exudation rate (1900 mg hr^{-1}) was found in S_1 (seeds sowing on 24 August) treatment and the lowest (201.20 mg hr^{-1}) in S_3 (seeds sowing on 23 October) treatment. Decrease in gradual exudation rate in late sowing might be due to the decrease in soil moisture content.

Interaction of micronutrient and sowing time had a significant influence on exudation rate (Appendix V and Table 2). The highest exudation rate (2352 mg hr^{-1}) was obtained from the treatment combination of 17 kg Zn ha^{-1} and 24 August (F_4S_1) while, the lowest (106 mg hr^{-1}) from the combination of 8.5 kg Zn ha^{-1} and 23 October (F_3S_3) treatment.

4.5. Relative water content

Relative water content (RWC) signifies the water content of plant. The relative water content was significantly influenced by micronutrient (Appendix V and Figure 9). The highest RWC (89.54 %) was found in F_4 (17 kg Zn ha^{-1}) treatment, which was statistically similar (86.10, 87.05 and 87.32 %, respectively) in F_3, F_2 and F_1 treatment and the lowest (84.05) was obtained from F_0 (control treatment i.e., no micronutrients). Differences in RWC might be due to the morpho-physiological differences among the micronutrient. Variations in RWC due to micronutrients were also observed by Islam *et al.* (2009a).

Relative water content was influenced by sowing time. The highest RWC (89.04 %) was obtained from S_1 (seeds sowing on 24 August) treatment, which was statistically similar (88.63 %) with S_2 (seeds sowing on 23 September) treatment and the lowest (82.77 %) was found in S_3 (seeds sowing on 23 October) treatment (Appendix V and Figure 9). Atmospheric relative humidity and temperature greatly influence the RWC of plant leaves. The highest RWC found in S_1 treatment (seeds sowing on 24 August) might be attributed to the highest relative humidity existing during RWC determination whereas, the lowest value found in S_3 (seeds sowing on 23 October) this might be attributed to lower relative humidity during RWC determination at first flowering. Variations in RWC due to relative humidity were also reported by Anwar *et al.* (2003) in chickpea.

Interaction of micronutrient and sowing time had a significant influence on relative water content of mungbean leaves (Appendix V and Table 2). The highest RWC (93.33 %) was obtain from the treatment combination of 17 kg Zn ha^{-1} and seeds sowing on 24 August (F_4S_1) which was statistically similar (93.04, 90.60 and 89.39 %, respectively) to F_0S_1, F_0S_2 and F_3S_2 treatment whereas, the lowest RWC (78.33 %) was observed in the treatment combination of no micronutrient and seeds sowing on 23 October (F_0S_3) which was statistically similar (79.89 and 80.42 %, respectively) to F_1S_3 and F_3S_3 treatments.

4.6. No. of branches plant^{-1}

The number of branches plant^{-1} was significantly varied among the micronutrient (Appendix V and Figure 11). Number of branches plant^{-1} increased with increasing the rate of micronutrient continued up to F_4 level. The maximum (2.00) number of branches plant^{-1} was counted from 17 kg Zn ha^{-1} and the minimum number (0.67) was counted from control (F_0) treatment which was statistically similar (1.58) with 1 kg B ha^{-1} (F_1) treatment. The study referred that 17 kg Zn ha^{-1} produced maximum number of branches plant^{-1}.

Different sowing time significantly affected the number of branches plant^{-1} of mungbean (Appendix V and Figure 12). The maximum number of branches plant^{-1} (1.33) was recorded from 24 August (S_1) sowing which was statistically similar (1.47) with 23 September (S_2) treatment and the minimum number of branches plant^{-1} (0.80) was counted from 23 October (S_3) treatment. Present study showed that 24 August produced maximum number of branches plant^{-1}.

