# GROWTH AND YIELD OF LENTIL AS INFLUENCED BY ZINC AND BORON MANAGEMENT

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# GROWTH AND YIELD OF LENTIL AS INFLUENCED BY ZINC AND BORON MANAGEMENT

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# CERTIFICATE

*This is to certify that the thesis entitled* **"GROWTH AND YIELD OF LENTIL AS INFLUENCED BY ZINC AND BORON MANAGEMENT"** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***AGRONOMY,*** *embodies the result of a piece of bona fide research work carried out by* ***Antar Kumar*** *Registration No.* ***19-10337*** *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 of during the course of this investigation has duly been acknowledged.*

**Dated:** **Prof. Dr. Parimal Kanti Biswas**

**Place:** Dhaka, Bangladesh **Supervisor**

# DEDICATED TO

# MY BELOVED PARENTS

## ABBREVIATIONS AND ACRONYMS

| | | |
|---|---|---|
| AEZ | = | Agro-Ecological Zone |
| ANOVA | = | Analysis of Variance |
| BARC | = | Bangladesh Agricultural Research Council |
| BARI | = | Bangladesh Agricultural Research Institute |
| BBS | = | Bangladesh Bureau of Statistics |
| BINA | = | Bangladesh Institute of Nuclear Agriculture |
| cm | = | Centimeter |
| CV % | = | Coefficient of Variation |
| DAS | = | Days After Sowing |
| e.g. | = | exempli gratia (L), for example |
| EC | = | Electrical conductivity |
| *et al.,* | = | And others |
| etc. | = | Etcetera |
| F | = | Fertilizer |
| FAO | = | Food and Agriculture Organization |
| g | = | Gram |
| ha | = | Hectare |
| i.e. | = | id est (L), that is |
| ICARDA | = | International Center for Agricultural Research in the Dry Areas |
| Kg | = | Kilograms |
| LSD | = | Least Significant Difference |
| m | = | Meter |
| MS | = | Master of Science |
| $m^2$ | = | Meter squares |
| µg | = | Microgram |
| mg | = | Milligram |
| No. | = | Number |

| | | |
|---|---|---|
| NPKS | = | Nitrogen, Phosphorus, Potassium and Sulphur |
| NS | = | Non-significant |
| % | = | Percentage |
| pH | = | Potential Hydrogen |
| ppm | = | Parts Per Million |
| R | = | Replication |
| RFD | = | Recommended Fertilizer Dose |
| SAU | = | Sher-e-Bangla Agricultural University |
| SRDI | = | Soil Resource and Development Institute |
| t | = | Ton |
| V | = | Variety |

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***The Author***

**GROWTH AND YIELD OF LENTIL AS INFLUENCED BY ZINC AND BORON MANAGEMENT**

## Abstract

A field experiment was conducted at Sher-e-Bangla Agricultural University during the period from November 2021 to March 2022 to evaluate the influence of micronutrient management on growth and yield of two lentil varieties viz. BARI Masur-8 ($V_1$) and Binamasur-8 ($V_2$) and 6 micronutrient management (No fertilizer - $F_1$, Recommended fertilizer dose (40-90-40-55 kg ha$^{-1}$ of urea-TSP-MoP-Gypsum) with Zn 10 kg $ZnSO_4$ ha$^{-1}$ as basal - $F_2$, RFD with Zn as foliar spray - $F_3$, RFD with Zn & B as foliar spray - $F_4$, 50 % RFD + 50 % cowdung (5 t ha$^{-1}$) - $F_5$ and 50 % RFD + 50 % cowdung + Zn & B as foliar spray - $F_6$). No significant effect had found for variety except 1000-seed weight but micronutrient management along with interactions significantly effects on all studied parameters of lentil. The higher 1000-seed weight (34.16 g) was recorded in BARI Masur-8. The highest plant height (37.09 cm), number of branches plant$^{-1}$ (7.03), dry weight of root plant$^{-1}$ (159.17 mg), dry weight of shoot plant$^{-1}$ (3319.33 mg) and number of pods plant$^{-1}$ (62.37) was observed at $F_6$ treatment. The highest number of nodules plant$^{-1}$ (2.83 at 60 DAS) and 1000-seed weight (31.68 g) were recorded at $F_2$ treatment. The highest weight of nodules plant$^{-1}$ (10.33 mg at 60 DAS), seed yield (2.62 t ha$^{-1}$), straw yield (2.12 t ha$^{-1}$) and biological yield (4.74 t ha$^{-1}$) were found at $F_3$ treatment. The highest plant height (38.45 cm), number of branches plant$^{-1}$ (7.40), number of pods plant$^{-1}$ (63.20), seed yield (2.91 t ha$^{-1}$) and harvest index (58.65 %) were recorded at $V_2F_6$ whereas the highest weight of nodules plant$^{-1}$ (26 mg), straw yield (2.22 t ha$^{-1}$) and biological yield (5.02 t ha$^{-1}$) were found at $V_1F_3$ but the highest 1000-seed weight (34.87 g) at $V_1F_1$. The highest number of seeds pod$^{-1}$ (1.83) was found at $V_2F_1$. So, the two studied varieties showed similar performance on yield. Foliar application of Zn has the potentiality to increase seed yield. Application of Zn is important for lentil cultivation. The variety Binamasur-8 with 50 % RFD + 50 % cowdung + Zn & B ($F_6$) as foliar spray could bring maximum yield (2.91 t ha$^{-1}$) of lentil that also similar with $F_2$, $F_3$ and $F_4$. Variety BARI Masur-8 gave the highest seed yield (2.79 t ha$^{-1}$) with $F_3$ that similar with $F_2$ and $F_5$.

