EFFECT OF ZINC AND MOLYBDENUM ON THE GROWTH AND YIELD OF GARDEN PEA

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CERTIFICATE

This is to certify that the thesis entitled **'Effect of Zinc and Molybdenum on the Growth and Yield of Garden Pea'** submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Soil Science**, embodies the results of a piece of bonafide research work carried out by **Ishrat Alam**, Registration No. **10-03930** 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: June 2016
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TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from December, 2015 to March 2016 to study the effect of zinc and molybdenum on the growth and yield of garden pea. The variety BARI Motorshuti-1 was used as the test crop. The experiment comprised of two factors as, Factor A: Levels of zinc (3 levels)- Zn_0: 0 kg Zn/ha (control), $Zn_{1.5}$: 1.5 kg Zn/ha, $Zn_{3.0}$: 3.0 kg Zn/ha and Factors B: Levels of molybdenum (3 levels)- Mo_0: 0 kg Mo/ha (control), $Mo_{0.3}$: 0.3 kg Mo/ha, $Mo_{0.6}$: 0.6 kg Mo/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In case of different levels of zinc, the tallest plant (62.08 cm), maximum number of pods/plant (19.96), the highest green pod yield (8.41 t/ha), the highest stover yield (9.79 t/ha) was recorded from $Zn_{3.0}$, whereas the shortest plant (56.76 cm), the lowest green pod yield (7.39 t/ha), the lowest stover yield (8.49 t/ha) was found from Zn_0. For different levels of molybdenum, the tallest plant (61.41 cm), the highest green pod yield (8.31 t/ha), the highest stover yield (9.69 t/ha) was found from $Mo_{0.6}$, while the shortest plant (57.18 cm), the minimum number of pods/plant (17.29), the lowest green pod yield (7.59 t/ha), the lowest stover yield (8.69 t/ha) was recorded from Mo_0. Due to the interaction effect of different levels of zinc and molybdenum, the tallest plant (65.50 cm), the highest green pod yield (8.91 t/ha) and the highest stover yield (10.65 t/ha) was found from $Zn_{3.0}Mo_{0.6}$ and the shortest plant (53.85 cm), the minimum number of pods/plant (14.20), the lowest green pod yield (6.68 t/ha) and the lowest stover yield (8.18 t/ha) was found from Zn_0Mo_0. Application of 3.0 kg Zn/ha & 0.6 kg Mo/ha and 1.5 kg Zn/ha & 0.3 kg Mo/ha showed statistically same green pod yield. So, combination of 1.5 kg Zn/ha & 0.3 kg Mo/ha can be more beneficial for the farmers to get better yield from the cultivation of garden pea.

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CHAPTER I

INTRODUCTION

Garden pea (*Pisum sativum* L.) belongs to the family *Fabaceae* is one of the world's oldest domesticated crops which was cultivated before 9th millennia BC (Zohary and Hopf, 2000). The crop is grown in many countries and currently ranks fourth among the pulses in the world with a cultivated area of 6.33 million hectares (FAOSTAT, 2013). The garden pea is a legume with great nutritional potential because of its high content of plant protein (27.8%), complex carbohydrates (42.65%), vitamins, minerals, dietary fibre and antioxidant compounds (Urbano *et al*., 2003). It is commonly used throughout the world and has high levels of amino acids like lysin and trypophan (Bhat *et al*., 2013). Nevertheless, its nutritional importance may be limited by the presence of trypsin inhibitors (TIA), lectins, a-galactoside oligosac-charides, polyphenols and phytic acid as non-nutritional components (Urbano *et al*., 2003).

In Bangladesh the area of garden pea has been drastically reduced due to introduction of HYV of rice and wheat. The area for pea cultivation in 2013 was 36,132 acres with the production was 11,842 tons but in 2007 it was 37,145 acres with the production was 12,610 tons (BBS, 2013). In Bangladesh most of the pea varieties are inbred type and the average yield of pea and the average world yield of pea is around 1.70 t ha^{-1} (FAO, 2012). Its cultivation maintains soil fertility through biological nitrogen fixation in association with symbiotic *Rhizobium* prevalent in nodules and thus plays a vital role in fostering sustainable agriculture (Negi *et al.*, 2006). Yield of garden pea is very low in Bangladesh and such low yield however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons, viz., unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of boro rice, fertilizer management especially micronutrients, insect infestation and improper or limited irrigation facilities. Among different factor micronutrients especially zinc and molybdenum are also the important factor.

For optimal growth and development, 17 essential elements are required for plants. These elements, which required in relatively high amounts, are called macronutrients or, in trace amounts are called micronutrients. While micronutrients are required in relatively smaller quantities for plant growth but they are very important. If any element is lacking in the soil or not adequately balanced with other nutrients, growth suppression or even complete inhibition may result (Mengel *et al.,* 2001). Micronutrients often act as cofactors in enzyme systems and participate in redox reactions, in addition to having several other vital functions in plants. Most importantly, micronutrients are involved in the key physiological processes of photosynthesis and respiration (Marschner, 1995; Mengel *et al.,* 2001) and their deficiency can impede these vital physiological processes thus limiting yield contributing characters as well as gain yield.

Zinc is an essential micronutrient involved in a wide variety of physiological processes and it plays an important role in several plant metabolic processes; it activates enzymes and is involved in protein synthesis and carbohydrate, nucleic acid and lipid metabolism (Marshner, 1986; Pahlsson, 1989). Within plants Zn seems to affect the capacity for water uptake and transport (Barcelo and Poschenrieder, 1990; Kasim, 2007; Disante *et al*., 2010) and to reduce the adverse effects of short periods of heat stress (Peck and McDonald, 2010) or of salt stress (Tavallali *et al*., 2010). However, like other heavy metals when Zn is accumulated in excess in plant tissues, it causes alterations in vital growth processes such as photosynthesis and chlorophyll biosynthesis and membrane integrity (De Vos *et al*., 1991). Since Zn is required for the synthesis of tryptophan (Brown *et al*., 1993; Alloway, 2004), which is a precursor of IAA, this metal also has an active role in the production of auxin, an essential growth hormone (Brennan, 2005). An excess of Zn has been reported to have a negative effect on mineral nutrition (Chaoui *et al*., 1997). In several crops, higher soil phosphorus contents may induce Zn deficiency (Chang, 1999; Foth and Ellis, 1997). Zinc (Zn) deficiency is a major yield-limiting factor in several Asian countries (Rehman *et al.,* 2012).

Molybdenum is an essential micronutrient and required for the formation of the nitrate reductase enzyme and in legume is directly involved in symbiotic nitrogen fixation (Williams and Fraustoda Silva, 2002; Roy *et al.*, 2006). Mo is an element that is translocated with low mobility in inside plants, which is the main reason for its low utilization by plant organs during the period of starvation (Gupta and Lipsett, 1981). It is an important co-factor component of key enzymes of assimilatory nitrogen metabolism, nitrogen fixation, nitrate uptake (Gupta and Lipsett, 1981; Campbell, 1999). Molybdenum has a positive effect on yield quality and nodules formation in legume crops and it increased plant height, number of branches and pods plant^{-1}, number of seeds plant^{-1} and seeds yield (Togay *et al*., 2008). Application of molybdenum into the soils increased the contents of potassium, phosphorus and crude protein (Anon., 2005). Molybdenum is required for growth of most biological organisms including plants (Graham and Stangoulis, 2005).

Considering the above mention perspective the present experiment was conducted with different levels of zinc and molybdenum on garden pea with the following objectives:

a. To observe the effect of zinc and molybdenum on growth and yield of garden pea;

b. To optimize the suitable dose of zinc and molybdenum as micronutrients on the growth and yield of garden pea.

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh and in many countries of the world garden pea is an important vegetable as well as pulse crop. The crop has conventional less attention by the researchers this crop has been grown normally without/minimum care or following minimum modern management practices. Based on this a very few research work related to growth and yield of garden pea especially using of micronutrients have been carried out in our country. However, researches are going on in home and abroad to maximize the yield of garden pea. Micronutrients play an important role in improving garden pea growth and yield. But research works related to micronutrients especially zinc and molybdenum are limited in Bangladesh context. However, some of the important and informative works and research findings related to the zinc and molybdenum and also other micronutrients so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Influence of zinc on yield contributing characters and yield

Kumar *et al*. (2014) conducted an experiment to evaluate the effect of inorganic, organic and biofertlizers on growth, yield and economics of garden pea. The seed inoculation with biofertilizers + zinc @ 5 kg ha^{-1} gave the significantly higher growth and yield attributes; seed yield (10.73 and 11.97 q ha^{-1}), straw yield (19.65 and 21.15 q ha^{-1}) and biological yield (30.56 and 33.13 q ha^{-1}) in both the years, respectively. In both the years, gross return (Rs. 36131 and 40151), net return (Rs. 24495 and 28515), B: C ratio (2.07 and 2.42), production efficiency (9.67 and 10.99 kg day^{-1} ha^{-1}) and economic efficiency (Rs. 221 and 262 day^{-1} ha^{-1}) was obtained with the combined applied of biofertilizers + zinc @ 5 kg ha^{-1}.

A study was carried out by Pandey *et al*. (2012) to find out the effects of Zn deficiency on antioxidant responses of two pea (*Pisum sativum* L.) genotypes, a Zn-efficient IPFD-99-13 and Zn-inefficient KPMR-500, grown in sand culture. In the pea genotype KPMR-500, Zn deficiency decreased dry matter yield, tissue Zn concentration, and antioxidant enzyme activities istronger than in the genotype IPFD-99-13. Zinc deficiency produced oxidative damage to pea genotypes due to enhanced accumulation of TBARS and H_2O_2 and decreased activities of antioxidant enzymes (Cu/Zn superoxide dismutase (SOD), catalase (CAT), peroxidase (POD), and ascorbate peroxidase (APX)). In the leaves of IPFD-99-13 genotype, the higher activity of ROS-scavenging enzyme, e.g., SOD, CAT, POD, and glutathione reductase, and antioxidants, such as ascorbate and non-protein thiols, led to the lower accumulation of H_2O_2 and lipid peroxides. These results suggest that, by maintaining an efficient antioxidant defense system, the IPFD-99-13 genotype shows a lower sensivity to Zn deficiency than the KPMR-500 genotype.

Two field experiments was conducted at EI-Bramoon Agricultural Research Farm of Mansoura Horticultural Research Station by El Sayed Hameda *et al*. (2012). The investigated effects of foliar spray with some microelements (Fe, Zn and Mn, 100 ppm) at different fertilizer sources (FYM, mineral fertilizer and control) and bio-fertilization with Rhizobium as well as their interactions on yield and yield components and chemical constituents of pea plant (*Pisum sativum*, L.) cv. Master-B. The foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as plant height, pod length, pod weight, number of green seeds/pod, weight of 100-green seed, seed index (1000-dry seed weight) and chemical constituents such as NPK, carbohydrates (%) and protein (%) of green seeds of pea plant in both seasons. The fertilization with FYM was the most reliable treatment compared with chemical fertilizer and control treatments.

An experiment was conducted by Alam *et al*. (2010) during two consecutive years to evaluate the performance of different fertilizer treatment on garden pea varieties under farmers' field condition in the medium high land under irrigated situation at the Farming System Research and Development (FSRD) site, Elenga, Tangail. Three verities viz. BARI Motor shuti-1 BARI Motor shuti-2 and BARI Motor shuti-3 was considered as first factor treatment. Fertilizer combination T_1: N_{50} P_{26} K_{42} S_{12} & T_2: N_{50} P_{26} K_{42} S_{12} + $B_{2.5}Mo_{2.5}$ $Zn_{2.5}$ kg/ha was taken as the second factor. BARI Motor shuti-1 and BARI motor shuti-2 along with the fertilizer dose N_{50}, P_{26} K_{42} S_{12} and 2.5 kg/ha of each Mo, B & Zn, produced the highest pod yield of 12.35 t/ha and 8.51 t/ha during 2006-07 and 2007-08 respectively.

Biswas *et al.* (2010) conducted a two-year field experiment during kharif season 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.

Stoyanova and Doncheva (2002) carried out an experiment to study the influence of succinate treatment on Zn toxicity was investigated using plant growth and mineral uptake as stress indicators. Pea plants (*Pisum sativum* L., cv. Citrine) was treated with various Zn concentrations (0.67 to 700 mM Zn) in the presence and absence of 0.2 mM Na-succinate. Plants pre-treated with succinate and then exposed to Zn exhibited higher dry root, stem and leaf weight than the plants treated with Zn alone. The amount of Zn in the roots, stems and leaves increased with greater Zn rates.

Srivastava *et al.* (2005) observed that in absence of applied B, there was no yield as no pods was 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.