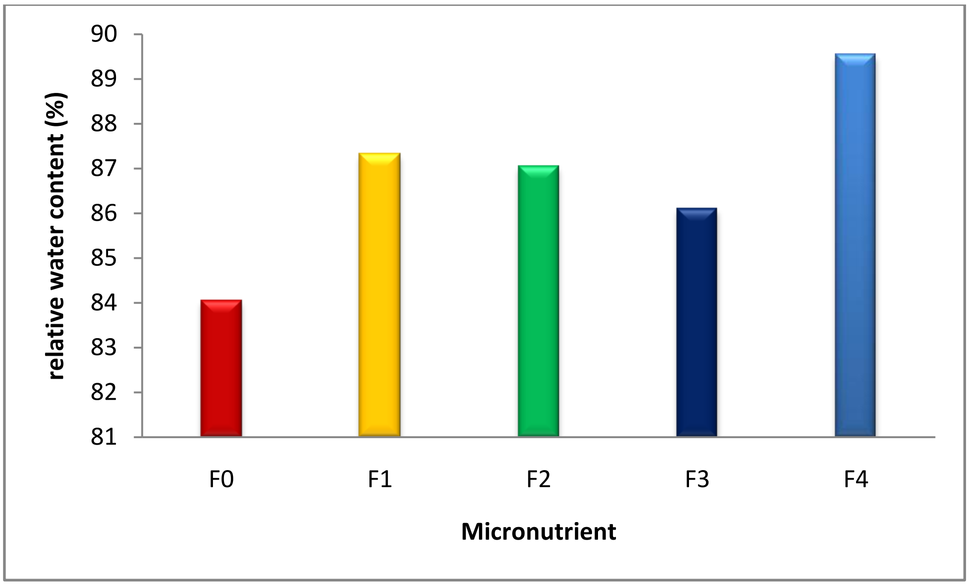

Figure 9. Effect of micronutrients on relative water content (%) of mungbean [LSD value = 4.22; F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2=RFD + 2 kg B ha^{-1}, F_3 =RFD + 8.5 kg Zn $ha^{-1}$and F_4 =RFD +17kg Zn ha^{-1}.]

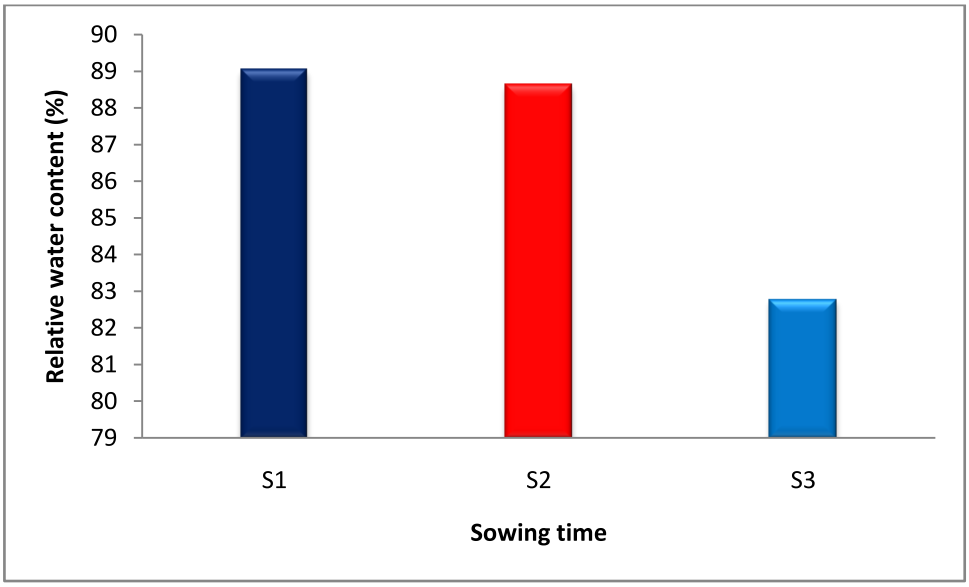

Figure 10. Effect of sowing time on relative water content (%) of mungbean [LSD value = 2.91; S_1=24 August, S_2=23 September and S_3=23 October.]

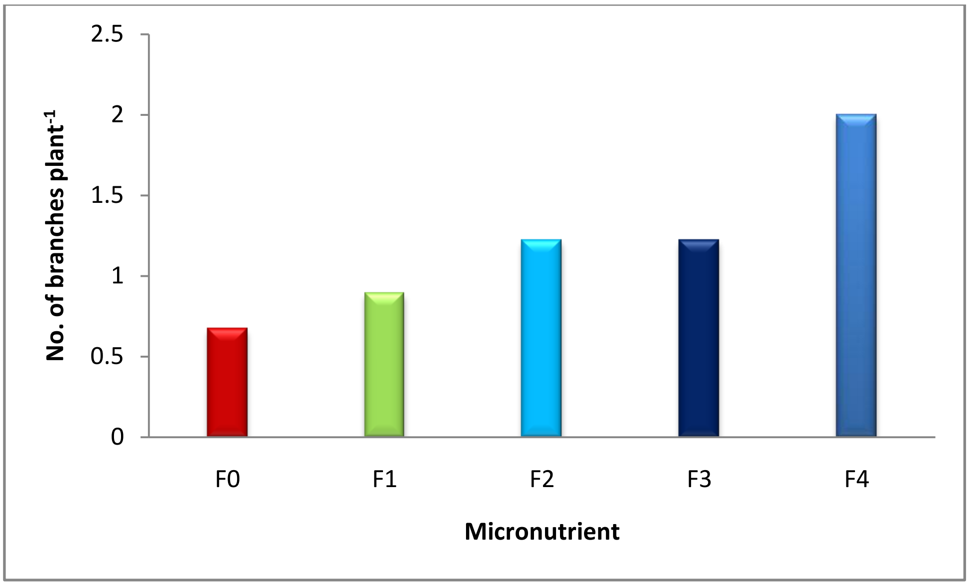

Figure 11. Effect of micronutrients on number of branches plant^{-1} of mungbean [LSD value = 0.40; F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2= RFD + 2 kg B ha^{-1}, F_3 =RFD + 8.5 kg Zn ha^{-1}and F_4 = RFD +17kg Zn ha^{-1}]