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# Chapter I

# Introduction

# INTRODUCTION

Pulses are vital components in diversification of Bangladesh's predominantly rice-based cropping system. Lentil (*Lens culinaris* Medik) is an important source of nutritional security, protein content of 18-30 % and essential micronutrients, e.g. Fe, Zn, β-carotene for improving health of humans and domestic animals (Togay *et al.*, 2015 and Bhatty, 1988). About 6.3 million tons of lentil was produced in 2016 worldwide, while lentil in the Asia Pacific region covers more than 50 % of area cultivated globally and accounts for almost 50 % of world's lentil. Lentil area and production in Bangladesh was about 1.41 lakh ha and 1.77 metric tons with an average yield of 1.26 t $ha^{-1}$ which contributed about 35 % to the total pulses production in Bangladesh (BBS, 2021). Domestic pulse production satisfies less than half of the country's needs. The rest is imported at a huge cost per annum. The huge demand and demand gap of the crop should make up by increasing domestic production which can be achieved through judicious nutrient management in already depleted soils (BARC, 2018).

Zinc deficiency in humans has emerged as a pressing global concern and requires immediate attention (McLean *et al*., 2009; Wessells and Brown, 2012). Hence, adequate zinc intake is imperative for maintaining good health in humans. Approximately 17.3 % of the global population and 30 % of South Asians suffers from inadequate Zn intake. An additional 175 million people globally, including 63 million in South Asia are expected to become Zn deficiency by 2050 (Smith and Myers, 2018).

Zinc and Boron deficiency is widespread in the country; much observed in wetland rice soils, light textured soils and calcareous soils (Jahiruddin *et al*., 1992; Rahman *et al*., 1993; Islam *et al*., 1997). Singh and Bhatt (2013) also reported that micronutrients required in small amount but contributed significantly on seed yield of lentil (16.2 %) by increasing the growth and uptake of nutrients. Combined use of different micro- and macronutrients can augment seed yield by 55 to 60 %, of which 20 to 25 % could be ascribed to the micronutrients (Islam *et al*., 2018). Hossain *et al*. (2020) reported the highest nutrient uptake, maximum nodulation (at 68 days after sowing, 63.5 $plant^{-1}$) and the highest protein content (26.6 %) in seed from the micronutrients (Zn, B, Mo) application in lentil. The main reason for soil Zn deficiency is the intensification of cropping systems by rice and lack of application of organic inputs over the past decades.

In South Asia, Zn deficiency is the second most yield-limiting nutrient deficiency after nitrogen in lowland rice (Read *et al*., 2019). Basal application of Zn incorporated in the soil before the last puddling or after transplanting is the most common practice however the foliar Zn application increased Zn concentration of grain and has the benefit of reducing the phytic acid content of the grain by inhibiting the conversion of inorganic phosphorus to phytic acid (Chamak, 2008) and therefore increases Zn bioavailability up to 65% in polished rice (Wei *et al*., 2012). Various studies have shown that a combination of soil and foliar application has resulted in both high yield and high grain Zn concentrations compared to soil or foliar application alone.

Foliar application of micronutrients was 6 to 20 times more useful than the soil application and improves the nutrition (Arif *et al.,* 2006). Foliar application of Zn reduces the micronutrient deficiencies and it was an efficient method because nutrients are easily absorbed through leaves and is best option to compensate micronutrient deficiencies in shorter period of time under rainfed regions (Nasiri *et al.,* 2010). Combined application of Zn and B significantly increased the plant height, root length, leaf area index, shoot and root dry weight and chlorophyll content (Panhwar *et al.,* 2011). Therefore, this field study was designed to evaluate the response of Zn and B application alone and in combination in improving productivity of lentil. This study was undertaken with the following objectives:

1. To compare the yield and other attributes of two lentil varieties
2. To determine the effect of Zn and B on lentil yield
3. To find out the interaction of variety and micronutrient (Zn & B) management on growth and yield of lentil.

# Chapter II

# Review of Literature

# REVIEW OF LITERATURE

In this chapter, an attempt has been made to review the available information regarding the influence of Zinc and Boron response, different nutrient sources on nodulation, growth and yield of lentil. The review of literature includes reports as studied by several investigators who were engaged in understanding the problems that may help in the explanation and interpretation of results of the present investigation.

## 2.1 Lentil

Lentil is an important legume crop that plays a significant role in nutritional security of our growing population. Lentil seed is an excellent source of Fe (73-90 mg $kg^{-1}$), Zn (44-54 mg $kg^{-1}$), and Se (425-673 µg $kg^{-1}$) compared with other grain legumes and cereals (Ray *et al.,* 2014; Thavarajah *et al.*, 2011). It is also a good source of protein, vitamins, and dietary fiber. All these benefits increase the importance of lentil in our diet to combat human micronutrient malnutrition globally. Moreover, the higher protein percentage makes lentils an important and more affordable plant-based substitute for animal protein.