Rizk and Abdo (2001) conducted two field experiments to investigate the response of mungbean (*Vigna radiata*) with some micronutrients at Giza Experimental Station, ARC, Egypt. Two cultivars of mungbean (V-2010 and VC-1000) was used in those investigations. 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 was sprayed once at 35 days after sowing (DAS). All treatments increased significantly, 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.

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 was 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 or 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.

Zaman *et al.* (1996) 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.

Saha *et al.* (1996) conducted a field experiment in pre-khraif seasons at Pundibari, India, Yellow season was given 0, 2.5 or 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 was 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.

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

2.2 Influence of molybdenum on yield contributing characters and yield

Two field experiments was carried out by Nadia and Abd El-Moez (2013) to evaluate the effect of different levels of molybdenum on nodules efficiency, growth, yield quantity and quality of seeds at Research and Production station, National Research Centre, EL-Nobaria site, Beheara Governorate, Delta Egypt, under drip irrigation system. Molybdenum enhance cowpea root nodules efficiency, growth, minerals composition, yield quantity compared with control plants. Molybdenum at 16 ppm resulted in maximum growth, nodules number and weight, nitrogenase activity, pods and seeds yield as well as nutritional and chemical content. Increasing molybdenum levels more than 16 ppm decreased the molybdenum promotive effect.

Ting Sun *et al*. (2013) conducted an experiment to study the effects of molybdenum (Mo) and boron (B) on the rhizosphere microorganisms and the soil enzyme activities of soybean. The soybeans was treated with seven different Mo and B supplements (control: without Mo and B) Mo_1 (0.0185 g kg^{-1}), B_1 (0.08 g kg^{-1}), $Mo_1 + B_1$ (0.0185 + 0.08 g kg^{-1}), Mo_2 (0.185 g kg^{-1}), B_2 (0.3 g kg^{-1}) and $Mo_2 + B_2$ (0.185 + 0.3 g kg^{-1}) throughout the plants' four growth stages. The results showed that Mo, B, and combined Mo and B treatments increased the soil microbial populations, stimulated the rhizosphere metabolisms, and improved the soil enzyme activities as well as yield.

A field trial was conducted by Zahoor *et al*. (2013) to evaluate the response of soybean to micronutrients viz. iron (Fe), molybdenum (Mo) and cobalt (Co). Results indicated that iron applied at the rate of 400 g ha^{-1} and molybdenum @ 20 g ha^{-1} had a significant effect on shoot length, shoot dry weight, number of nodules $plant^{-1}$, nodules fresh weight and thousand seed weight. The highest seed yield 42.28% over control, dry matter yield, seed nitrogen and seed protein content was recorded by combined application of Fe at the rate of 400 g ha^{-1} and Mo @ 20 g ha^{-1}.

A field experiment was conducted by Shil *et al*. (2007) to find out the optimum dose of boron and molybdenum for yield maximization on chickpea (cv. BARI Chola-5) during the rabi season. Four levels each of and molybdenum (0, 1, 1.5 and 2 kg/ha) along with a blanket dose of $N_{20}P_{25}K_{35}S_{20}$ Zn_2 kg/ha & cowdung 5 t/ha was applied in this study. The combination of $B_{2.5}Mo_{1.5}$ kg/ha and $B_{2.5}Mo_1$ kg/ha produced significantly higher yield in both the years of study at Jessore and Rahmatpur, respectively. The said treatments produced the highest mean yields of 2.10 and 1.49 t/ha for Jessore and Rahmatpur, respectively, which was around 53% higher over control (B M_0). The combined application of both boron and molybdenum was found superior to their single application even though boron played major role in augmenting the yield. However, from the regression analysis, the optimum treatment combination was calculated as $B_{2.34}Mo_{1.44}$ kg/ha for Jessore and $B_{2.20}Mo_{1.29}$ kg/ha for Rahmatpur.

Hristozkova (2006) examined the role of molybdenum (Mo) and copper (Cu) in regulation the activities of the enzymes involved in primary nitrogen assimilation in particular the nitrate reductase (EC 1.6.6.1) and glutamine synthetase (EC 6.3.1.2). Pea plants was grown in a phytotron chamber at 12 h photoperiod, day /night temperature $25/18^0$C and photon flux density of 95 μmol $m^{-1}S^{-1}$ until 21^{st} day. Plants was grown at full strength Helriegel nutrient solution competed with micronutrients as in Hoagland and Arnon and reduced Mo and Cu concentrations. Although only extremely small amounts of Mo and Cu are required for normal plant growth, reduced supply with Mo and Cu to the growth medium decreased activities of the enzymes (nitrate reductase and glutamine synthetase) involved at initial steps of nitrate assimilation, fresh weight, and plastid pigment content (total chlorophyll and carotenoids). Accumulation of nitrates in plant tissues enhanced, especially in the variants with restrictive Cu concentration.

Liu Peng *et al*. (2005) conducted an experiment in pot culture with three cultivars (Zheehun no. 3, Zheehum of Mo and/or B sufficiently increased the absorption of Mo and B by soybean. High supply of Mo enhanced Mo absorption and content. Combined application of proper Mo and B levels led to more Mo absorption by soybean and hence higher Mo content, than single application of proper Mo level at early stage but less at later stage. The Mo absorbed by soybean mainly accumulated in seeds.

Meschede *et al*. (2004) carried out a field experiment in Brazil, to investigate the effect of Mo and Co as foliar application and seed treatment on grain yield, seed protein content and agronomic traits of soybean cv. BRS 133. The treatments consisted of combination of seed treatment with and without Mo and Co (Comol; 12% Mo and 2% Co) and foliar application at different stages at development with the following commercial products; Comol at V_4 stage, Bas-Citrus (10% N, 4% Zn, 3.7% S, 3% Mn and 0.5% B) at V_4 stage, A control without Mo and Co application was included. The seed treatment with Mo and Co increased the seed protein content and grain yield.

Masto *et al.* (2004) conducted a pot experiment during rabi season in Hyderabad using soybean as the test crop. The treatment used in the study consisted of two levels of liming (0 and 3.5 tons ha^{-1} based on lime requirement), two levels of P (0 and 10 mg P kg^{-1}) and three levels of Mo (0, 0.25 and 0.5 mg Mo kg^{-1}). It was observed that liming at 3.5 tons ha^{-1} and phosphorus applied at 10 mg P kg^{-1}, both combine with 0.5 mg Mo kg^{-1} resulted to maximum values of phosphorus and molybdenum better than all other treatments and control.

Pires *et al*. (2004) carried out an experiment to study the effects of the foliar application of Mo on the yield of common bean (*P. vulgaris*). The treatments consisted of a control (without Mo), 80 g Mo ha^{-1} applied at 15 days after emergence (DAE), 40 g Mo ha^{-1} applied at 15 and 20 DAE, 40 g Mo ha^{-1} applied at 15 and 25 DAE, 40 g Mo ha^{-1} applied at 15 and 30 DAE, 80 g Mo ha^{-1} applied at 20 DAE, 40 g Mo ha^{-1} applied at 20 and 25 DAE, 40 g Mo ha^{-1} applied at 20 and 30 DAE, 80 g Mo ha^{-1} applied at 25 DAE, and 40 g Mo ha^{-1} applied at 25 and 30 DAE. Mo foliar spray increased the yield and harvest index in summer-autumn cultivation when started at 15 or 20 DAE, but not at DAE. Rate partitioning did not significantly increase the yields. In winter-spring cultivation, all treatments increased the yields.

Nasreen and Farid (2003) conducted a field experiment to study the effect of different nutrients on yield, yield components and nutrient uptake by garden pea cv. BARI Motorsuti-1 grown in Grey Terrace soil during the winter (rabi) seasons. Application of different nutrients caused significant increases in yield and nutrient uptake. The highest fresh pod yield and protein content was achieved by the treatment of $N_{30}P_{50}K_{40}S_{20}Mo_1B_1$ and it was not significantly different from the $N_{30}P_{50}K_{40}S_{20}N_{30}P_{50}K_{40}S_{20}Mo_1$ and $N_{30}P_{50}K_{40}S_{20}Mo_1B_1Zn_1$ treatments. Uptake of N, P, K, S, and Zn by shoot and seed was also highest under the treatment N_{30} P_{50} K_{40} S_{20} Mo_1 B_1 and not significantly different from $N_{30}P_{50}K_{40}S_{20}Mo_1$ and $N_{30}P_{50}K_{40}S_{20}Mo_1B_1Zn_1$. Addition of Mo, B and Zn with NPKS did not show any significant change in pod yield. Application of $N_{30}P_{50}K_{40}S_{20}Mo_1$,$N_{30}P_{50}K_{40}S_{20}$ Mo_1B_1 and $N_{30}P_{50}K_{40}S_{20}Mo_1B_1Zn_1$ kg/ha was not economical, but treatment N30 $P_{50}K_{40}S_{20}$ kg/ha proved to be the most economically profitable for garden pea production.

Pessoa *et al*. (2000) investigated the effects of molybdenum (Mo) leaf application in beans using levels of Mo was 0, 40, 80 and 120 g ha^{-1} and ammonium molybdate applied to the leaves 25 days after emergence. There was a quadratic response due to increasing doses of Mo application, on the leaf and grain concentrations of Mo, total N and organic N. Leaf Mo increased from 0.49 mg kg^{-1} (control) up to o.95 mg kg^{-1}, where improved N utilization resulting in higher leaf and grain concentrations of total N and organic N, better plant growth and darker green leaves.

Kushwaha (1999) conducted a field study during the winter seasons at Kanpur, Uttar Pradesh on sandy loam soil to study the effect of zinc, boron and molybdenum on the growth and yield of French bean (*Phaseolus vulgaris cv.* PDR 14) and 25 kg $ZnSO_4$, 10 kg borax and 1 kg sodium molybdate/ha was applied individually or in all combinations. All trace elements generally increased seed and haulm yield. Mean seed yield was 1736 kg/ha in controls and the highest 2459 kg with borax alone.

Manga *et al.* (1999) reported that the growth and yield of bean was influenced by phosphorus and molybdenum fertilization. In their trail, the crop received 0, 13 or 26 kg P and 0, 0.5 or 1.0 kg ammonium molybdate/ha. Molybdenum application increased the number of pods per plant, number of seeds per pod and seed yield. The seed yield increase was 15.7 and 25.9% when 0.5 and 1.0 kg ammonium molybdate/ha respectively was applied.

Andrade *et al.* (1999) reported that the growth and yield of bean was influenced by molybdenum fertilization by the foliar applications of 0, 30, 60, 90 or 120 g Mo/ha. There was no significant effects of Mo rates or rate x cultivar interaction on yield or yield components. There was significant differences among the cultivars for height of first pod, seed number per pod, 100-seed weight and yield.

Hazra and Tripathi (1998) observed that molybdenum application at the rate of 1.5 kg/ha increased forage and seed yields in calcareous soil.

Mandal *et al.* (1998) observed that dry matter yield of lentil was increased by the application of lime. P and Mo. Plant dry matter/pot was highest with 100% lime + 50 mg P + 1 mg Mo. Yield response to Mo application was highest, followed by lime and P.

Bhuiyan *et al*. (1998) conducted a field experiment on grey terrace soil of Gajipur to observe the effect of rhizobial inoculam, Mo and B on the nodulation, yield and agronomic performances of chickpea. *Rhizobiom inoculam* along with phosphorus, potash, boron and molybdenum gave significantly higher nodule number, nodule weight, stover yield and seed yield.

Bukhoriev (1997) conducted a field trails on dark soil low in B and Mo, irrigated soybean was given no trace elements or 1 kg B at sowing and/or 50 g Mo as an ammonium molybdate seed treatment. Application of B + Mo increased the number and weight of nodules ha^{-1} by 24 and 29% respectively. Applying either B or Mo gave smaller increases. Seed yields was 2.60 t ha-1 in the control, 2.72 t with B, 2.76 t with Mo and 2.95 t with B + Mo. Seed protein content and protein yield was highest with the application of B + Mo.

Rodrigues (1996) conducted an experiment with *P. vulgaris* cultivars with the application of 0, 40, 80 or 120 g Mo/ha to the leaves at 25 days after emergence. They gave the highest seed yields (1.62-1.93 t/ha) in all seasons. Only in the dry summer/autumn season there was no response to Mo; in the rainy summer season and autumn/winter the response of seed yield to Mo was quadratic with highest yields corresponding 76-81 g Mo/ha. Application of all doses of Mo significantly increased pod number/plant, harvest index and 100-seed weight. It is suggested that increasing rates of applied foliar Mo beyond 20-40 g/ha, as commonly practiced and should result in economically viable yield increases.

Lopez *et al.* (1996) grew *Phaseolus vulgaris cv*. In Buenos Aires in nutrient solution containing 1, 5 or 10 mg Mo/litre Mo content in roots, stems and leaves increased over time. Root Absorption Index (Mo in roots/Mo in nutrient solution) was highest in 1 mg Mo/litre. This concentration provided the plant growth with Mo requirement, but there was no visible damage caused by higher Mo concentrations.