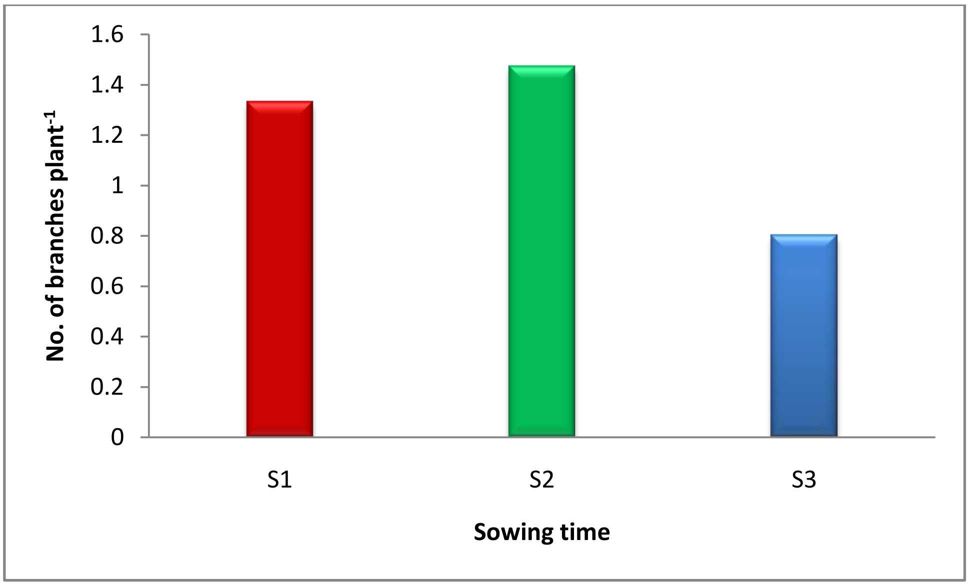

Figure 12. Effect of sowing time on number of branches plant^{-1} of mungbean [LSD value = 0.31; S_1=24 August, S_2=23 September and S_3= 23 October.]

Table 2. Interaction effect of micronutrient and sowing time on exudation rate, relative water content and number of branches plant^{-1} of mungbean

Treatments	Exudation rate (mg hr^{-1})	Relative water content (%)	No. of branches plant^{-1}
F_0S_1	1964.00 c	93.04 a	1.00 c
F_0S_2	966.00 h	90.60 ab	1.00 c
F_0S_3	173.00 l	78.33 f	0.33d
F_1S_1	1252.00 f	84.25 df	1.00 c
F_1S_2	1700.00 e	88.00 b-d	0.67 c
F_1S_3	320.00 j	79.89 f	1.00 c
F_2S_1	2011.00 b	86.08 cd	0.67 c
F_2S_2	826.00 i	86.53 b-d	2.00 b
F_2S_3	180.00 l	88.54 bc	1.00 c
F_3S_1	1921.00 d	88.48 bc	1.00 c
F_3S_2	1247.00 f	89.39 a-c	1.67 b
F_3S_3	106.00 m	80.42 ef	1.00 c
F_4S_1	2352.00 a	93.33 a	3.00 a
F_4S_2	1153.00 g	88.62 bc	2.00 b
F_4S_3	227.00 k	86.67 b-d	1.00 c
$LSD_{(0.05)}$	34.55	4.22	0.33
CV (%)	1.89	2.91	19.92

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability.
F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2–=RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn ha^{-1}and F_4 = RFD +17kg Zn ha^{-1}.
S_1=24 August, S_2=23 September and S_3= 23 October.

Interaction effect of micronutrient and sowing time significantly influenced number of branches plant $^{-1}$ (Appendix V and Table 2). The maximum number of branches plant^{-1} (3.00) was recorded from the combination of 17kg Zn ha^{-1} and 24 August sowing (F_4S_1) whereas, the minimum number (0.37) of branches plant^{-1} was recorded from the treatment combination of no micronutrient and 23 October sowing (F_0S_3).

4.7. Pod length

Statistically significant differences were found for pod length of mungbean due to micronutrient (Appendix VI and Table 3). The maximum length of pod (9.08 cm) was recorded from 17 kg Zn ha^{-1} which was statistically similar (8.90 and 8.60 cm, respectively) to F_2 and F_3 treatment whereas, the minimum (8.43 cm) was observed from no micronutrient which was statistically similar (8.49 cm) to F_1 treatment.

Length of pod of mungbean differed significantly due to sowing time (Appendix VI and Table 4). The maximum length of pod (9.42 cm) was recorded from 24 August sowing and the minimum (8.18 cm) was found in23 September sowing which was statistically similar (8.49 cm) to 23 October sowing.