The variety of BARI Masur-8 is known for its stable and high yield. Seed sowing date is up to the last week of November. Plant height is 50-55 cm. Seed size is larger and seed color is reddish brown. Thousand seed weight is 22-23 g. Crop duration is 110-115 days. The seed yield of BARI Masur-8 is 2.2-2.3 t $ha^{-1}$ (BARI, 2017). It is rich in Fe (72- 75 ppm) and Zn (58-60 ppm), important nutritional qualities essential to combat micronutrient malnutrition, ‘the hidden hunger’. It also provides combined resistance to stem phylium blight and rust (ICARDA, 2015). This is a big assurance for farmers since stem phylium blight is a serious threat to lentil throughout South Asia (Bangladesh, Nepal and eastern Indian states).

The variety of Binamasur-8 is known for high yield variety. Seed sowing date is up to the last week of November. It is disease tolerant, early ripening variety. The variety is cultivated in all kind of soil but sandy loam soil is better. It is also cultivated as rely crop. Plant height of the variety is 32- 38 cm. The leaves turn straw color during maturity seed color is deep brown and cotyledons are bright orange. It has a 1000-seed weight is 23-25 g. The duration of this crop is 95-100 days. Its yield is 1800-2200 kg $ha^{-1}$ (BINA, 2014).

## 2.2 Effect of variety on lentil production

Lentil variety of BARI Masur-8 matures in 115-120 d and fits well into existing rice-based cropping patterns. It is a medium-height (35 cm) and medium-seeded (1.94 g $100^{-1}$ seed) cultivar having a high level of tolerance to wilt (*Fusarium oxysporum* f. sp.) and root rot diseases. Lentil variety of BARI Masur-8 showed high yield potential (1973 kg $ha^{-1}$) and high concentrations of Fe (74 mg $kg^{-1}$), Zn (61 mg $kg^{-1}$), and Se (325 μg $kg^{-1}$) in seed (Zaman *et al*., 2022). The performance of Binamasur-8 is the best for maximizing seed yield with short maturity period. Lentil variety of Binamasur-8 produced 2.37 t $ha^{-1}$ yields with 88 maturity days. Among all the BINA developed lentil varieties Binamasur-8 was found pioneer followed by Binamasur-5 in respect of seed yield with earliest maturity period (Khatun *et al*., 2021).

## 2.3 Role of micronutrient management

The pulse crop yield status in Bangladesh is generally low. There are so many reasons for low yield. Plant nutrients like Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Calcium (Ca), and Magnesium (M) deficiency, among them, is an important factor, especially micronutrients like Zn and B. The extent and magnitude of nutrient deficiency has aggravated in the recent past due to intensive agriculture and indiscriminate use of plant nutrients (Anonymous, 2009).

### 2.3.1 Role of zinc in plant

The Zn plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome (Tisdale *et al*., 1994). Seven plant enzymes activated by Zn are involved in carbohydrate metabolism, maintenance of the intuit of cellular membranes, protein synthesis, regulation of auxin synthesis and pollen formation (Marschner, l995). The regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants are Zn dependent (Cakmak, 2000). Its deficiency results in the development of abnormalities in plants which become visible as deficiency symptoms such as stunted growth, chlorosis and smaller leaves, spikelet sterility. Micronutrient Zn deficiency can also adversely affect the quality of harvested products; plants susceptibility to injury by high light or temperature intensity and to infection by fungal diseases can also increase (Marschner, 1995). Zinc seems to affect the capacity for water uptake and transport in plants and also reduce the adverse effects of short periods of heat and salt stress (Kasim, 2007). As Zn is required for the synthesis of tryptophan which is a precursor of IAA, it also has an active role in the production of an essential growth hormone auxin (Alloway, 2004). The Zn is required for integrity of cellular membranes to preserve the structural orientation of macromolecules and ion transport systems. Its interaction with phospholipids and sulphydryl groups of membrane proteins contributes for the maintenance of membranes (Tavallali *et al*., 2010). Zn is one of the essential plant nutrients that functions in diverse metabolic, regulatory, and developmental processes (Broadly *et al*., 2007). Apart from being a constituent of Zn-metalloenzymes, Zn flinctions as a constituent of several regulatory proteins like the Zn finger ones that interact with DNA and control gene expression (Liu *et al*., 2005). Zn plays an important role in plant-reproductive development for initiation of flowering, floral development, male and female gametogenesis, fertilization, and seed development. Even under marginal Zn deficiency condition, the development of anthers in wheat is severely retarded (Sharma *et al*., 1990). Pandey *et al*. (1995) reported that Zn deficiency induced a change in exine morphology and reduced pollen viability. Zn deficiency has also been shown to change stigmatic size, morphology, and exudations, inhibiting pollen-stigma interaction (Pandey *et al*., 2006; 2009b). It was recently documented that Zn foliar application is a simple way for making quick correction of plant nutritional status, as reported for maize (Grzebisz *et al*., 2008) and green gram (Pathak and Pandey, 2010). Most researches on Zn foliar application focused on alleviating its deficiency, particularly on wheat and maize cultivated in semiarid regions of the world (Cakmak, 2008; Potaezycki and Grzebisz, 2009). They explored the effect of Zn foliar application on the reproductive development of chickpea with a view to assess its effect on pollen stigma interaction and on the Zn content in seeds for improved dietary intake by human.