Zaman *et al.* (1996) carried out an experiment on mungbean and found that and found that 1 kg Mo/ha produced 40.49% higher plant height, 44.6% higher root length, 97% higher nodule number and 180% higher nodule weight over control. They also reported 89% higher branches/plant with 2 kg Mo/ha over control.

Berger *et al.* (1995) found that application of 20 g Mo/ha at sowing and a further foliar application of 20 g Mo/ha at 25 days after emergence had a greater effect when French bean plants was grown on poorer soil.

Li and Gupta (1995) conducted an experiment to observed that application of molybdenum (2mg soil) increased leaf nitrogen and shoot, root and nodule dry weight but did not significantly increase mean photosynthesis, nodule nitrogenase activity and chlorophyll content in soybean.

Tej *et al.* (1995) found that molybdenum application @ 1 kg/ha had marked beneficial effect on the number of filled grains per pod and grain yield of mungbean. He cited that due to the omission of molybdenum, the number of filled grains/pod was 10.2 as compared to 12.4 for treatment with molybdenum.

Wang *et al.* (1995) showed that the application of molybdenum increased the yield by 11.45% and 45%, respectively at low level of N (0.05g N/kg soil) and high level of N (0.2g N/kg soil). The fresh weight of wheat seedlings by 18.6-80.1% and dry weight by 23.7-80.6% increased respectively compare to control. They also pointed out that molybdenum also increased the efficiency of nitrogen fertilizer utilization.

Muralidharan and Jose (1994) reported that combined application of Zn, Mn, B, Cu, Mo, S and Mg increased the yield, while application of B and Mn only in cultivar joyti, produced yield about 2.31 and 2.09 t/ha, respectively compared with the control yield (2.07 t/ha). The treatment in rabi season gave grain yields of 2.96 and 3.01 t/ha, respectively compared to control (2.81 t/ha).

Gupta and Vyas (1994) conducted a field trails at kota, Rajasthan to determine the effect of phosphorus, zinc and molybdenum on the yield and quality of soybean. They applied 0, 40, 80 kg P_2O_5 ha^{-1} as superphosphate, 0, 15, 30 kg $ZnSO_4$ ha^{-1} and 0, 0.5 kg Na2MoO4 ha^{-1} and reported that seed yield was highest by the application of Mo with 40 kg P_2O_5 and 15 kg $ZnSO_4$ ha^{-1}. Seed protein content was increased by P, Zn and Mo application while oil content was increased by Zn application only.

Kumar *et al.* (1993) reported that seed yield of lentil increased with increasing Mo and P rates and was highest with the combine application of Mo and P at the highest 2 ppm Mo and 50 P rates. P and Mo concentration and uptake in seed and straw increased with increasing Mo and P rates.

Singh *et al*. (1992) reported that application of molybdenum @ 1 kg/ha increased the grain yield of chickpea significantly. Further increase in molybdenum level had no effect on the yield.

Sarkar and Banik (1991) carried out an experiment on green gram and observed the molybdenum application significantly increased pods/plant; seed/pod 1000 seed weight, seed yield and straw yield. They also reported that application of molybdenum at the rate of 0 and 0.25 kg/ha gave 11.45 q/ha straw yield, 19.25 and 20.18 pods/plant, respectively.

Padma *et al*. (1989) conducted an experiment with the application of N (20 kg/ha), P (50 kg/ha) and K (50 kg/ha) on bean. Mo (as sodium molybdate) at 75 or150 ppm was applied, individually and in combination, as foliar sprays 20 days after sowing and again 40 days after sowing. Control plants was sprayed with distilled water. The greatest plant height (35.0 cm), number of leaves/plant (14.6), number of branches/plant (4.3), tap root length (20.4 cm), leaf area/plant (941.2 cm), leaf area index (0.60) and DM production (62.8 g/plant) was obtained with the 75 ppm Mo+2.5 ppm B treatment.

Anwar (1989) conducted a field experiment at BARI farm, Faridpur in Calcareous Dark Flood plain soil with mungbean (*Vigna rediata* L.). He observed that application of molybdenum had significant effect on grain yield and molybdenum content in straw bulk and grain.

Sheudzhen *et al*. (1985) conducted an experiment with basal application of 120 kg N + 90 kg P_2O_5 + 60 kg K_2O/ha with 0.05% molybdenum and the highest yields was achieved with 0.05% Mo (7.46 t/ha) compared to (6.14 t/ha) zero trace element. Molybdenum treatment gave rise to the greatest N and P uptake by the plants.

FAO (1983) reported that application of molybdenum @ 0.4 kg/ha is sufficient for the maximum nodulation in legumes on acid soils. Total molybdenum content of most agricultural soils lies between 0.6 and 3.5 ppm with an average available content of 0.2 ppm molybdenum occurs in soil mainly as molybdenum (MoO_4). This particular minor element is an essential component of two major enzymes nitrogenous and nitrate as pointed out by Mengel and Kirkby (1982).

From the above cited reviews, it may be concluded that optimum doses of zinc and molybdenum are the prerequisite for attaining optimum growth and highest yield of garden pea. The literature revealed that the influence of zinc and molybdenum have not been studied well and have no definite conclusion for the production of garden pea under the agro climatic condition of Bangladesh.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from December, 2015 to March 2016 to study the effect of zinc and molybdenum on growth and yield of garden pea. The materials and methods for this experiment includes a short description of the location of experimental site, soil and climatic condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure. The details description have been presented below under the following headings-

3.1 Experimental site

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The experimental site is situated between $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude and at an elevation of 8.4 m from sea level (Anon., 1989). A Map of the experimental location have been presented in Appendix I.

3.2 Characteristics of soil

The land type of the experimental soil was high land with general soil type is Deep Red Brown Terrace Soil and the soil belongs to the Tejgaon series under the Agro-ecological Zone of Madhupur Tract (AEZ-28). A composite sample of the experimental field was made by collecting soil from several spots of the field at a depth of 0-15 cm before initiation of the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed for some important physical and chemical properties. The soil was having a texture of Silty Clay Loam with pH and organic matter 5.7 and 1.13%, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay and the details have been presented in Table 1.

Table 1. Characteristics of experimental field soil as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Research Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty Clay Loam
pH	6.2
Organic matter (%)	1.13
Total N (%)	0.06
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

3.3 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period was collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II.

3.4 Planting material

The variety BARI Motorshuti-1 was used as the test crop. The seeds was collected from the Agronomy Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. BARI Motorshuti-1 was the released variety of garden pea, which was recommended by the national seed board.

3.5 Land preparation

In ‘zoe’ condition around field capacity the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 4 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds was removed. The first ploughing and the final land preparation was done on 15th and 23th December, 2015, respectively. Experimental land was divided into unit plots following the design of experiment.

3.6 Treatments of the experiment

The experiment comprised of two factors

Factor A: Levels of zinc (3 levels)

i) Zn_0: 0 kg Zn/ha (control)

ii) $Zn_{1.5}$: 1.5 kg Zn/ha

iii) $Zn_{3.0}$: 3.0 kg Zn/ha

Factors B: Levels of molybdenum (3 levels)

i) Mo_0: 0 kg Mo/ha (control)

ii) $Mo_{0.3}$: 0.3 kg Mo/ha

iii) $Mo_{0.6}$: 0.6 kg Mo/ha

There was in total 9 (3×3) treatment combinations such as Zn_0Mo_0, $Zn_0Mo_{0.3}$, $Zn_0Mo_{0.6}$, $Zn_{1.5}Mo_0$, $Zn_{1.5}Mo_{0.3}$, $Zn_{1.5}Mo_{0.6}$, $Zn_{3.0}Mo_0$, $Zn_{3.0}Mo_{0.3}$ and $Zn_{3.0}Mo_{0.6}$.

3.7 Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MoP), gypsum, zinc sulphate and ammonium molybdate were used as a source of nitrogen, phosphorous, potassium, gypsum, sulphur, zinc and molybdenum, respectively. N, P, K and S was provided at the rate of 90, 60, 60 and 40 kg hectare^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation and zinc and molybdenum was applied as per treatment. All of the fertilizers except urea was applied during final land preparation.

3.8 Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three (3) replications. An area of 15 m × 20 m was divided into blocks. The size of the each unit plot was 4.0 m × 1.6 m. The space between two blocks and two plots was 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.9 Sowing of seeds in the field

The seeds of garden pea was sown on December 27, 2015 in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 30 cm.

3.10 Intercultural operations

3.10.1 Thinning

Seeds started germination of four days after sowing (DAS). Thinning was done two times; first thinning was done at 8 DAS and second was done at 15 DAS to maintain optimum plant population in each plot.

3.10.2 Irrigation and weeding

Irrigation was provided before 25 and 40 DAS for optimizing the vegetative growth of garden pea for the all experimental plots equally. The crop field was weeded as per necessary.

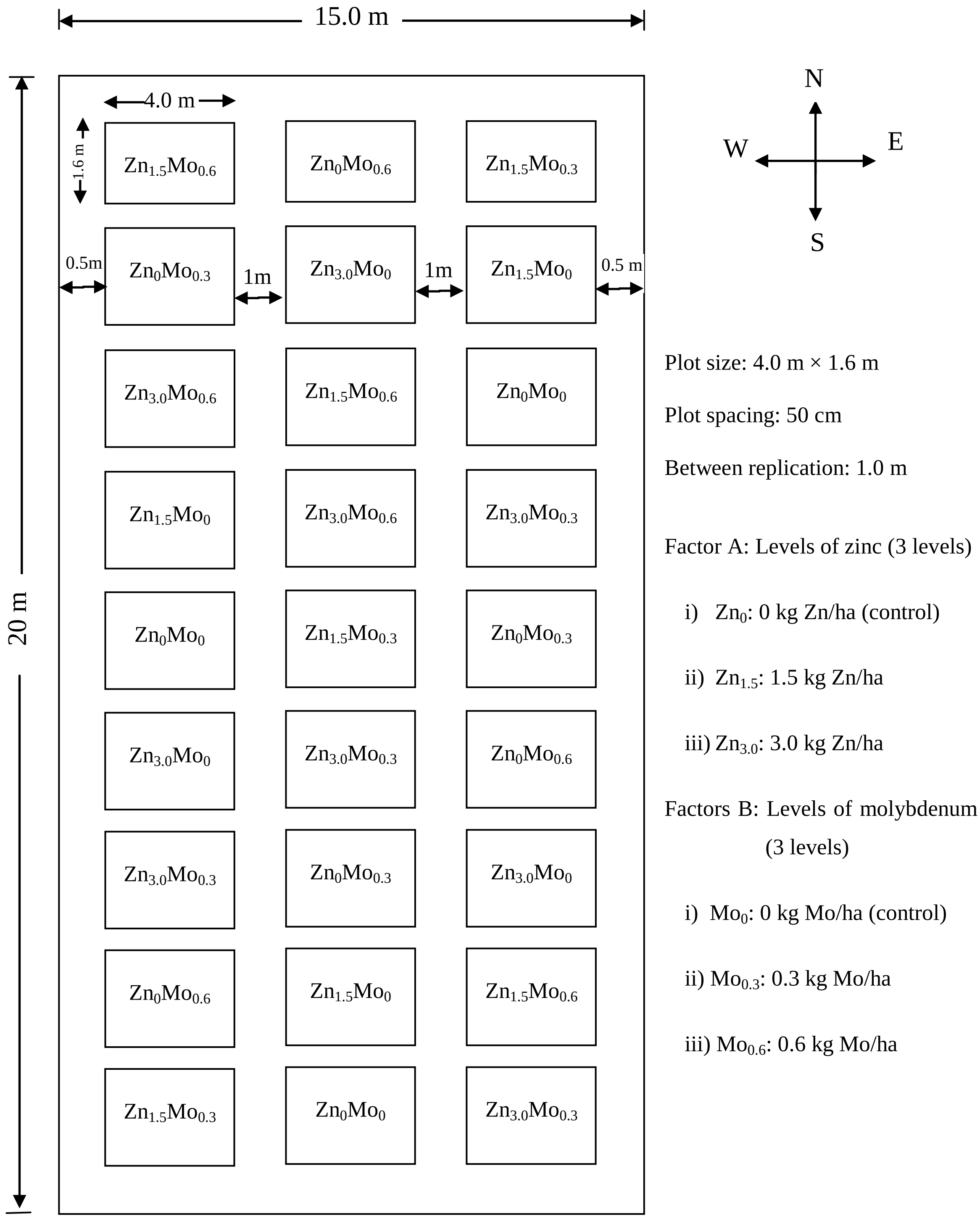

Figure 1. Layout of the experimental plot

3.10.3 Protection against insect and pest

At early stage of plant growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 mm with 1 litre water for two times at 15 days interval after seedlings germination to control the insects.