Interaction effect between micronutrient and sowing time showed significant variation in length of pod (Appendix VI and Table 5). The maximum pod length (10.60 cm) was recorded from the treatment combination of 17 kg Zn ha^{-1} and 24 August sowing and the minimum (7.50 cm) was observed from the treatment combination of no micronutrient and 23 October sowing.

Table 3. Effect of micronutrients on pod characteristics and 1000-seed weight of mungbean

Treatments	Pod length (cm)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000-seed weight (g)
F_0	8.43 b	10.61 d	8.73 c	33.92 e
F_1	8.49 b	13.14 b	9.56 b	36.92 c
F_2	8.90 ab	11.48 c	9.04 bc	35.67 d
F_3	8.60 ab	11.17 c	9.44 b	37.66 b
F_4	9.08 a	14.17 a	10.33 a	40.04 a
$LSD_{(0.05)}$	0.48	0.47	0.59	0.36
CV (%)	3.31	2.30	3.73	0.59

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability.
F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2=RFD + 2 kg B ha^{-1}, F_3 =RFD + 8.5 kg Zn $ha^{-1}$and F_4 = RFD +17kg Zn ha^{-1}

Table 4. Effect of sowing time on pod characteristics and 1000-seed weight of mungbean

Treatments	Pod length (cm)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000-seed weight (g)
S_1	9.42 a	14.74 a	10.06 a	39.06 a
S_2	8.18 b	13.46 b	9.77 a	38.55 b
S_3	8.49 b	8.13 c	8.43 b	32.92 c
$LSD_{(0.05)}$	0.37	0.36	0.45	0.28
CV (%)	3.31	2.30	3.73	0.59

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability.
S_1=24 August, S_2=23 September and S_3=23 October.

4.8. Number of pods $plant^{-1}$

Statistically significant differences were found for number of pods $plant^{-1}$ of mungbean due to micronutrient (Appendix VI and Table 3). The highest number of pods $plant^{-1}$ (14.17) was recorded from 17 kg Zn ha^{-1}(F_4) whereas, the lowest (10.61) was observed from no micronutrient (F_0).

Number of pods $plant^{-1}$ of mungbean differed significantly due to sowing time (Appendix VI and Table 4). The height number of pods $plant^{-1}$ (14.74) was recorded from 24 August (S_1) sowing whereas, the lowest (8.13) was found from 23 October (S_3) sowing.

Interaction between micronutrient and sowing time showed significant variation in number of pods $plant^{-1}$ (Appendix VI and Table 5). The highest number of pods $plant^{-1}$ (17.67) was recorded from the treatment combination of 17 kg Zn ha^{-1} and seeds sowing on 24 August (F_4S_1) whereas, the lowest (7.00) was observed from the treatment combination of no micronutrient and 23 October (F_0S_3) sowing.

Table 5. Interaction effect of micronutrients and sowing time on pod characteristics and 1000-seed weight of mungbean

Treatments	Pod length (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000-seed weight (g)
F_0S_1	9.10 bc	12.83 ef	9.50 cd	37.50 g
F_0S_2	8.70 cd	12.00 g	9.20 de	36.00 j
F_0S_3	7.50 g	7.00 j	7.50 h	28.25 m
F_1S_1	8.70 cd	16.33 b	10.33 b	37.54 g
F_1S_2	8.20 ef	14.50 c	10.00 bc	37.05 h
F_1S_3	8.57 de	8.60 h	8.33 fg	36.17 ij
F_2S_1	9.50 b	13.89 d	8.80 ef	38.00 f
F_2S_2	8.00 f	12.47 f	10.33 b	38.50 e
F_2S_3	9.20 b	8.07 i	8.00 gh	30.50 l
F_3S_1	9.20 b	13.00 e	10.00 bc	39.41 d
F_3S_2	8.00 f	12.00 g	9.33 de	40.40 c
F_3S_3	8.60 de	8.50 hi	9.00 de	33.17 k
F_4S_1	10.60 a	17.67 a	11.67 a	42.83 a
F_4S_2	8.033 f	16.33 b	10.00 bc	40.78 b
F_4S_3	8.60 de	8.50 hi	9.33 de	36.50 i
$LSD_{(0.05)}$	0.48	0.47	0.59	0.36
CV (%)	3.31	2.30	3.73	0.59

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability.
F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2= RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn ha^{-1}and F_4 = RFD +17kg Zn ha^{-1}
S_1=24 August, S_2=23 September and S_3= 23 October.

4.9. Number of seeds pod^{-1}

Statistically significant differences were found for number of seeds pod^{-1} of mungbean due to micronutrient (Appendix VI and Table 3). The maximum number of seedspod^{-1} (10.33) was recorded from F_4 treatment and the minimum (8.73) was observed from F_0treatment which was statistically similar (9.04) to F_2 treatment.