Oktem (2019) conducted a study aimed to determine the effects of different zinc (Zn) levels on the grain yield and some phenological characteristics of the F.rat-87 red lentil variety (*Lens culinaris* Medik.). The F.rat-87 lentil variety and Zn sulfate ($ZnSO_4.7H_2O$) were used as the plant material and Zn source, respectively. The Zn levels used were the control (0 kg $ha^{-1}$ Zn), 5 kg $ha^{-1}$Zn, 10 kg $ha^{-1}$ Zn, 15 kg $ha^{-1}$ Zn, 20 kg $ha^{-1}$ Zn, and 25 kg $ha^{-1}$ Zn. The Zn levels were significant for the harvest index, 1000-kernel weight, protein rate, and grain yield. All of the tested characteristics were positively affected by increasing applications of Zn. The grain, leaf, and soil Zn contents were higher with increasing levels of Zn. Although the highest grain yield was at 15 kg $ha^{-1}$ Zn, according to the regression analysis, the optimum Zn level was 17 kg $ha^{-1}$ Zn. However, the economic Zn level was determined as 15 kg $ha^{-1}$ Zn.

Singh and Bhatt (2013) were conducted a field experiment to develop zinc management strategy for late sown lentil (*Lens culinaris* Medik) crop alone or in cropping system. Four levels of Zn, viz. $Zn_1$ control (0.0 %), $Zn_2$ (0.02 %), $Zn_3$ (0.04 %), $Zn_4$ (0.08 %) were applied as foliar twice (first at pre-flowering and second at post podding stage). Highest (42.2 cm) and lowest (32.8 cm) plant height at harvest was recorded with application of 0.08 % Zn and in control treatment. Longest (12.1cm) and shortest (7.9cm) root was recorded in the plots treated with 0.08 % Zn and control respectively. Zn treatment (0.04 %) produced maximum lentil seed (1238.6 kg $ha^{-1}$), whereas lowest (1063.1 kg $ha^{-1}$) was recorded under control. Highest nitrogen concentration (1.98 per cent) and N uptake (55.7 kg $ha^{-1}$) was recorded in plots fertilized with Zn applied @ 0.08 %. Gradual buildup of organic carbon, N, P and K and zinc content in the soil were also noticed. It is recommended that under late sown condition foliar feeding with 0.04 % Zn twice during pre-flowering and post podding stage will increase lentil seed yield by 16.2 %.

### 2.3.2 Role of boron in plant

Boron is necessary for growth of new cells. Without adequate supply of boron, the number and retention of flower reduces and pollen tube growth is less; consequently, less fruits are developed (Miller and Donahue, 1997).

Boron plays a vital role in physiological process of plants such as cell maturation, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolism, cytokinin synthesis, acid and phenol metabolisms. The functions of Boron are primarily extra-cellular and related to lignifications and xylem differentiation (Lewis, 1980), membrane stabilization (Pilbeani and Kirkby, 1983) and alteration of enzymatic reactions (Dugger, 1983).

Boron has direct and indirect effect on fertilization. Indirect effects are related to the increase in amount and change in sugar composition of the left nectar, whereby the flowers of species that rely on pollinating insects become more attractive to insects (Smith and Johnson, 1969: Drikson, 1979). Direct effects of B are reflected by the close relationship between B supply and pollen producing capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al*., 1981). Boron is also essential for sugar translocation. So, it affects in carbon and nitrogen metabolism of plants (Jackson and Chapman, 1975).

The effect of boron on the development of the pollen grain of wheat was studied by Li *et al*. (1978) and Rerkasem *et al*. (1989b). The process of fertilization involves the germination of the pollen grain and the growth of the pollen tube down the style into the ovary. In general, boron shortage produces pollen grains that are small and that do not build up starch. Pollens that develop normally may still be affected by boron deficit (Vaughan, 1977; and Cheng and Rerkasem, 1993).

Some plant species have a low boron (B) requirement and may also be sensitive to elevated B level even only slightly above those needed for normal growth. Therefore, toxic effect of B is caused by unnecessary use of B fertilizers (Gupta, 1979). There was a special boron demand for pollen tube growth, in which callose formed at the pollen-style "invasion" was physiologically inactivated by the development of borate-callose complexes (Lewis, 1980).

Rerkasem *et al*. (1993) also opined that extra boron was needed to maintain efficient oxidation of phenols formed in the "inversion" of the style by germination of pollen tube.

Cheng and Rerkasem, (1993) reported that wheat growing in the low boron soils exhibited symptoms of male sterility, which included poorly developed anthers and nonviable pollen grains. Grain set failure lower seed yield and male sterility symptoms were associated with low boron concentration in the flag leaf. Failure in grain set up to 100 % of florets was frequently observed. They also reported that poor grain set in wheat depressed seed yield by 40- 50% on soils having low boron content (0.08- 0.12 mg $kg^{-1}$).