3.11 Crop sampling and data collection

Five plants from each treatment was randomly selected and marked with sample card. Plant height was recorded from selected plants at harvesting time.

3.12 Harvest and post harvest operations

Harvesting was done when 90% of the green pods became mature to harvest**.** The matured pods was collected by hand picking from a pre demarcated area of 1.0 m^2 at the center of each plot.

3.13 Data collection

The following data was recorded

i. Plant height
ii. Number of branches/plant
iii. Number of pods/plant
iv. Pod length
v. Number of seeds/pod
vi. Weight of 100 green seeds (g)
vii. Weight of 100 mature seeds (g)
viii. Pod yield/plant
ix. Green pod yield/hectare
x. Stover yield/hectare
xi. Soil pH, organic matter, total nitrogen, available P, exchangeable K, available Zn and Mo in post harvest soil

3.14 Procedure of data collection

3.14.1 Plant height

The plant height was measured at harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.14.2 Number of branches/plant

The number of branches/plant was counted at harvest. Data was recorded from 5 plants from each plot and average number of branches/plant was recorded as per treatment.

3.14.3 Number of pods/plant

Numbers of total pods of selected plants from each plot was counted and the mean numbers was expressed as per plant basis. Data was recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.14.4 Pod length

Pod length was taken of randomly selected ten pods and the mean length was expressed on pod^{-1} basis.

3.14.5 Number of seeds/pod

The number of seeds/pods was recorded from randomly selected 10 pods at the time of harvest. Data was recorded as the average of 10 pods from each plot.

3.14.6 Weight of 100 green seeds

One hundred cleaned, green seeds from each treatment was counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.14.7 Weight of 100 mature seeds

One hundred cleaned, mature seeds from each treatment was counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.14.8 Pod yield/plant

The seeds from green pods was collected from 10 selected plants and weighted by a digital weighing machine and then converted the weight of five plants into per plant and expressed in gram.

3.14.9 Green pod yield/hectare

The pod collected from 6.4 (4.0 m ×1.6 m) square meter of each plot was cleaned. The weight of pods was taken and converted the yield in t/ha.

3.14.10 Stover yield/hectare

The stover collected from 6.4 (4.0 m ×1.6 m) square meter of each plot. The weight of stover was taken and converted the yield in t/ha.

3.15 Post harvest soil sampling

After harvest of crop soil samples was collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples was kept in plastic container to determine the physical and chemical properties of soil.

3.16 Soil analysis

Soil samples was analyzed for both physical and chemical characteristics viz. Soil pH, organic matter, total nitrogen, available P, exchangeable K, available Zn and Mo in post harvest soil. The soil samples was analyzed by the following standard methods as follows:

3.16.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al.*, 1982.

3.16.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results was expressed in percentage (Page *et al.*, 1982).

3.16.3 Total nitrogen

Total N content of soil was determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 was added. The flasks was swirled and heated 200^0C and added 3 ml H_2O_2 and then heating at 360^0C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests was used for nitrogen determination (Page *et al.*, 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates was titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100/S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.16.4 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity was measured colorimetrically at 660 nm wavelength and readings was calibrated with the standard P curve (Page *et al*., 1982).

3.16.5 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*., 1982).

3.17 Statistical analysis

The data obtained for different parameters was statistically analyzed to find out the significant difference of different levels of zinc and molybdenum. The mean values of all the characters was calculated and analysis of variance was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the effect of zinc and molybdenum on the growth and yield of garden pea. Data on different yield contributing characters, yield and nutrient status of post harvest soil was recorded. The analyses of variance (ANOVA) of the data on different recorded parameters are presented in Appendix III-V. The findings of the experiment have been presented and discussed with the help of table and graphs and possible interpretations was given under the following headings:

4.1 Yield contributing characters and yield of garden pea

4.1.1 Plant height

Statistically significant variation was recorded in terms of plant height of garden pea due to different levels of zinc (Appendix III). Data revealed that the tallest plant (62.08 cm) was recorded from $Zn_{3.0}$, which was statistically similar (60.44 cm) to $Zn_{1.5}$, whereas the shortest plant (56.76 cm) was found from Zn_0 i.e. control condition (Table 2). From the recorded data it was observed that, with the increase of application of zinc nutrients plant height showed increasing trend. Zinc ensured the availability of other macro and micro nutrients that created a favorable condition for the growth of garden pea with optimum vegetative growth and the ultimate results was the tallest plant (Pandey *et al*., 2012). Stoyanova and Doncheva (2002) reported that Zn nutrient accumulated in plant tissues and it causes alterations in vital growth processes such as photosynthesis and chlorophyll biosynthesis and ultimate results was the longest plant due to the application of zinc fertilizer. Alam *et al*. (2010) reported longest plant with the application of 2.5 kg Zn ha^{-1} in earlier experiment. El Sayed Hameda *et al*. (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as plant height.

Table 2. Effect of zinc and molybdenum on yield contributing characters of garden pea

Treatments	Plant height (cm)	Number of branches/plant	Number of pods/plant	Pod length (cm)	Number of seeds/pod
Levels of zinc					
Zn_0	56.76 b	2.87 b	16.40 b	6.78 b	5.61 c
$Zn_{1.5}$	60.44 a	3.02 b	19.58 a	7.47 a	6.17 b
$Zn_{3.0}$	62.08 a	3.24 a	19.96 a	7.76 a	6.62 a
$LSD_{(0.05)}$	3.146	0.192	1.820	0.383	0.385
Level of significance	0.01	0.01	0.01	0.01	0.01
Levels of molybdenum					
Mo_0	57.18 b	2.82 c	17.29 b	6.87 b	5.71 b
$Mo_{0.3}$	60.70 a	3.04 b	18.76 ab	7.44 a	6.24 a
$Mo_{0.6}$	61.41 a	3.27a	19.89 a	7.69 a	6.44 a
$LSD_{(0.05)}$	3.146	0.192	1.820	0.383	0.385
Level of significance	0.05	0.01	0.05	0.01	0.01
CV(%)	5.27	6.29	7.70	5.22	6.27

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Different levels of molybdenum showed statistically significant differences on plant height of garden pea (Appendix III). The tallest plant (61.41 cm) was found from $Mo_{0.6}$ which was statistically similar (60.70 cm) to $Mo_{0.3}$, while the shortest plant (57.18 cm) from Mo_0 i.e. control condition (Table 2). It was revealed that with the increase of molybdenum plant height increased upto the highest level. Hazra and Tripathi (1998) observed that molybdenum application at the rate of 1.5 kg/ha increased forage in calcareous soil.

Interaction effect of different levels of zinc and molybdenum varied significantly in terms of plant height of garden pea (Appendix III). The tallest plant (65.50 cm) was recorded from $Zn_{3.0}Mo_{0.6}$ which was statistically similar (64.20 cm, 62.24 cm and 61.67 cm, respectively) to $Zn_{1.5}Mo_{0.3}$, $Zn_{3.0}Mo_0$ and $Zn_{1.5}Mo_{0.6}$. On the other hand, the shortest plant (53.85 cm) was found from Zn_0Mo_0 i.e. control condition which was statistically similar (55.47 cm) to $Zn_{1.5}Mo_0$ treatment combination (Table 3). El Sayed Hameda *et al*. (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as plant height.

4.1.2 Number of branches/plant

Different levels of zinc showed statistically significant variation effect in terms of number of branches/plant of garden pea (Appendix III). The maximum number of branches/plant (3.24) was recorded from $Zn_{3.0}$, whereas the minimum number of branches/plant (2.87) was found from Zn_0 i.e. control condition which was statistically similar (3.02) to $Zn_{1.5}$ (Table 2).

Number of branches/plant of garden pea showed statistically significant differences due to different levels of molybdenum (Appendix III). The maximum number of branches/plant (3.27) was found from $Mo_{0.6}$ which was closely followed (3.04) by $Mo_{0.3}$, while the minimum number of branches/plant (2.82) was recorded from Mo_0 i.e. control condition (Table 2). Hazra and Tripathi (1998) observed that molybdenum application at the rate of 1.5 kg/ha increased forage yields in calcareous soil.

Table 3. Interaction effect of zinc and molybdenum on yield contributing characters of garden pea

Treatments	Plant height (cm)	Number of branches/plant	Number of pods/plant	Pod length (cm)	Number of seeds/pod
Zn_0Mo_0	53.85 d	2.53 d	14.20 d	6.47 d	5.43 d
$Zn_0Mo_{0.3}$	59.38 bcd	3.13 bc	18.00 bc	7.07 cd	5.87 bcd
$Zn_0Mo_{0.6}$	57.05 cd	2.93 bc	17.00 cd	6.80 cd	5.53 d
$Zn_{1.5}Mo_0$	55.47 d	2.87 c	17.87 bc	7.07 cd	5.63 cd
$Zn_{1.5}Mo_{0.3}$	64.20 ab	2.93 bc	17.47 bcd	7.50 bc	6.33 bc
$Zn_{1.5}Mo_{0.6}$	61.67 abc	3.27 b	23.40 a	7.83 ab	6.53 b
$Zn_{3.0}Mo_0$	62.24 abc	3.07 bc	17.00 cd	7.07 cd	6.07 bcd
$Zn_{3.0}Mo_{0.3}$	58.50 bcd	3.07 bc	20.80 ab	7.77 ab	6.53 b
$Zn_{3.0}Mo_{0.6}$	65.50 a	3.60 a	22.07 a	8.43 a	7.27 a
$LSD_{(0.05)}$	5.450	0.333	3.153	0.664	0.666
Level of significance	0.05	0.05	0.01	0.05	0.05
CV(%)	5.27	6.29	7.70	5.22	6.27

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Statistically significant variation was recorded due to the interaction effect of different levels of zinc and molybdenum in terms of number of branches/plant of garden pea (Appendix III). The maximum number of branches/plant (3.60) was recorded from $Zn_{3.0}Mo_{0.6}$ which was closely followed by other combination except Zn_0Mo_0 and $Zn_{1.5}Mo_0$. On the other hand, the minimum number of branches/plant (2.53) was found from Zn_0Mo_0 i.e. control condition which was closely followed (2.87) by $Zn_{1.5}Mo_0$ treatment combination (Table 3).

4.1.3 Number of pods/plant

Statistically significant variation was recorded in terms of number of pods/plant of garden pea due to different levels of zinc (Appendix III). The maximum number of pods/plant (19.96) was recorded from $Zn_{3.0}$ which was statistically similar (19.58) to $Zn_{1.5}$, whereas the minimum number of pods/plant (16.40) was found from Zn_0 i.e. control condition (Table 2). Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher growth and yield attributes.

Different levels of molybdenum showed statistically significant differences on number of pods/plant of garden pea (Appendix III). The maximum number of pods/plant (19.89) was found from $Mo_{0.6}$ which was statically similar (18.76) to $Mo_{0.3}$, while the minimum number of pods/plant (17.29) was recorded from Mo_0 i.e. control condition (Table 2). Togay *et al*. (2008) reported that molybdenum increased pods/plant.

Interaction effect of different levels of zinc and molybdenum varied significantly in terms of number of pods/plant of garden pea (Appendix III). The maximum number of pods/plant (23.40) was recorded from $Zn_{1.5}Mo_{0.6}$ which was statistically similar (22.07 and 20.80) to $Zn_{3.0}Mo_{0.6}$ and $Zn_{3.0}Mo_{0.3}$. On the other hand, the minimum number of pods/plant (14.20) was found from Zn_0Mo_0 which was statistically similar (17.00 and 17.47) to Zn_0Mo_0, $Zn_{3.0}Mo_0$ and $Zn_{1.5}Mo_{0.3}$ treatment combination (Table 3).

4.1.4 Pod length

Pod length of garden pea showed statistically significant variation due to different levels of zinc (Appendix III). The longest pod (7.76 cm) was recorded from $Zn_{3.0}$ which was statistically similar (7.47 cm) to $Zn_{1.5}$, whereas the shortest pod (6.78 cm) was found from Zn_0 i.e. control condition (Table 2). Rizk and Abdo (2001) reported that yield components showed a highly significant increase with the application of Zn (0.2 or 0.4 g/l) compared to the control. Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher growth and yield attributes.

Statistically significant differences was observed due to different levels of molybdenum on pod length of garden pea (Appendix III). The longest pod (7.69 cm) was found from $Mo_{0.6}$ which was statically similar (7.44 cm) to $Mo_{0.3}$, while the shortest pod (6.87 cm) was recorded from Mo_0 i.e. control condition (Table 2).

Interaction effect of different levels of zinc and molybdenum varied significantly in terms of pod length of garden pea (Appendix III). The longest pod (8.43 cm) was recorded from $Zn_{3.0}Mo_{0.6}$ which was statistically similar (7.83 cm and 7.77 cm) to $Zn_{1.5}Mo_{0.6}$ and $Zn_{3.0}Mo_{0.3}$. On the other hand, the shortest pod (6.47 cm) was found from Zn_0Mo_0 which was statistically similar (6.80 cm and 7.07 cm) to $Zn_0Mo_{0.6}$, $Zn_0Mo_{0.3}$, $Zn_{1.5}Mo_0$ and $Zn_{3.0}Mo_0$ treatment combination (Table 3).