Number of seeds pod^{-1} of mungbean differed significantly due to sowing time (Appendix VI and Table 4). The height number of seeds pod^{-1} (10.06) was recorded from S_1 treatment which was statistically similar (9.77) to S_2 treatment whereas, the lowest number of seeds pod^{-1} (8.43) was found from S_3 treatment.

Interaction effect between micronutrient and sowing time showed significant variation in number of seeds pod^{-1} (Appendix VI and Table 5). The maximum number of seeds pod^{-1} (11.67) was recorded from the treatment combination of F_4S_1 whereas, the minimum (7.50) was observed from the treatment combination of F_0S_3 which was statistically similar (8.00) to F_2S_3.

4.10. 1000-seed weight

Statistically significant differences were found for 1000-seed weight of mungbean due to micronutrient (Appendix VI and Table 3). The maximum 1000-seed weight (40.04 g) was recorded from the 17 kg Zn ha^{-1} (F_4) whereas, the minimum 1000-seed weight (33.92 g) was observed from the no micronutrient (F_0) treatment.

1000-seed weight of mungbean differed significantly due to sowing time (Appendix VI and Table 4). The highest 1000-seed weight (39.06 g) was recorded from the 24 August (S_1) sowing and the lowest (32.92 g) was found from 23 October (S_3) sowing.

Interaction effect between micronutrient and sowing time showed significant variation in 1000-seed weight of mungbean (Appendix VI and Table 5). The highest 1000-seed weight (42.83 g) was recorded from the treatment combination of F_4S_1 and the lowest (28.25 g) was observed from the treatment combination of F_0S_3.

4.11.Seed yield

Seed yield showed significant differences among micronutrients (Appendix VII and Table 6). The highest seed yield (1.78 t ha^{-1}) was observed from 17 kg Zn ha^{-1} treatment whereas, the lowest (0.82 t ha^{-1}) was found in no micronutrient treatment.

Seed yield of mungbean varied significantly due to the variations of sowing time (Appendix VII and Table 7). The highest seed yield (1.55 t ha^{-1}) was observed from 24 August sowing whereas, the lowest (1.16 t ha^{-1}) was found in 23 October sowing.

Statistically significant differences were recorded for the interaction effect of micronutrient and sowing timeon seed yield of mungbean (Appendix VII and Table 8). The maximum seed yield (1.85 t ha^{-1}) was observed from the combination of17 kg Zn ha^{-1} with 24 August sowing whereas, the minimum (0.68 t ha^{-1}) was found in the treatment combination of no micronutrient with 23 October sowing.

4.12. Stover yield

Stover yield of mungbean were significantly influenced by micronutrient treatments (Appendix VII and Table 6). The maximum stover yield (3.10 t ha^{-1}) was observed from the F_0 treatment whereas, the minimum (1.73 t ha^{-1}) was found in the F_4 treatment.

Stover yield of mungbean were significantly influenced by sowing time (Appendix VII and Table 7). The maximum stover yield (3.20 t ha^{-1}) was observed from the S_3 treatment whereas, the minimum (1.82 ha^{-1}) was found in the S_1 treatment.

Micronutrient and sowing time interacted significantly on straw yield of mungbean (Appendix VII and Table 8). The highest stover yield (3.87 t ha^{-1}) was observed from the treatment combination of F_0S_3 whereas, the lowest (1.17 t ha^{-1}) was found in the treatment combination of F_2S_1 which was statistically similar (1.20 t ha^{-1}) to F_4S_1.

Table 6. Effect of micronutrients on yield and harvest index of mungbean

Treatments	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
F_0	0.82 d	3.10 a	3.92 a	21.54 d
F_1	1.21 c	2.83 b	4.05 a	30.88 c
F_2	1.55 b	2.02 c	3.57 b	45.60 b
F_3	1.55 b	2.04 c	3.60 b	44.26 b
F_4	1.78 a	1.73 d	3.51 b	51.42 a
$LSD_{(0.05)}$	0.07	0.14	0.15	2.01
CV (%)	3.10	3.63	2.42	3.11

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability.
F_0=recommended fertilizer dose (RFD), F_1 =RFD + 1 kg B ha^{-1}, F_2= RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn $ha^{-1}$and F_4 = RFD +17kg Zn ha^{-1}.

Table 7. Effect of sowing time on yield and harvest index of mungbean

Treatments	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
S_1	1.55 a	1.82 c	3.36 b	47.19 a
S_2	1.44 b	2.02 b	3.46 b	41.90 b
S_3	1.16 c	3.20 a	4.36 a	27.12 c
$LSD_{(0.05)}$	0.06	0.11	0.12	1.56
CV (%)	3.10	3.63	2.42	3.11

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability.
S_1=24 August, S_2=23 September and S_3= 23 October.