Adhikary *et al*. (2018) conducted a field experiment to assess the effect of foliar applications of Boron on growth, yield attributing characters and yield of lentil, cv. Moitree (WBL-77). Results revealed that grain yield increased significantly with foliar application of Boron in to 3 splits (at 15, 40 DAS and at flower initiation stage), along with soil application of NPK over control. Application of boron recorded 26.98 % higher seed yield than soil application of sole NPK fertilizers. The maximum plant height (38.86 cm), pods $plant^{-1}$ (45.40), seed yield (11.34 q $ha^{-1}$) and BCR (2.06) were recorded in soil application of NPK along with 0.5 % foliar application of Boron in to 3 splits i.e. at 15, 40 DAS and at flower initiation stage.

Khurana and Arora (2012) studied the response of boron from two sources (borax and granular) and reported that the application of 0.75 kg B $ha^{-1}$ through borax and granular increased lentil seed yield by 21.4 and 23.3 %, respectively, over control indicating 2 % higher response with granular application. Boron content in lentil seed increased from 12.2 micro g $g^{-1}$ in control treatment to the maximum of 24.1 µg $g^{-1}$ with the application of 1.25 kg B $ha^{-1}$ through granular. There was 24.6 % increase in seed yield of soybean with the application of 1.25 kg B $ha^{-1}$ through either of fertilizer source. Total B content increased to maximum of 59.8 % over control when B was applied through borax.

Chakraborty (2009) conducted field experiments to study the effect of B and Mo to the growth, and yield of lentil grown on inherently poor lateritic soil. The lentil (cv. B77) was raised with application of B and Mo either separately or in mixture through foliage or to soil along with NPK fertilizers. The leaf area index, above ground dry matter and crop growth rate increased with the application of B and Mo. Soil application of B coupled with foliar application of Mo enhanced the yield attributing characters and yield of the lentil crop. The study indicated that growing of lentil in lateritic soils depleted the nutrients particularly micronutrients which resulted in loss of yield and could be recovered, if the relevant micronutrients are supplemented through appropriate application methods and dosage.

**2.3.3 Combined effect of B and Zn**

Karan *et al*. (2019) conducted a field experiment to study the response of lentil cultivars on yield and nutrient balance in the soil in relation to various levels of Z and B. Results revealed that lentil cultivar PL 639 produced significantly highest grain, straw and biological yield of lentil than the other cultivars of lentil. Grain, straw and biological yield of lentil was significantly increased with the application of 1 kg B $ha^{-1}$ than control. Highest available nutrient viz., N, P, K, S, Zn and B in the soil showed increasing trend with lentil cultivar in sequence in DPL 62< K 75 < PL 406 < PL 639 after two consecutive crop seasons. The contents of available N, K, Zn and B in the soil showed increasing trend while available P and S showed decreasing trend with the increasing levels of zinc. Highest available N, P, K, S, Zn and B in the soil was restored more in 1 kg B/ha applied plot, however, minimum available N, P, K, S, Zn and B in the soil was obtained in control. Hence, application of zinc @ 8-10 kg and boron @ 1 kg $ha^{-1}$ is recommended for sustainable lentil production.

Saha *et al*. (2018) conducted a field experiment to study the effect of B and Zn on growth, yield and economics of 'Moitree' lentil (*Lens culinaris* Medik.). Two micronutrients, viz. boron (B) and zinc (Zn), with variations in method and time of applications had significant effect on plant height, dry-matter (DM) production, and crop- growth rate (CGR) throughout the cropping season. The crop treated with recommended dose of fertilizer (RDF) + soil application of B @ 1.0 kg $ha^{-1}$) resulted in the highest aerial dry matter yield (132.7 $gm^{-2}$) at 75 days after sowing (DAS) and crop-growth rate (3.23 g $m^{-2}$ $day^{-1}$) between 46 and 75 DAS compared to the other treatments. Although the foliar spray of both B @ 0.1 % and Zn @ 0.25 % twice at 40 and 60 DAS recorded the highest number of pods $plant^{-1}$ (102.2) and seed yield (1.21 t $ha^{-1}$), single spraying of B @ 0.1 % at 40 DAS to lentil recorded moderate yield (1.15 t $ha^{-1}$), maximum net return (27,009 $ha^{-1}$) and benefit: cost ratio (1.86).

Quddus *et al*. (2014) was conducted to evaluate the effect of B and Zn on the yield and yield contributing characters of lentil (*Lens culinaris* Medik.) and to estimate the optimum dose of Zn and B for yield maximization. There were 16 treatment combinations comprising four levels each of Zinc (0, 1.0, 2.0 and 3.0 kg $ha^{-1}$) and Boron (0, 0.5, 1.0 and 1.5 kg $ha^{-1}$) along with a blanket dose of $N_{20}$ $P_{16}$ $K_{30}$ $S_{10}$ kg $ha^{-1}$ were used. Results showed that the combination of $Zn_{3.0}B_{1.5}$ produced significantly higher seed yield (1156 kg $ha^{-1}$). The lowest seed yield (844 kg $ha^{-1}$) was found in control ($Zn_0B_0$) combination. The combined application of zinc and boron were superior to their single application. Therefore, the combination of Zn and B may be considered as suitable dose for lentil cultivation in Bangladesh. But from regression analysis, the optimum treatment combination was $Zn_{2.85}$ and $B_{1.44}$ for Madaripur, Bangladesh.