4.1.5 Number of seeds/pod

Statistically significant variation was recorded in terms of number of seeds/pod of garden pea due to different levels of zinc (Appendix III). The maximum number of seeds/pod (6.62) was recorded from $Zn_{3.0}$ which was closely followed (6.17) by $Zn_{1.5}$, whereas the minimum number of seeds/pods (5.61) was found from Zn_0 i.e. control condition (Table 2). Rizk and Abdo (2001) reported that yield components showed a highly significant increase with the application of Zn (0.2 or 0.4 g/l) compared to the control.

Different levels of molybdenum showed statistically significant differences on number of seeds/pod of garden pea (Appendix III). The maximum number of seeds/pod (6.44) was found from $Mo_{0.6}$ which was statically similar (6.24) to $Mo_{0.3}$, while the minimum number of seeds/pod (5.71) was recorded from Mo_0 i.e. control condition (Table 2). Sarkar and Banik (1991) observed the molybdenum application significantly increased seeds/pod.

Interaction effect of different levels of zinc and molybdenum varied significantly in terms of number of seeds/pod of garden pea (Appendix III). The maximum number of seeds/pod (7.27) was recorded from $Zn_{3.0}Mo_{0.6}$ which was closely followed (6.53, 6.07 and 5.87) by $Zn_{3.0}Mo_{0.3}$, $Zn_{1.5}Mo_{0.6}$, $Zn_{3.0}Mo_0$ and $Zn_0Mo_{0.3}$ and they was statistically similar. On the other hand, the minimum number of seeds/pod (5.43) was found from Zn_0Mo_0 which was statistically similar (5.53) $Zn_0Mo_{0.6}$ treatment combination (Table 3).

4.1.6 Weight of 100 green seeds

Statistically non significant variation was recorded in terms of weight of 100 green seeds of garden pea due to different levels of zinc (Appendix IV). The highest weight of 100 green seeds (43.25 g) was recorded from $Zn_{3.0}$, whereas the lowest weight of 100 green seeds (41.47 g) was observed from Zn_0 i.e. control condition which was also statistically similar to $Zn_{1.5}$ (Table 4). Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher weight of 1000 seeds.

Different levels of molybdenum showed statistically non significant differences on weight of 100 green seeds of garden pea (Appendix IV). The highest weight of 100 green seeds (43.09 g) was found from $Mo_{0.6}$, while the lowest weight of 100 green seeds (41.84 g) was recorded from Mo_0 i.e. control condition (Table 4). Sarkar and Banik (1991) observed the molybdenum application significantly increased 1000 seed weight.

Interaction effect of different levels of zinc and molybdenum varied non significantly in terms of weight of 100 green seeds of garden pea (Appendix IV). The highest weight of 100 green seeds (44.06 g) was recorded from $Zn_{3.0}Mo_{0.6}$ and the lowest weight of 100 green seeds (41.25 g) was found from Zn_0Mo_0 treatment combination (Table 5).

4.1.7 Weight of 100 mature seeds

Different levels of zinc varied non significantly in terms of weight of 100 mature seeds of garden pea (Appendix IV). The highest weight of 100 mature seeds (28.24 g) was found from $Zn_{3.0}$, while the lowest weight of 100 mature seeds (26.39 g) was recorded from Zn_0 i.e. control condition which was also statistically similar to $Zn_{1.5}$ (Table 4).

Weight of 100 mature seeds of garden pea showed statistically non significant differences due to different levels of molybdenum (Appendix IV). The highest weight of 100 mature seeds (27.74 g) was recorded from $Mo_{0.6}$, whereas the lowest weight of 100 mature seeds (26.87 g) was observed from Mo_0 i.e. control condition (Table 4).

Statistically non significant variation was recorded due to the interaction effect of different levels of zinc and molybdenum in terms of weight of 100 mature seeds of garden pea (Appendix IV). The highest weight of 100 mature seeds (28.86 g) was observed from $Zn_{3.0}Mo_{0.6}$ and the lowest weight of 100 mature seeds (26.08 g) was recorded from $Zn_0Mo_{0.6}$ treatment combination (Table 5).

Table 4. Effect of zinc and molybdenum on weight of 100 seeds and yield of garden pea

Treatments	Weight of 100 green seeds (g)	Weight of 100 mature seeds (g)	Pod yield/plant (g)	Green pod yield/hectare (ton)	Stover yield/hectare (ton)
Levels of zinc					
Zn_0	41.47	26.39	67.69 b	7.39 b	8.49 b
$Zn_{1.5}$	42.88	27.46	70.76 a	8.18 a	9.47 a
$Zn_{3.0}$	43.25	28.24	72.25 a	8.41 a	9.79 a
$LSD_{(0.05)}$	--	--	2.774	0.432	0.177
Level of significance	NS	NS	0.01	0.01	0.01
Levels of molybdenum					
Mo_0	41.84	26.87	64.52 c	7.59 b	8.69 b
$Mo_{0.3}$	42.67	27.48	71.54 b	8.08 a	9.38 a
$Mo_{0.6}$	43.09	27.74	74.64 a	8.31 a	9.69 a
$LSD_{(0.05)}$	--	--	2.774	0.432	0.177
Level of significance	NS	NS	0.01	0.01	0.01
CV(%)	5.22	7.01	6.90	6.19	4.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Table 5. Interaction effect of zinc and molybdenum on weight of 100-seeds and yield of garden pea

Treatments	Weight of 100-green seeds (g)	Weight of 100-mature seeds (g)	Pod yield/plant (g)	Green pod yield/hectare (ton)	Stover yield/hectare (ton)
Zn_0Mo_0	41.25	26.08	60.04 e	6.68 c	8.18 e
$Zn_0Mo_{0.3}$	41.52	26.45	72.21 bc	7.82 b	9.04 cde
$Zn_0Mo_{0.6}$	41.65	26.64	69.78 c	7.67 b	8.22 e
$Zn_{1.5}Mo_0$	42.22	27.08	63.74 de	7.71 b	8.52 de
$Zn_{1.5}Mo_{0.3}$	42.86	27.56	67.54 cd	8.48 ab	9.70 abc
$Zn_{1.5}Mo_{0.6}$	43.56	27.73	81.00 a	8.36 ab	10.20 ab
$Zn_{3.0}Mo_0$	42.05	27.44	61.08 e	7.93 b	9.32 bcd
$Zn_{3.0}Mo_{0.3}$	43.63	28.42	74.88 b	8.39 ab	9.40 bcd
$Zn_{3.0}Mo_{0.6}$	44.06	28.86	81.84 a	8.91 a	10.65 a
$LSD_{(0.05)}$	--	--	4.804	0.749	0.921
Level of significance	NS	NS	0.01	0.05	0.05
CV(%)	5.22	7.01	6.90	6.19	4.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

4.1.8 Pod yield/plant

Statistically significant variation was recorded in terms of pod yield/plant of garden pea due to different levels of zinc (Appendix IV). The highest pod yield/plant (72.25 g) was recorded from $Zn_{3.0}$ which was statistically similar (70.76 g) to $Zn_{1.5}$, whereas the lowest pod yield/plant (67.69 g) was observed from Zn_0 i.e. control condition (Table 4). Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher pod yield/plant.

Different levels of molybdenum showed statistically significant differences on pod yield/plant of garden pea (Appendix IV). The highest pod yield/plant (74.64 g) was found from $Mo_{0.6}$ which followed (71.54 g) by $Mo_{0.3}$, while the lowest pod yield/plant (64.52 g) was found from Mo_0 i.e. control condition (Table 4).

Interaction effect of different levels of zinc and molybdenum varied significantly in terms of pod yield/plant of garden pea (Appendix IV). The highest pod yield/plant (81.84 g) was recorded from $Zn_{3.0}Mo_{0.6}$ which was statistically similar (81.00 g) to $Zn_{1.5}Mo_{0.6}$. On the other hand, the lowest pod yield/plant (60.04 g) was found from Zn_0Mo_0 treatment combination which was statistically similar (61.08 g) to $Zn_{3.0}Mo_0$ (Table 5).

4.1.9 Green pod yield/hectare

Statistically significant variation was recorded in terms of green pod yield/hectare of garden pea due to different levels of zinc (Appendix IV). The highest green pod yield/hectare (8.41 ton) was recorded from $Zn_{3.0}$ which was statistically similar (8.18 ton) to $Zn_{1.5}$, whereas the lowest green pod yield/hectare (7.39 ton) was observed from Zn_0 i.e. control condition (Table 4). Alam *et al*. (2010) reported that 2.5 kg ha^{-1} of each Zn produced the highest seeds yield of 8.51 t ha^{-1}. Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher seed yield (11.97 q ha^{-1}).

Different levels of molybdenum showed statistically significant differences on green pod yield/hectare of garden pea (Appendix IV). The highest green pod yield/hectare (8.31 ton) was found from $Mo_{0.6}$ which was statically similar (8.08 ton) to $Mo_{0.3}$, while the lowest green pod yield/hectare (7.59 ton) was recorded from Mo_0 i.e. control condition (Table 4). Sheudzhen *et al.* (1985) reported highest yield with 0.05% Mo (7.46 t/ha) compared to (6.14 t/ha) zero trace element. Hazra and Tripathi (1998) observed that molybdenum application at the rate of 1.5 kg/ha increased seed yields.

Interaction effect of different levels of zinc and molybdenum varied significantly in terms of green pod yield/hectare of garden pea (Appendix IV). The highest green pod yield/hectare (8.91 ton) was recorded from $Zn_{3.0}Mo_{0.6}$ which was statistically similar (8.48 ton, 8.39 ton and 8.36 ton) to $Zn_{1.5}Mo_{0.3}$, $Zn_{3.0}Mo_0$ and $Zn_{1.5}Mo_{0.6}$. On the other hand, the lowest green pod yield/hectare (6.68 ton) was found from Zn_0Mo_0 treatment combination (Table 5).

4.1.10 Stover yield/hectare

Statistically significant variation was recorded in terms of stover yield/hectare of garden pea due to different levels of zinc (Appendix IV). The highest stover yield/hectare (9.79 ton) was recorded from $Zn_{3.0}$ which was statistically similar (9.47 ton) to $Zn_{1.5}$, whereas the lowest stover yield/hectare (8.49 ton) was observed from Zn_0 i.e. control condition (Table 4). Kumar *et al.* (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher straw yield (21.15 q ha^{-1}).

Different levels of molybdenum showed statistically significant differences on stover yield/hectare of garden pea (Appendix IV). The highest stover yield/hectare (9.69 ton) was found from $Mo_{0.6}$ which was statistically similar (9.38 ton) to $Mo_{0.3}$, while the lowest stover yield/hectare (8.69 ton) was recorded from Mo_0 i.e. control condition (Table 4). Sarkar and Banik (1991) observed the molybdenum application significantly increased straw yield.

Interaction effect of different levels of zinc and molybdenum varied significantly in terms of stover yield/hectare of garden pea (Appendix IV). The highest stover yield/hectare (10.65 ton) was recorded from $Zn_{3.0}Mo_{0.6}$ which was statistically similar (10.20 ton and 9.70 ton) to $Zn_{1.5}Mo_{0.6}$ and $Zn_{1.5}Mo_{0.3}$. On the other hand, the lowest stover yield/hectare (8.18 ton) was found from Zn_0Mo_0 treatment combination which was statistically similar (10.22 ton) to $Zn_1Mo_{0.6}$ (Table 5).

4.2 Nutrient status of post harvest soil

4.2.1 Soil pH

Statistically non significant variation was recorded in terms of soil pH in post harvest soil of garden pea due to different levels of zinc (Appendix V). The recorded data revealed that the highest soil pH (6.37) was recorded from $Zn_{3.0}$, while the lowest soil pH (6.17) was observed from Zn_0 i.e. control condition (Table 6).

Different levels of molybdenum showed statistically non significant differences on soil pH of post harvest soil of garden pea (Appendix V). The highest soil pH (6.34) was found from $Mo_{0.6}$ and the lowest soil pH (6.24) was recorded from Mo_0 i.e. control condition (Table 6).

Interaction effect of different levels of zinc and molybdenum varied non significantly in terms of soil pH of post harvest soil of garden pea (Appendix V). The highest soil pH (6.42) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest soil pH (6.15) was observed from Zn_0Mo_0 i.e. control condition (Table 7).

4.2.2 Organic matter

Organic matter content of post harvest soil of garden pea varied non significantly due to different levels of zinc (Appendix V). Data revealed that the highest organic matter (1.34%) was recorded from $Zn_{3.0}$, while the lowest organic matter (1.26%) was found from Zn_0 i.e. control condition (Table 6).