Table 8. Interaction effect of micronutrients and sowing time on yield and harvest index of mungbean

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_0S_1	0.77 j	2.46 d	3.23 fg	23.84 h
F_0S_2	0.68 k	2.63 c	3.31 f	20.54 i
F_0S_3	0.51 l	3.71 a	4.22 ab	12.09 k
F_1S_1	1.33 f	2.36 de	3.69 d	36.04 e
F_1S_2	1.05 i	2.03 f	3.08 hi	34.09 e
F_1S_3	0.75 jk	3.61 a	4.36 a	17.20 j
F_2S_1	1.44 de	1.01 j	2.45 k	58.78 b
F_2S_2	1.53 c	1.61 g	3.14 gh	48.73 d
F_2S_3	1.17 h	2.96 b	4.13 b	28.33 g
F_3S_1	1.49 cd	1.38 i	2.87 j	51.92 c
F_3S_2	1.41 e	1.56 gh	2.97 ij	47.47 d
F_3S_3	1.25 g	2.66 c	3.91 c	31.97 f
F_4S_1	1.85 a	1.03 j	2.88 j	64.24 a
F_4S_2	1.68 b	1.43 hi	3.11 gi	54.02 j
F_4S_3	1.28 fg	2.23 e	3.51 e	36.47 e
$LSD_{(0.05)}$	0.07	0.14	0.15	2.01
CV (%)	3.10	3.63	2.42	3.11

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability.
F_0–recommended fertilizer dose (RFD), F_1= RFD + 1 kg B ha^{-1}, F_2= RFD + 2 kg B ha^{-1}, F_3 = RFD + 8.5 kg Zn ha^{-1}and F_4 = RFD +17kg Zn ha^{-1}.
S_1= 24 August, S_2 = 23 September and S_3 = 23 October.

4.13. Biological yield

Micronutrient respond significantly in producing biological yield (Appendix VII and Table 6). The maximum biological yield (4.05 t ha^{-1}) was observed from F_1 treatment which was statistically similar (3.92 t ha^{-1}) to F_0 treatment whereas, the minimum (3.51 t ha^{-1}) was found in F_4 treatment, which was statistically similar (3.57 and 3.60 t ha^{-1}, respectively) to F_2 and F_3 treatment.

Sowing time showed significant variation in producing biological yield (Appendix VII and Table 7). The highest biological yield (4.36 t ha^{-1}) was observed from S_3treatmentand the lowest (3.36 t ha^{-1}) was found in S_1treatmentwhich was statistically similar (3.46 t ha^{-1}) to S_2 treatment.

Interaction between micronutrient and sowing time showed significant variation in biological yield (Appendix VII and Table 8). The maximum biological yield (4.36 t ha^{-1}) was recorded from the treatment combination of F_1S_3 which was statistically similar (4.22 t ha^{-1}) to F_0S_3 whereas, the lowest (2.78 t ha^{-1}) was observed from the treatment combination of F_2S_1.

4. 14. Harvest Index

A significant difference was observed due to micronutrient treatment on harvest index (Appendix VII and Table 6). The maximum harvest index (51.42 %) was observed from 17 kg Zn ha^{-1}(F_4) whereas, the minimum (21.54 %) was found from the no micronutrient (F_0) treatment.

A significant difference was observed due to sowing time on harvest index (Appendix VII and Table 7). The maximum harvest index (47.19 %) was observed from 24 August (S_1) sowing whereas, the minimum (27.12 %) was found from 23 October (S_3) sowing.

Micronutrient and sowing time interact significantly on harvest index of mungbean (Appendix VII and Table 8). The height harvest index (64.24 %) was observed from the treatment combination of 17 kg Zn ha^{-1} and 24 August (F_4S_1) sowing whereas, the lowest (12.09 %) was found in the treatment combination of no micronutrient and 23 October (F_0S_3) sowing. Present study reveled that 17 kg Zn ha^{-1} and 24 August sowing produced maximum harvest index (%).

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Sher-e-Bangla Agricultural University farm Dhaka, in the kharif –II season during the period from August 2013 to January 2014 to study the effect of sowing date and micronutrients (B and Zn) on water relation and yield of mungbaen. The experiment consists of five levels of micronutrient viz. control treatment, 1 kg B ha^{-1}, 2 kg B ha^{-1}, 8.5 kg Zn ha^{-1} and 17 kg Zn ha^{-1} and three different sowing time viz. 24 August, 23 September and 23 October. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3.0 m × 2.0m. Chemical fertilizers were applied as per its recommended dose.

Results showed that 1st emergence, 80% emergence and 50% flowering was significantly influenced by micronutrient. At 1st emergence, 80% emergence and 50% flowering, F_4 (17.0 kg Zn ha^{-1}) treatment showed minimum days (2.17, 3.63 and 31.67 days, respectively). The highest exudation rate (1244 mg hr^{-1}) and relative water content (89.54 %) was found from F_4 (17 kg Zn ha^{-1}) treatment. The maximum number of branches $plant^{-1}$ (2.00), length of pod (9.08 cm), number of pod $plant^{-1}$ (14.17), number of seeds pod^{-1} (10.33) and 1000 seed weight (40.04 g) was counted from 17 kg Zn ha^{-1}. The highest seed yield (1.78 t ha^{-1}), straw yield (3.10 t ha^{-1}), biological yield (4.05 t ha^{-1}) and harvest index (51.42 %) was observed from 17 kg Zn ha^{-1} (F_4).