**2.4 Micronutrient content in soil**

**2.4.1 Zinc status in soil**

Zinc is a micronutrient since it is required relatively to a smaller amount than macronutrients. The forms of zinc in soils are: solution zinc absorbed $Zn^{2+}$ (on clay surfaces, organic matter, carbonates and oxide minerals) organically complexes $Zn^{2+}$ and $Zn^{2+}$ substituted for $Mg^{2+}$ in the crystal lattices of clay minerals. The range in maximum zinc absorption by different soils as 60 to 70 µg $g^{-1}$ for Ca- saturated samples. However, in natural vary in acid soils (pH<4.0), zinc combination in solution was reported to be on an average 7.131 g $L^{-1}$ (Itoh *et al*., 1978).

**2.4.2 Boron status in soil**

Boron can be found in four forms in the soil are $H_3BO_3$, $H_2BO_3^-$, $HBO_3^-$ and $BO_3^{3-}$. These are the plant available forms of the nutrient. The total B content of soils lies between 20 to 200 $\mu gg^{-1}$ with the available (hot water soluble) B fraction ranging from 0.4 to 0.5 $\mu gg^{-1}$ (Gupta, 1979). It occurs in soil mainly as undissociated $H_3BO_3^-$ . Plants absorb B primarily in the form of HB032. This may be the main reason why B is leached so easily from soil. Plants absorb B primary in the form of $HBO_3^{2-}$ and to smaller extent as $H_2BO_3^-$, $BO_3^{3-}$.

### 2.5 Micronutrient deficiency symptoms

#### 2.5.1 Symptoms of Zn deficiency in plant

Interveinal chlorosis, stunted growth, little leaf, rosette of plants and isolated red points are found on leaves (Nambiar and Motiramani, 1981).

#### 2.5.2 Symptoms of B deficiency in plants

The deficiency symptoms of some B sensitive crops like Lycopersicon. Brassica, legumes and fruit plants are chlorosis and browning of young leaves, lesion in pith and roots. B deficient stems and leaves were found to be brittle while B deficient leaves and stems are flaccid (Dunn *et al*., 2005).

# Chapter III

# Materials and Methods

# MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2021 to April 2022. Detailed of the experimental materials and methods followed in the study are presented in this chapter. The experiment was conducted to study the influence of variety, micronutrient and their methods of interactions on nodulation, growth and yield of lentil.

## 3.1 Site description

### 3.1.1 Geographical location

The experimental area was situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004) (Appendix I).

### 3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ 28. This was a region of complex relief and soils developed over the Modhupur clay, where flood plain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as islands surrounded by floodplain (Appendix I).

### 3.1.3 Climate

This area characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March) as it is sub-tropical climate.

### 3.1.4 Soil

Soil pH ranged from 5.6-6.5 and had organic matter 1.10-1.99 %. The soil of the experimental site belongs to the general soil type, shallow red brown terrace soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. The experimental area was flat having available irrigation and drainage system and above flood level.

### 3.2 Details of the experiment

The experiment was conducted at Sher-e-Bangla Agricultural University farm in a split-plot design (Appendix II).

#### 3.2.1 Treatments: 12

Main plot (Variety): 2

i. BARI Masur-8 ($V_1$)
ii. Binamasur-8 ($V_2$)

Sub-plot (Micronutrient management): 6

i. Control (No fertilizer) - $F_1$
ii. Recommended fertilizer dose (40-90-40-55 kg $ha^{-1}$ of urea-TSP-MoP-Gypsum) with Zn 10 kg $ha^{-1}$ $ZnSO_4$ as basal - $F_2$
iii. RFD with Zn as foliar spray - $F_3$
iv. RFD with Zn & B as foliar spray - $F_4$
v. 50 % RFD + 50 % cowdung (5 t $ha^{-1}$) - $F_5$
vi. 50 % RFD + 50 % cowdung (5 t $ha^{-1}$) + Zn & B as foliar spray - $F_6$

Treatment Combination: $V_1F_1$, $V_1F_2$, $V_1F_3$, $V_1F_4$, $V_1F_5$, $V_1F_6$, $V_2F_1$, $V_2F_2$, $V_2F_3$, $V_2F_4$, $V_2F_5$, $V_2F_6$

#### 3.2.2 Experimental design and layout

The experiment was laid out in a split-plot design with three replications. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was (4.5 m × 2 m). The distances between plot to plot and replication to replication were 0.50 m and 0.75 m, respectively.

## 3.3 Crop/Planting material

BARI Masur-8 and Binamasur-8 were used as planting material.

### 3.3.1 Description of variety

**BARI Masur-8**

Lentil variety BARI Masur-8 was used as experimental material. BARI Masur-8 was developed by Bangladesh Agricultural Research Institute (BARI), Gazipur. The line was selected on the 18 basis of yield, disease tolerant, late ripening etc. The variety is cultivated in all kind of soil but randy loam soil is better. It is also cultivated as rely crop. Plant height of the variety is 32- 38 cm. The leaves turn straw color during maturity seed color is deep brown & cotyledons are bright orange. The 1000-seed weight is 25-28 g. The duration of this crop is 110-115 days. It yields 1800-2300 kg $ha^{-1}$.

**Binamasur-8**

Lentil variety Binamasur-8 was used as experimental material. Binamasur-8 was developed by Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. The line was selected on the 18 basis of yield, disease tolerant, early ripening etc. The variety is cultivated in all kind of soil but randy loam soil is better. It is also cultivated as rely crop. Plant height of the variety is 32- 38 cm. The leaves turn straw color during maturity seed color is deep brown & cotyledons are bright orange. The 1000-seed weight is 23-25 g. The duration of this crop is 95-100 days. It yields 1800-2200 kg $ha^{-1}$.