Table 6. Effect of zinc and molybdenum on pH, organic matter, available P, Zn and Mo of post harvest soil of garden pea

Treatments	Soil pH	Organic matter (%)	Available P (ppm)	Available Zn (ppm)	Available Mo (ppm)
Levels of zinc					
Zn_0	6.17	1.26	18.79	0.258 c	0.326
$Zn_{1.5}$	6.32	1.31	19.57	0.366 b	0.333
$Zn_{3.0}$	6.37	1.34	19.81	0.432 a	0.343
$LSD_{(0.05)}$	--	--	--	0.025	--
Level of significance	NS	NS	NS	0.01	NS
Levels of molybdenum					
Mo_0	6.24	1.26	19.12	0.343	0.236 c
$Mo_{0.3}$	6.28	1.32	19.42	0.354	0.375 b
$Mo_{0.6}$	6.34	1.33	19.63	0.358	0.392 a
$LSD_{(0.05)}$	--	--	--	--	0.010
Level of significance	NS	NS	NS	NS	0.01
CV(%)	4.91	8.37	7.50	6.97	4.91

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Table 7. Interaction effect of zinc and molybdenum on pH, organic matter, available P, Zn and Mo of post harvest soil of garden pea

Treatments	Soil pH	Organic matter (%)	Available P (ppm)	Available Zn (ppm)	Available Mo (ppm)
Zn_0Mo_0	6.15	1.20	18.55	0.251	0.230
$Zn_0Mo_{0.3}$	6.16	1.29	18.86	0.260	0.364
$Zn_0Mo_{0.6}$	6.21	1.30	18.96	0.262	0.385
$Zn_{1.5}Mo_0$	6.26	1.28	19.47	0.357	0.234
$Zn_{1.5}Mo_{0.3}$	6.33	1.32	19.57	0.366	0.375
$Zn_{1.5}Mo_{0.6}$	6.39	1.32	19.67	0.374	0.392
$Zn_{3.0}Mo_0$	6.32	1.30	19.36	0.422	0.243
$Zn_{3.0}Mo_{0.3}$	6.36	1.35	19.83	0.435	0.386
$Zn_{3.0}Mo_{0.6}$	6.42	1.37	20.25	0.439	0.399
$LSD_{(0.05)}$	--	--	--	--	--
Level of significance	NS	NS	NS	NS	NS
CV(%)	4.91	8.37	7.50	6.97	4.91

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Statistically non significant differences was observed in terms of organic matter of post harvest soil of garden pea due to different levels of molybdenum (Appendix V). The highest organic matter (1.33) was recorded from $Mo_{0.6}$, while the lowest organic matter (1.26) from Mo_0 i.e. control condition (Table 6).

Statistically non significant variation was recorded due to the interaction effect of different levels of zinc and molybdenum in terms of organic matter of post harvest soil of garden pea (Appendix V). The highest organic matter (1.37) was recorded from $Zn_{3.0}Mo_{0.6}$ and the lowest organic matter (1.20) from Zn_0Mo_0 i.e. control condition (Table 7).

4.2.3 Total nitrogen

Statistically non significant variation was recorded in terms of total nitrogen in post harvest soil of garden pea due to different levels of zinc (Appendix V). The highest total nitrogen (0.073%) was recorded from $Zn_{3.0}$, while the lowest total nitrogen (0.070%) was observed from Zn_0 i.e. control condition (Figure 2).

Different levels of molybdenum showed statistically non significant differences on total nitrogen of post harvest soil of garden pea (Appendix V). The highest total nitrogen (0.074%) was found from $Mo_{0.6}$ and the lowest total nitrogen (0.069%) was recorded from Mo_0 i.e. control condition (Figure 3).

Interaction effect of different levels of zinc and molybdenum varied non significantly in terms of total nitrogen of post harvest soil of garden pea (Appendix V). The highest total nitrogen (0.075%) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest total nitrogen (0.068%) was observed from Zn_0Mo_0 i.e. control condition (Figure 4).

4.2.4 Available P

Statistically non significant variation was recorded in terms of available P in post harvest soil of garden pea due to different levels of zinc (Appendix V). The highest available P (19.81 ppm) was recorded from $Zn_{3.0}$, while the lowest available P (18.79 ppm) was observed from Zn_0 i.e. control condition (Table 6).

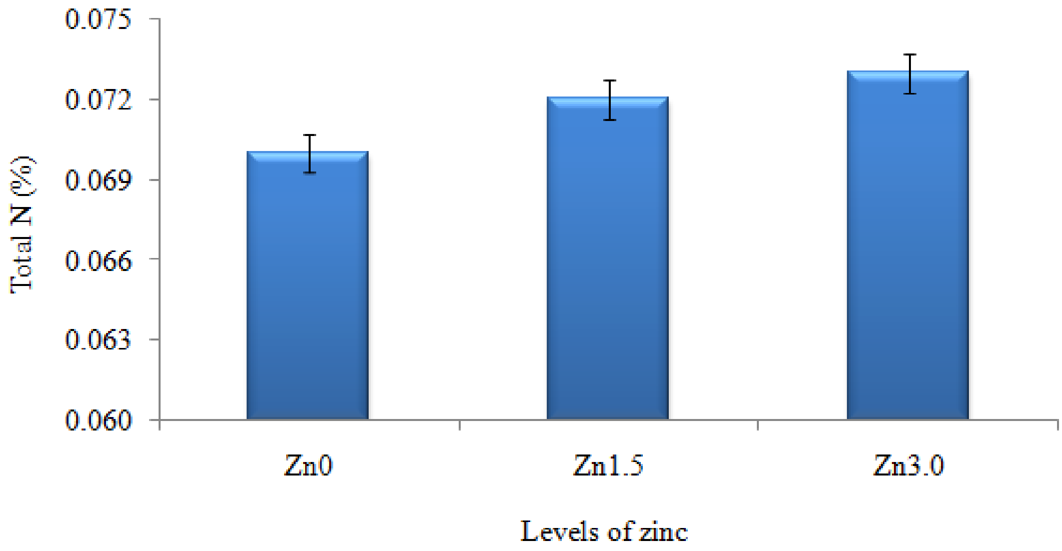

Figure 2. Effect of different levels of zinc on total N in post harvest soil of garden pea. Vertical bars represent LSD value.

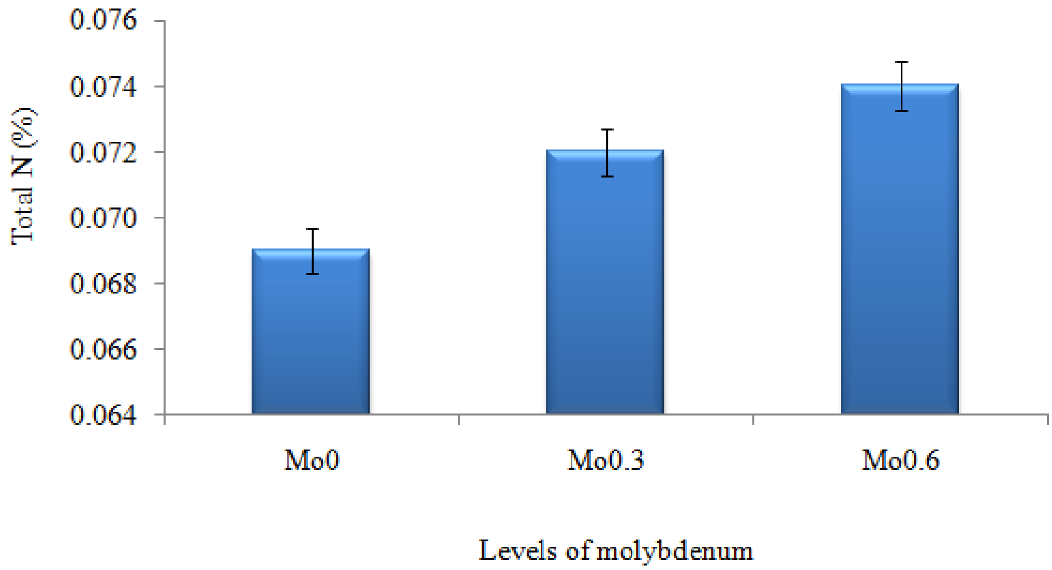

Figure 3. Effect of different levels of molybdenum on total N in post harvest soil of garden pea. Vertical bars represent LSD value.

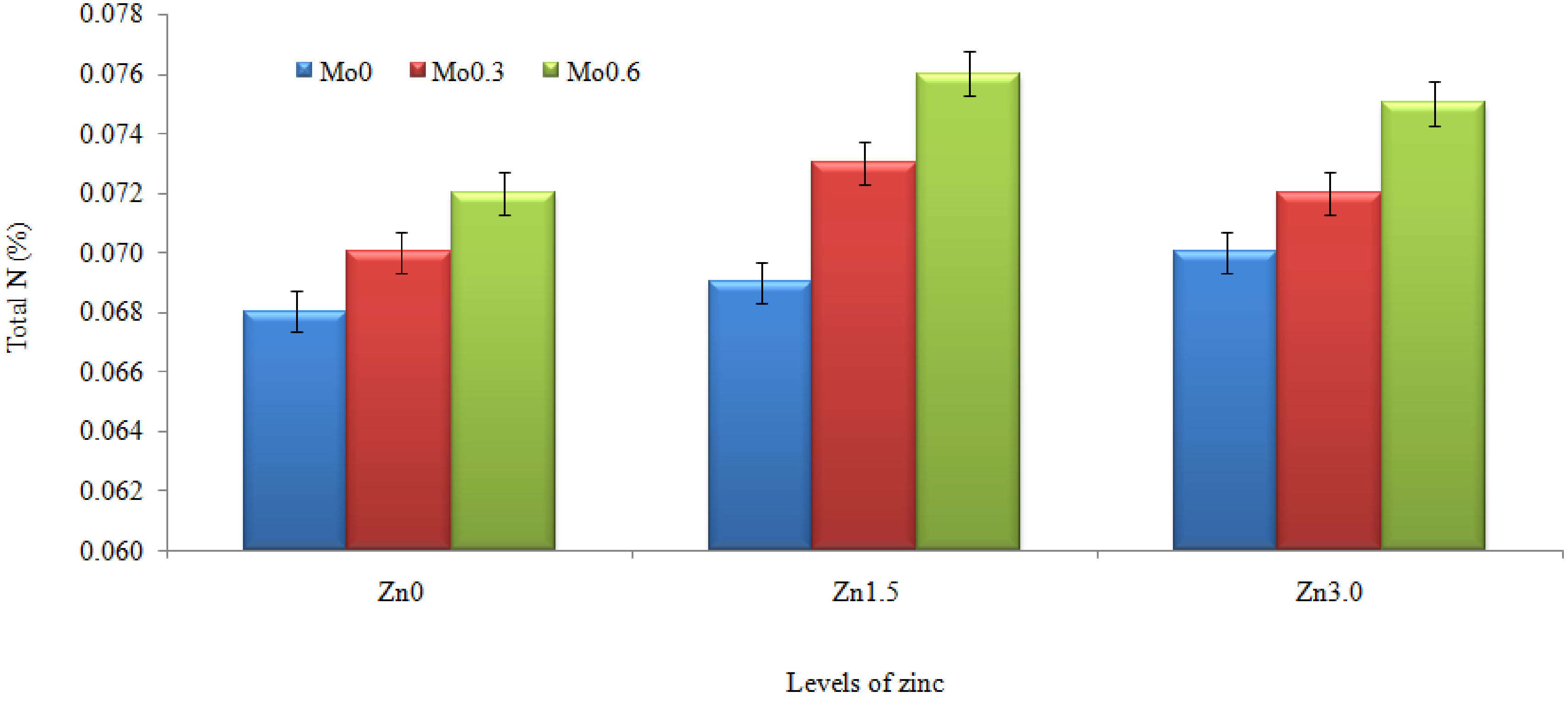

Figure 4. Interaction effect of different levels of zinc and molybdenum on total N in post harvest soil of garden pea. Vertical bars represent LSD value.

Different levels of molybdenum showed statistically non significant differences on available P of post harvest soil of garden pea (Appendix V). The highest available P (19.63 ppm) was found from $Mo_{0.6}$ and the lowest available P (19.12 ppm) was recorded from Mo_0 i.e. control condition (Table 6).

Interaction effect of different levels of zinc and molybdenum varied non significantly in terms of available P of post harvest soil of garden pea (Appendix V). The highest available P (20.25 ppm) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest available P (18.55 ppm) from Zn_0Mo_0 i.e. control condition (Table 7).

4.2.5 Exchangeable K

Statistically non significant variation was recorded in terms of exchangeable K in post harvest soil of garden pea due to different levels of zinc (Appendix V). The highest exchangeable K (0.117 me %) was recorded from $Zn_{3.0}$, while the lowest exchangeable K (0.111 me %) from Zn_0 i.e. control condition (Figure 5).