Significant variation of days to 1st emergence, 80% emergence and 50% flowering was found due to sowing time. The minimum days to 1st emergence (2.14 days), days to 80% emergence (3.84 days) were required in S_1 (seeds sowing on 24 August) treatment and 34.24 days for 50% flowering was required in S_3 (seeds sowing on 23 October) treatment. The highest exudation rate (1900 mg hr^{-1}) and RWC (89.04 %) were obtained from S_1 treatment (seeds sowing on 24 August). The maximum number of branches $plant^{-1}$ (1.33), length pod (9.42 cm), number of pods plant^{-1} (14.74), number of seeds pod^{-1} (10.06) and 1000-seed weight (39.06 g) was recorded from S_1 treatment. The highest seed yield (1.55 t ha^{-1}) and harvest index (47.19 %) were found from S_1 treatment.

The minimum duration for 1st emergence (1.80 days), 80% emergence (3 days) was recorded from the treatment combination of 17.0 kg Zn ha^{-1} and 24 August sowing (F_4S_1) and 50% flowering (31.30 days) was recorded from the treatment combination of 17.0 kg Zn ha^{-1} and 23 October sowing (F_4S_3). The highest exudation rate (2352 mg hr^{-1}) and RWC (93.33 %) were obtained from the treatment combination of 17 kg Zn ha^{-1} and 24 August sowing. The maximum number of branches plant^{-1} (3.00), length of pod (10.60 cm), number of pods plant^{-1} (17.67), number of seeds pod^{-1} (11.67) and 1000-seed weight (42.83 g) was found from the treatment combination of F_4S_1. The maximum seed yield (1.85 t ha^{-1}) and harvest index (64.24 %) were observed from the treatment combination of 17 kg Zn ha^{-1} with 24 August (F_4S_1).

From the study following conclusion can be made-

1. Increasing micro nutrients level increases exudation rate, relative water content, number of branches plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, weight of thousand seeds, harvest index except B @ 2 kg/ha for exudation rate.
2. Delayed sowing from 24 august to 23 October reverse the effects for all the parameters except days to 50% flowering.
3. Application of recommended fertilizer dose along with 17 kg Zn/ha for sowing seed in 24 August seemed to be more suitable for getting higher yield in mungbean.

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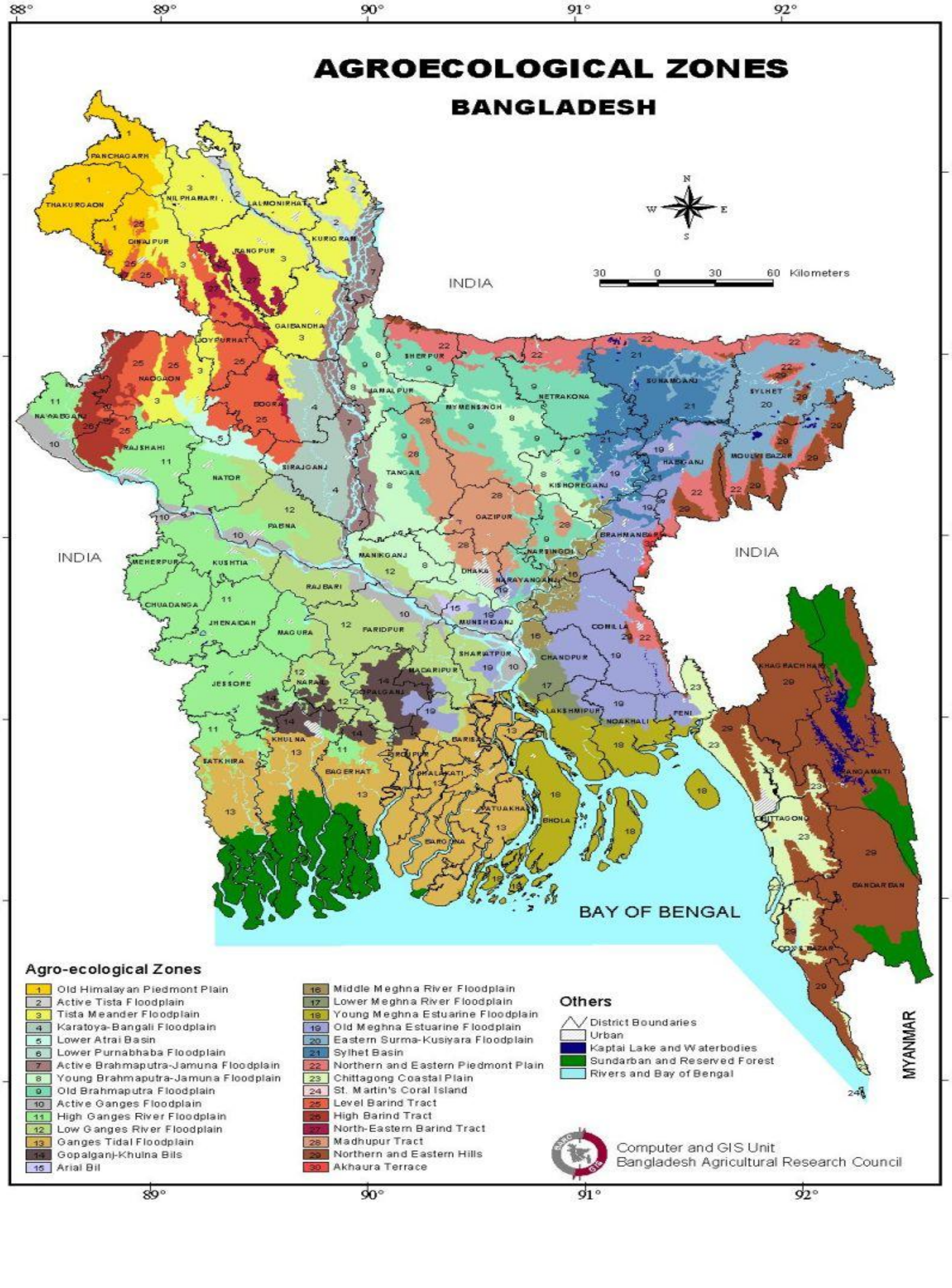
Appendices