## 3.4 Crop management

### 3.4.1 Seed collection

Seeds of BARI Masur-8 were collected from BARI, Joydebpur, Gazipur, Bangladesh and seeds of Binamasur-8 were collected from BINA, Mymensingh.

### 3.4.2 Seed sowing

Seeds were sown in the field on 24 November, 2021. The field was labeled properly and was divided into 36 plots. The seeds of BARI Masur-8 and Binamasur-8 were sown by hand in 30 cm apart from lines with continuous spacing at about 3 cm depth at the rate of 45 g $plot^{-1}$ on 24 November, 2021.

### 3.4.3 Preparation of experimental land

A pre-sowing irrigation was given on November 22, 2021. After that the land was open with the help of a tractor drawn disc harrow, then ploughed with rotary plough twice followed by laddering to achieve a medium tilt required for the crop under consideration. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on November 23, 2021 according to experimental specification. Individual plots were cleaned and finally prepared the plot.

### 3.4.4 Fertilizer application

The recommended chemical fertilizer managements were 45 kg $ha^{-1}$ urea, 90 kg $ha^{-1}$ TSP, 40 kg $ha^{-1}$ MoP, 55 kg $ha^{-1}$ Gypsum ($CuSO_4.2H_2O$), 10 kg $ha^{-1}$ $ZnSO_4$ and 10 kg $ha^{-1}$ Boric Acid respectively. All the fertilizers as per treatment were mixed with soil thoroughly at the time of final land preparation after making plot. The cow dung was used @ 5 t $ha^{-1}$ as per treatment. The foliar application of zinc and boron was applied during flower initiation.

### 3.4.5 Intercultural operations

#### 3.4.5.1 Thinning

The plots were thinned out on 15 days after sowing to maintain a uniform plant stand which facilitates proper aeration and light for optimum growth and development of the crops.

#### 3.4.5.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done, first weeding was done at 15 days after sowing followed by second weeding at 15 days after first weeding.

#### 3.4.5.3 Irrigation

Irrigation water was given to each plot, first irrigation as pre-sowing and other two irrigations 3 days before weeding.

#### 3.4.5.4 Drainage

Drainage channel were properly prepared to easy and quick drained out of excess water.

#### 3.4.5.5 Protective measures

The crop was infested by insects and diseases, those were effectively and timely controlled by applying recommended insecticides and fungicides. Rovral 50 wp @10 g 5 $L^{-1}$ for using as protection of *Fusarium sp*.

### 3.4.6 Harvesting and post-harvest operation

Maturity of crop was determined when 80-90 % of the pods become straw color. The harvesting of Binamasur-8 was done up to 9 March, 2022 and BARI Masur-8 12 March, 2022. Five pre-selected plants $plot^{-1}$ were harvested from which different yield attributing data were collected. Middle portion of each plot (2 $m^2$) was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording seed and straw yield. The seeds were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally seed, husk and straw yields $plot^{-1}$ were determined and converted to kg $ha^{-1}$.

### 3.4.7 Recording of data

Plant height and branches $plant^{-1}$ data were determined from 30 days of growth duration and continued until harvest having 25 days interval. Dry weights of plant were collected by harvesting respective number of plants at 30, 60 and 90 DAS from the inner rows leaving border rows and harvest area for grain. The following data were recorded during the experimentation.

**A. Crop growth characters**

i. Plant height (at 30, 55, 80 DAS and at harvest)
ii. Number of branch plant$^{-1}$ (at 30, 55, 80 DAS and at harvest)
iii. Dry weight of root plant$^{-1}$ (at 30, 60 and 90 DAS)
iv. Dry weight of shoot plant$^{-1}$ (at 30, 60 and 90 DAS)
v. Number of nodule plant$^{-1}$ (at 60 and 90 DAS)
vi. Nodule weight plant$^{-1}$ (at 60 and 90 DAS)

**B. Yield and other crop characters**

i. Number of pods plant$^{-1}$
ii. Length of pods plant$^{-1}$
iii. Number of seeds pod$^{-1}$
iv. 1000-seed weight
v. Seed yield
vi. Straw yield
vii. Biological yield
viii. Harvest index

**3.4.8 Detailed procedures of recording data**

A brief outline of the data recording procedure followed during the study given below:

**A. Crop growth characters**

**3.4.8.1 Plant height**

The height of 5 randomly selected plants from each plot for every treatment of all three replications was taken carefully at harvest and after 30, 55, 80 days after sowing and at harvest of two varieties. Plant height was measured from the above ground portion to the tip of the plants.

**3.4.8.2 Number of branches plant$^{-1}$**

The number of branches plant$^{-1}$ were counted carefully from 5 randomly selected plants from each plot for every treatment of all three replications when it became 30, 55 and 80 days after sowing and at harvest.

#### 3.4.8.3 Number of nodules plant$^{-1}$

The nodules plant$^{-1}$ were counted carefully from 5 randomly selected plants from each plot uprooted for every treatment of all three replications when it became 60 and 90 DAS and then averaged.