Different levels of molybdenum showed statistically non significant differences on exchangeable K of post harvest soil of garden pea (Appendix V). The highest exchangeable K (0.117 me %) was found from $Mo_{0.6}$ and the lowest exchangeable K (0.112 me %) from Mo_0 i.e. control condition (Figure 6).

Interaction effect of different levels of zinc and molybdenum varied non significantly in terms of exchangeable K of post harvest soil of garden pea (Appendix V). The highest exchangeable K (0.119 me %) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest exchangeable K (0.108 me %) was observed from Zn_0Mo_0 i.e. control condition (Figure 7).

4.2.6 Available Zn

Statistically significant variation was recorded in terms of available Zn in post harvest soil of garden pea due to different levels of zinc (Appendix V). The highest available Zn (0.432 ppm) was recorded from $Zn_{3.0}$ which was closely followed (0.366 ppm) by $Zn_{1.5}$, while the lowest available Zn (0.258 ppm) was observed from Zn_0 i.e. control condition (Table 6).

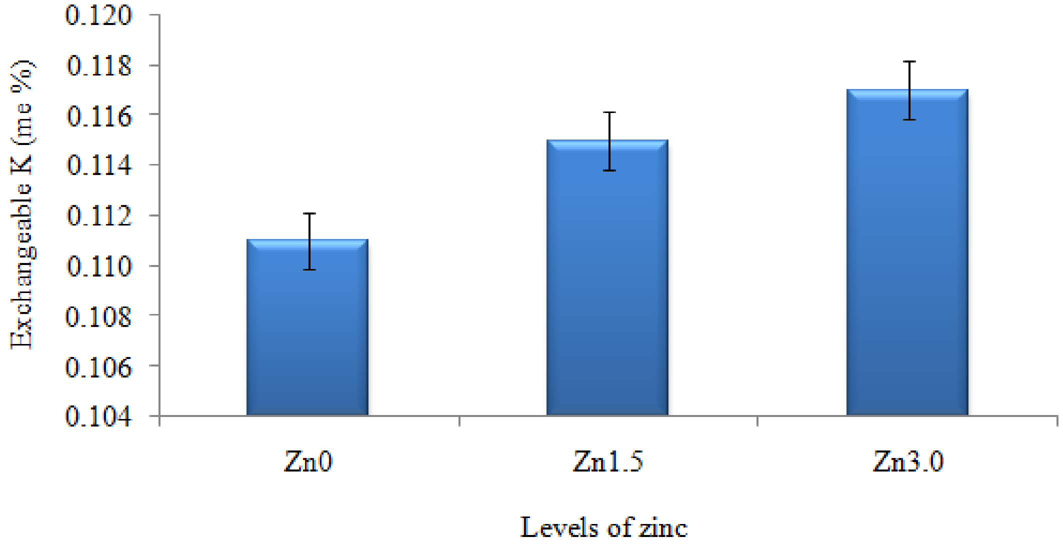

Figure 5. Effect of different levels of zinc on exchangeable K in post harvest soil of garden pea. Vertical bars represent LSD value.

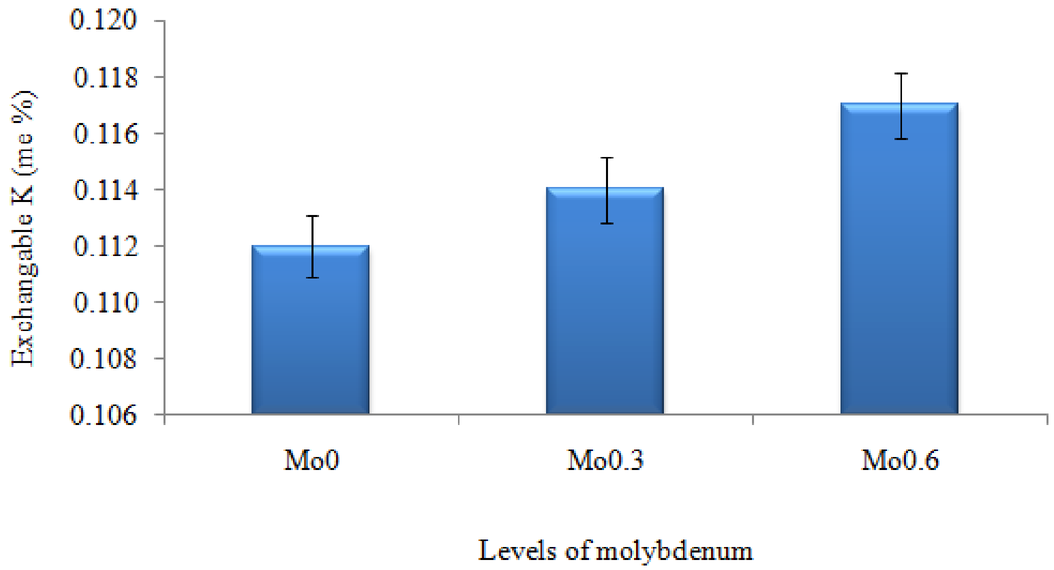

Figure 6. Effect of different levels of molybdenum on exchangeable K in post harvest soil of garden pea. Vertical bars represent LSD value.

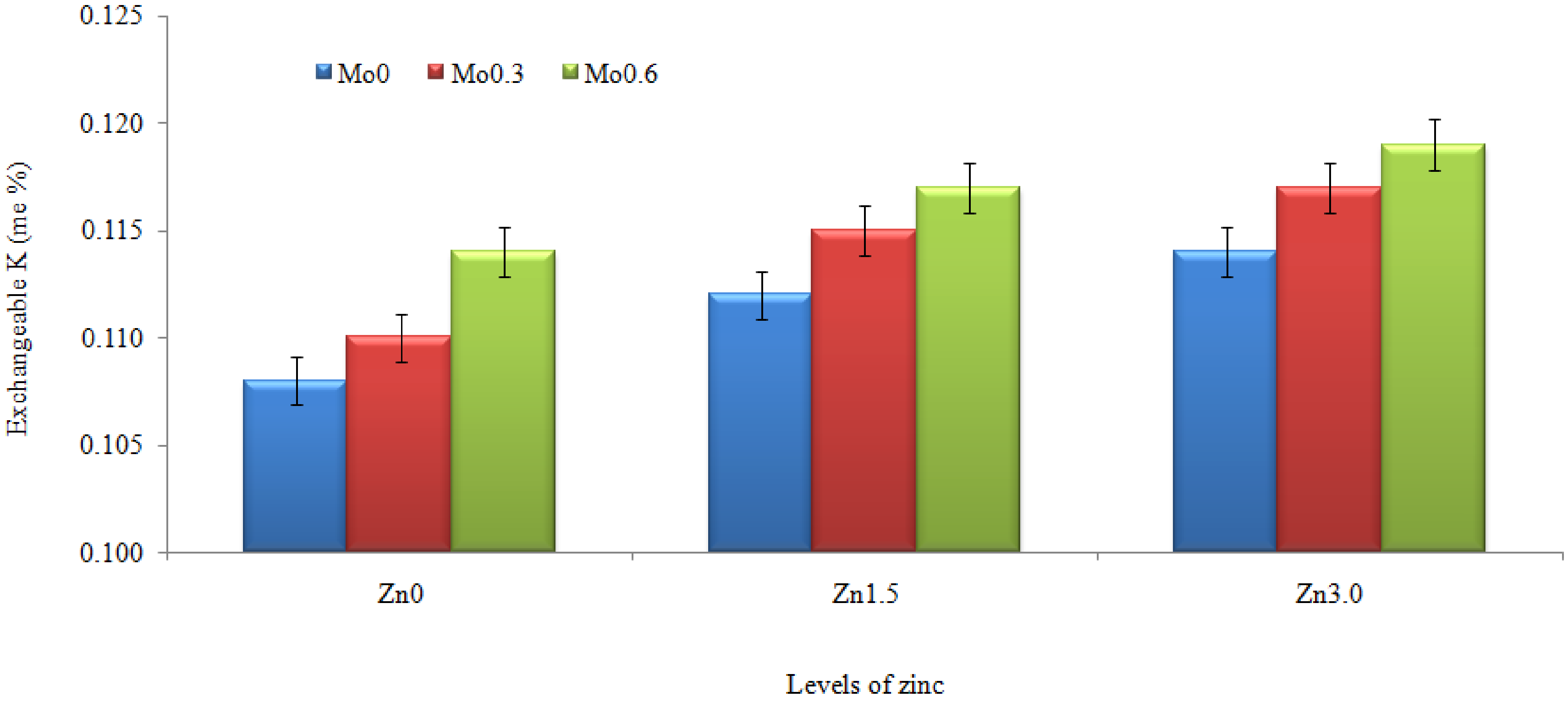

Figure 7. Interaction effect of different levels of zinc and molybdenum on exchanegable K in post harvest soil of garden pea. Vertical bars represent LSD value.

Different levels of molybdenum varied non significantly on available Zn of post harvest soil of garden pea (Appendix V). The highest available Zn (0.358 ppm) was found from $Mo_{0.6}$ and the lowest available Zn (0.343 ppm) was recorded from Mo_0 i.e. control condition (Table 6).

Interaction effect of different levels of zinc and molybdenum varied non significantly in terms of available Zn of post harvest soil of garden pea (Appendix V). The highest available Zn (0.439 ppm) was recorded from $Zn_{3.0}Mo_{0.6}$, while the lowest available Zn (0.251 ppm) from Zn_0Mo_0 i.e. control condition (Table 7).

4.2.7 Available Mo

Statistically non significant variation was recorded in terms of available Mo in post harvest soil of garden pea due to different levels of zinc (Appendix V). The highest available Mo (0.343 ppm) was recorded from $Zn_{3.0}$ and the lowest available Mo (0.326 ppm) from Zn_0 i.e. control condition (Table 6).

Different levels of molybdenum varied significantly on available Mo of post harvest soil of garden pea (Appendix V). The highest available Mo (0.392 ppm) was found from $Mo_{0.6}$, which was closely followed (0.375 ppm) by $Mo_{0.03}$ and the lowest available Mo (0.236 ppm) from Mo_0 i.e. control condition (Table 6).

Interaction effect of different levels of zinc and molybdenum varied non significantly in terms of available Mo of post harvest soil of garden pea (Appendix V). The highest available Mo (0.399 ppm) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest available Mo (0.230 ppm) was observed from Zn_0Mo_0 i.e. control condition (Table 7).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from December, 2015 to March 2016 to study the effect of zinc and molybdenum on growth and yield of garden pea. The variety BARI Motorshuti-1 was used as the test crop. The experiment comprised of two factors as, Factor A: Levels of zinc (3 levels)- Zn_0: 0 kg Zn/ha (control), $Zn_{1.5}$: 1.5 kg Zn/ha' $Zn_{3.0}$: 3.0 kg Zn/ha and Factors B: Levels of molybdenum (3 levels)- Mo_0: 0 kg Mo/ha (control), $Mo_{0.3}$: 0.3 kg Mo/ha, $Mo_{0.6}$: 0.6 kg Mo/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters, yield and nutrient status of post harvest soil was recorded.

In case of different levels of zinc, the tallest plant (62.08 cm) was recorded from $Zn_{3.0}$, whereas the shortest plant (56.76 cm) was found from Zn_0 i.e. control condition. The maximum number of branches/plant (3.24) was recorded from $Zn_{3.0}$, whereas the minimum number of branches/plant (2.87) was found from Zn_0. The maximum number of pods/plant (19.96) was recorded from $Zn_{3.0}$, whereas the minimum number of pods/plant (16.40) was found from Zn_0. The longest pod (7.76 cm) was recorded from $Zn_{3.0}$, whereas the shortest pod (6.78 cm) was found from Zn_0. The maximum number of seeds/pod (6.62) was recorded from $Zn_{3.0}$, whereas the minimum number (5.61) from Zn_0. The highest weight of 100 green seeds (43.25 g) was recorded from $Zn_{3.0}$, whereas the lowest weight (41.47 g) from Zn_0. The highest weight of 100 mature seeds (28.24 g) was found from $Zn_{3.0}$, while the lowest weight (26.39 g) from Zn_0. The highest pod yield/plant (72.25 g) was recorded from $Zn_{3.0}$, whereas the lowest pod yield/plant (67.69 g) from Zn_0. The highest green pod yield/hectare (8.41 ton) from $Zn_{3.0}$, whereas the lowest (7.39 ton) from Zn_0. The highest stover yield/hectare (9.79 ton) was recorded from $Zn_{3.0}$, whereas the lowest (8.49 ton) from Zn_0. The highest soil pH (6.37) was recorded from $Zn_{3.0}$, while the lowest soil pH (6.17) from Zn_0. The highest organic matter (1.34%) was recorded from $Zn_{3.0}$, while the lowest organic matter (1.26%) from Zn_0. The highest total nitrogen (0.073%) was recorded from $Zn_{3.0}$, while the lowest total nitrogen (0.070%) was observed from Zn_0. The highest available P (19.81 ppm) was recorded from $Zn_{3.0}$, while the lowest available P (18.79 ppm) was observed from Zn_0. The highest exchangeable K (0.117 me %) was recorded from $Zn_{3.0}$, while the lowest exchangeable K (0.111 me %) from Zn_0. The highest available Zn (0.432 ppm) was recorded from $Zn_{3.0}$, while the lowest available Zn (0.258 ppm) was observed from Zn_0. The highest available Mo (0.343 ppm) was recorded from $Zn_{3.0}$ and the lowest available Mo (0.326 ppm) from Zn_0.