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh



Appendix II. Characteristics of Agronomy Farm soil is analyzed by Soil ResourcesDevelopment Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Ferm, SAU, Dhaka
AEZ	Madhupur 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	Fallow-Mungbean

B. Physical and chemical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Textural class	Silty
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1 00 g soil)	0.10
Available S (ppm)	45

Source : SRDI(2013)

Appendix III. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimentalsite during the period from August 2013 to January 2014

Month	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day (hrs)
	Maximum	Minimum	Mean			
August, 2013	36.0	23.6	29.8	81	319	4.0
September,2013	34.8	24.4	29.6	81	279	4.4
October, 2013	34.8	18.0	26.4	77	227	5.8
November, 2013	29.7	20.1	24.9	65	5	6.4
December, 2013	26.9	15.8	21.35	68	0	7.0
January, 2014	24.6	12.5	18.7	66	0	5.5

Source: Bangladesh Meteorological Department (Climate & weather division), Agargoan, Dhaka – 1212

Appendix IV: Error mean square values for Days to1st emergence, 80 % emergence and 50% flowering of mungbean

Source of variation	Degrees of freedom	Days to 1st emergence	Days to 80 % emergence	Days to 50% flowering
Replication	2	0.054	0.054	2.406
Macronutrient (A)	4	0.700*	2.633*	68.689*
Sowing time (B)	2	4.104*	5.378*	4.726*
A × B	8	0.049*	0.106*	0.063*
Error	28	0.017	0.017	0.513

*Significant at 5% level of probability** Significant at 1% level of probability

Appendix V: Error mean square values for exudation rate, relative water content and number of branches plant^{-1} of mungbean

Source of variation	Degrees of freedom	Exudation rate	Relative water content	No. of branches plant^{-1}
Replication	2	776.467	7.339	0.200
Macronutrient (A)	4	76182.522**	35.779**	2.300*
Sowing time (B)	2	10904591.267*	184.301**	1.867**
A × B	8	379245.656*	41.218*	1.033*
Error	28	426.657	6.367	0.057

*Significant at 5% level of probability** Significant at 1% level of probability

Appendix VI: Error mean square values for pod length, number of pods plant^{-1}, number of seeds pod^{-1} and 1000-seed weight of mungbean

Source of variation	Degrees of freedom	Pod length	Number of pod plant^{-1}	Number of seeds pod^{-1}	1000-seed weight
Replication	2	0.003	0.016	0.054	0.083
Macronutrient (A)	4	0.694*	19.888*	3.298*	46.829*
Sowing time (B)	2	6.185*	184.347**	11.310*	174.046*
A × B	8	1.130**	3.123*	1.238*	9.744**
Error	28	0.083	0.078	0.123	0.046

*Significant at 5% level of probability** Significant at 1% level of probability

Appendix VII: Error mean square values for seed yield, stover yield, biological yield and harvest index of mungbean

Source of variation	Degrees of freedom	Seed yield	Straw yield	Biological yield	Harvest index
Replication	2	0.005	0.029	0.057	0.944
Macronutrient (A)	4	1.247*	3.108**	0.518*	1340.745*
Sowing time (B)	2	0.595**	8.374*	4.547*	1623.569*
A × B	8	0.031*	0.156**	0.250**	35.573*
Error	28	0.002	0.007	0.008	1.447

*Significant at 5% level of probability** Significant at 1% level of probability