For different levels of molybdenum, the tallest plant (61.41 cm) was found from $Mo_{0.6}$, while the shortest plant (57.18 cm) from Mo_0 i.e. control condition. The maximum number of branches/plant (3.27) was found from $Mo_{0.6}$, while the minimum number of branches/plant (2.82) from Mo_0. The maximum number of pods/plant (19.89) from $Mo_{0.6}$, while the minimum number (17.29) from Mo_0. The longest pod (7.69 cm) was found from $Mo_{0.6}$, while the shortest pod (6.87 cm) from Mo_0. The maximum number of seeds/pod (6.44) was found from $Mo_{0.6}$, while the minimum number (5.71) from Mo_0. The highest weight of 100 green seeds (43.09 g) was found from $Mo_{0.6}$, while the lowest weight (41.84 g) from Mo_0. The highest weight of 100 mature seeds (27.74 g) was recorded from $Mo_{0.6}$, whereas the lowest weight (26.87 g) from Mo_0. The highest pod yield/plant (74.64 g) was found from $Mo_{0.6}$, while the lowest (64.52 g) was found from Mo_0. The highest green pod yield/hectare (9.31 ton) was found from $Mo_{0.6}$, while the lowest green pod yield/hectare (8.59 ton) was recorded from Mo_0. The highest stover yield/hectare (9.69 ton) was found from $Mo_{0.6}$, while the lowest (8.69 ton) from Mo_0. The highest soil pH (6.34) was found from $Mo_{0.6}$ and the lowest soil pH (6.24) was recorded from Mo_0. The highest organic matter (1.33) was recorded from $Mo_{0.6}$, while the lowest organic matter (1.26) was observed from Mo_0. The highest total nitrogen (0.074%) was found from $Mo_{0.6}$ and the lowest total nitrogen (0.069%) was recorded from Mo_0. The highest available P (19.63 ppm) was found from $Mo_{0.6}$ and the lowest available P (19.12 ppm) was recorded from Mo_0. The highest exchangeable K (0.117 me %) was found from $Mo_{0.6}$ and the lowest exchangeable K (0.112 me %) was recorded from Mo_0. The highest available Zn (0.358 ppm) was found from $Mo_{0.6}$ and the lowest available Zn (0.343 ppm) was recorded from Mo_0. The highest available Mo (0.392 ppm) was found from $Mo_{0.6}$ and the lowest available Mo (0.236 ppm) was recorded from Mo_0.

Due to the interaction effect of different levels of zinc and molybdenum, the tallest plant (65.50 cm) was recorded from $Zn_{3.0}Mo_{0.6}$ and the shortest plant (53.85 cm) was found from Zn_0Mo_0 i.e. control condition. The maximum number of branches/plant (3.60) was recorded from $Zn_{3.0}Mo_{0.6}$ and the minimum number of branches/plant (2.53) from Zn_0Mo_0. The maximum number of pods/plant (23.40) was recorded from $Zn_{1.5}Mo_{0.6}$ and the minimum number of pods/plant (14.20) from Zn_0Mo_0. The longest pod (8.43 cm) was recorded from $Zn_{3.0}Mo_{0.6}$ and the shortest pod (6.47 cm) from Zn_0Mo_0. The maximum number of seeds/pod (7.27) was recorded from $Zn_{3.0}Mo_{0.6}$ and the minimum number (5.43) from Zn_0Mo_0. The highest weight of 100 green seeds (44.06 g) was recorded from $Zn_{3.0}Mo_{0.6}$ and the lowest weight of 100 green seeds (41.25 g) from $Zn_0Mo_{0.6}$. The highest weight of 100 mature seeds (28.86 g) was observed from $Zn_{3.0}Mo_{0.6}$ and the lowest weight of 100 mature seeds (26.08 g) from $Zn_0Mo_{0.6}$. The highest pod yield/plant (81.84 g) was recorded from $Zn_{3.0}Mo_{0.6}$ and the lowest pod yield/plant (60.04 g) from Zn_0Mo_0. The highest green pod yield/hectare (8.91 ton) was recorded from $Zn_{3.0}Mo_{0.6}$ and the lowest green pod yield/hectare (6.68 ton) from Zn_0Mo_0. The highest stover yield/hectare (10.65 ton) was recorded from $Zn_{3.0}Mo_{0.6}$ and the lowest stover yield/hectare (8.18 ton) from Zn_0Mo_0. The highest soil pH (6.42) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest soil pH (6.15) from Zn_0Mo_0. The highest organic matter (1.37) was recorded from $Zn_{3.0}Mo_{0.6}$ and the lowest organic matter (1.20) from Zn_0Mo_0. The highest total nitrogen (0.075%) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest total nitrogen (0.068%) from Zn_0Mo_0. The highest available P (20.25 ppm) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest available P (18.55 ppm) from Zn_0Mo_0. The highest exchangeable K (0.119 me %) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest exchangeable K (0.108 me %) from Zn_0Mo_0. The highest available Zn (0.439 ppm) was recorded from $Zn_{3.0}Mo_{0.6}$, while the lowest available Zn (0.251 ppm) from Zn_0Mo_0. The highest available Mo (0.399 ppm) was recorded from $Zn_{3.0}Mo_{0.6}$, whereas the lowest available Mo (0.230 ppm) was observed from Zn_0Mo_0.

Conclusion:

From the findings it was found that application of 3.0 kg Zn/ha and 0.6 kg Mo/ha and 1.5 kg Zn/ha & 0.3 kg Mo/ha showed statistically same seed yield. So, it can be concluded that combination of 1.5 kg Zn/ha and 0.3 kg Mo/ha can be more beneficial for the farmers to get better yield from the cultivation of garden pea.

Recommendation:

Considering the above results of this experiment, further studies in the following areas may be suggested:

- Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.
- More experiments may be carried out with other organic and also macro nutrients.

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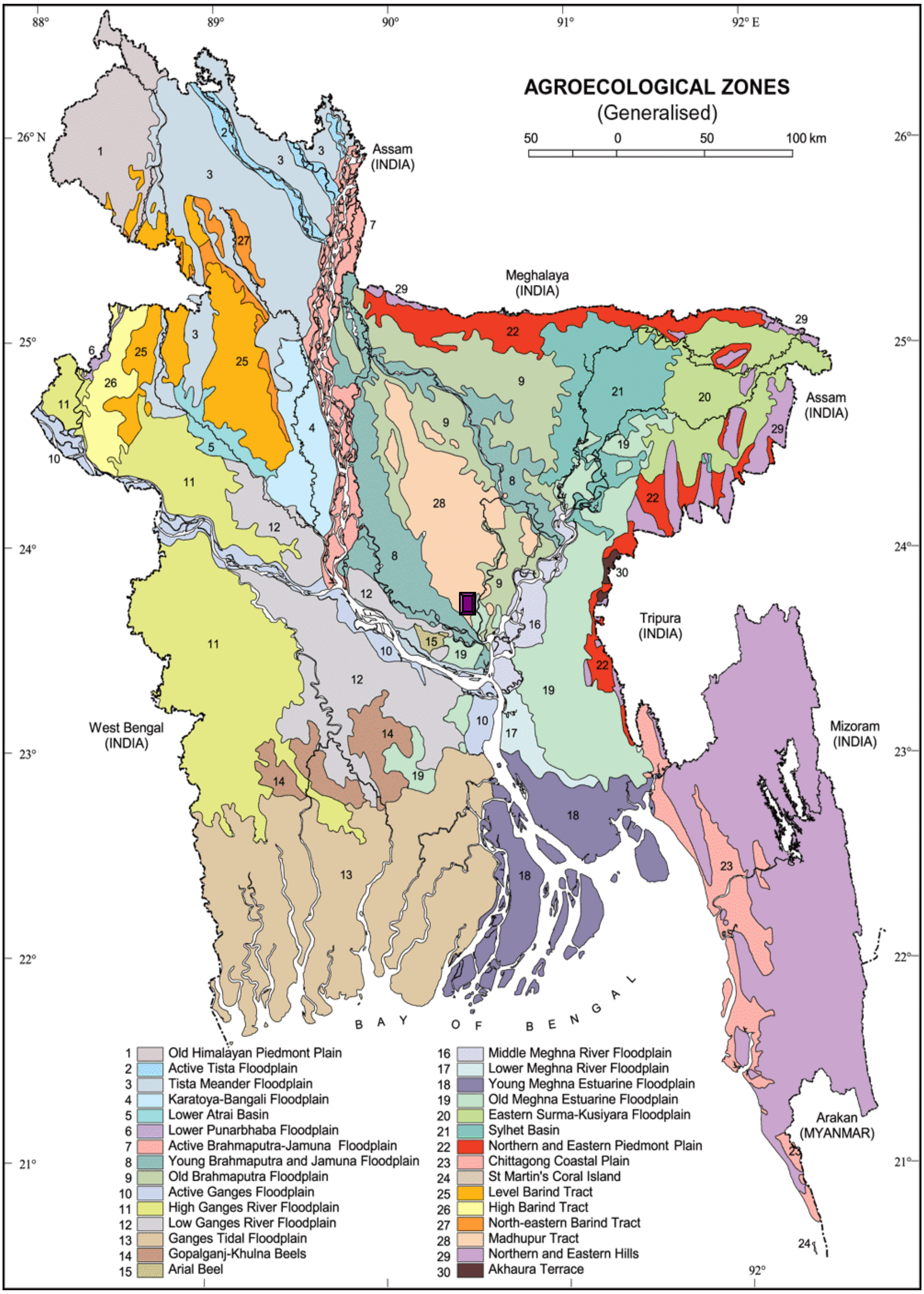
APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2015 to March 2016

Month	*Air temperature (ºc)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2015	25.8	16.0	78	00	6.8
December, 2015	22.4	13.5	74	00	6.3
January, 2016	24.5	12.4	68	00	5.7
February, 2016	27.1	16.7	67	30	6.7
March, 2016	31.4	19.6	54	11	8.2

* Monthly average, * Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1207

Appendix III. Analysis of variance of the data on yield contributing characters of garden pea as influenced by zinc and molybdenum

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm)	Number of branches/plant	Number of pods/plant	Pod length (cm)	Number of seeds/pod
Replication	2	1.338	0.013	0.338	0.141	0.058
Levels of zinc (A)	2	66.822**	0.324**	34.324**	2.271**	2.308**
Levels of molybdenum (B)	2	45.991*	0.444**	15.293*	1.604**	1.293**
Interaction (A×B)	4	37.264*	0.129*	25.098**	0.256*	0.314*
Error	16	9.913	0.037	3.318	0.147	0.148

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on weight of 100 seeds and yield of garden pea as influenced by zinc and molybdenum

Source of variation	Degrees of freedom	Mean square				
		Weight of 100 green seeds (g)	Weight of 100 mature seeds (g)	Pod yield/plant (g)	Green pod yield/hectare (ton)	Stover yield/hectare (ton)
Replication	2	7.146	0.014	0.034	0.026	0.020
Levels of zinc (A)	2	76.222	8.577	12.342**	2.588**	4.107**
Levels of molybdenum (B)	2	63.333	6.842	15.234**	1.202**	2.353**
Interaction (A×B)	4	59.000	5.945	11.892**	0.588*	1.092*
Error	16	57.324	5.404	3.452	0.187	0.283

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on pH, organic matter, total N, available P, exchangeable K and Zn and Mo of post harvest soil of garden pea as influenced by zinc and molybdenum

Source of variation	Degrees of freedom	Mean square						
		Soil pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (me%)	Available Zn (ppm)	Available Mo (ppm)
Replication	2	0.003	0.000	0.0001	0.568	0.0001	0.006	0.000
Levels of zinc (A)	2	0.091	0.013	0.00015	2.546	0.00018	0.699**	0.001
Levels of molybdenum (B)	2	0.022	0.012	0.00014	0.576	0.00019	0.0053	0.066**
Interaction (A×B)	4	0.001	0.001	0.00015	0.095	0.00016	0.0001	0.0004
Error	16	0.095	0.012	0.00013	2.114	0.00014	0.0060	0.0001

** Significant at 0.01 level of probability;