#### 3.4.8.4 Dry weight of roots plant$^{-1}$

Five randomly selected plants from each plot were harvested at 30, 60 and 90 days after sowing. Then the roots were separated from the plants and dried properly by oven (above 72 hours) and individual root weight was taken to make them average for each treatment.

#### 3.4.8.5 Dry weight of shoot plant$^{-1}$

Five randomly selected plants from each plot were harvested at 30, 60 and 90 days after sowing. Then the shoots were separated from the plants and dried properly by oven (above 72 hours) and individual shoot weight was taken to make them average for each treatment.

#### 3.4.8.6 Nodules weight plant$^{-1}$

Five randomly selected plants from each plot were uprooted after 60 and 90 days after sowing. Then the nodules were separated from the roots and dried properly by oven (above 72 hours) and individual nodule weight was taken to make them average for each treatment.

### B. Yield and yield contributing characters

#### 3.4.9.1 Pods plant$^{-1}$

The pods of ten pre-selected plants were collected from each plot at the time of harvest and then counted total number and then averaged them for pods plant$^{-1}$.

#### 3.4.9.2 Pod length plant $^{-1}$

The pods of ten pre-selected plants were collected from each plot at the time of harvest and then determined each pod length and then averaged them for pod length.

#### 3.4.9.3 Seeds pod$^{-1}$

Ten preselected pods were collected from each plot at the time of harvest and then counted seeds of each pod and then averaged them for seeds pod$^{-1}$.

#### 3.4.9.4 1000-seed weight

Thousand seeds from of each plot were collected and their weights (g) were taken by digital electric balance.

#### 3.4.9.5 Seed yield

Grains of 2 $m^2$ area in each plot was weighed and converted into t ha$^{-1}$. The grain weight was taken at 12% moisture content of the grains.

#### 3.4.9.6 Straw yield

Straw of central 2 $m^2$ area in each plot was sun dried and weighed. Then the weight was converted in t ha$^{-1}$.

#### 3.4.9.7 Biological yield

Biological yield was calculated by adding the grain yield and straw yield. Biological yield = Grain yield + Straw yield.

#### 3.4.9.8 Harvest index

Harvest index denotes the ratio of economic yield (seed yield) to biological yield and was calculated with following formula.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

#### 3.4.9.9 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique using statistical computer software CropStat and the means were adjudged at 0.05% level of significance by LSD.

# Chapter IV

# Results and Discussion

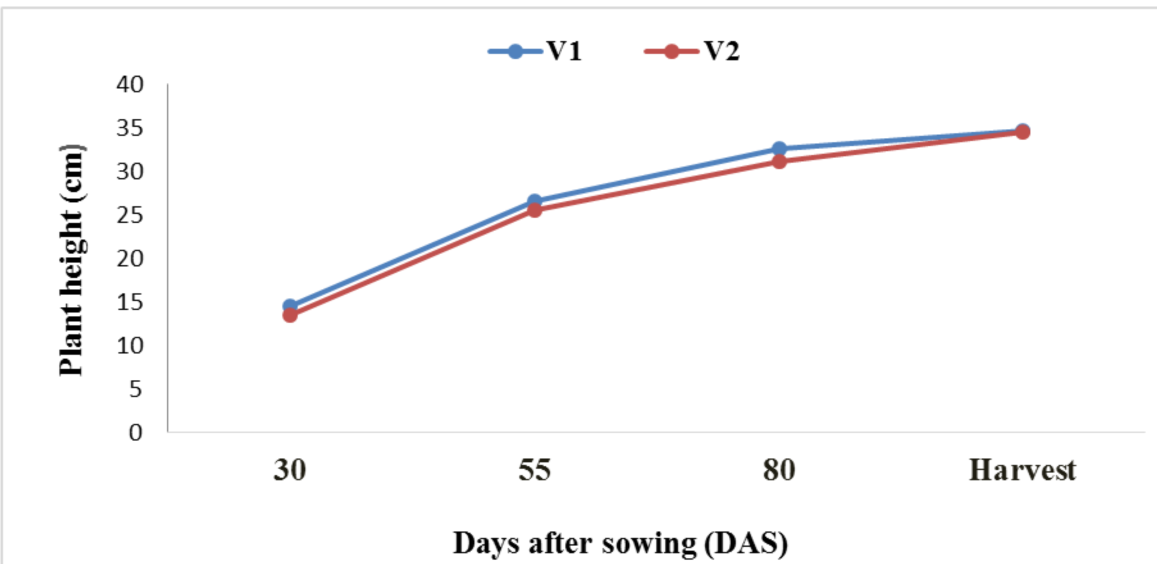
# RESULTS AND DISCUSSION

The experiment was conducted to find out the influence of variety and micronutrient management on growth and yield of lentil. The analyses of variance (ANOVA) of the data on different parameters are also given in the appendices. The results have been presented and discussed with interpretations have been given under the following headings:

## 4.1 Plant height

### 4.1.1 Effect of variety

There were no significant variations of plant height recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 1 and Appendix III). At 30 DAS, the numerically maximum plant height (14.44 cm) was given by BARI Masur-8 and the plant height (13.47 cm) was given by Binamasur-8. Similar trend of plant height also observed at 55, 80 DAS and at harvest. At harvest, the numerically maximum plant height (34.57 cm) was given by BARI Masur-8 and the plant height (34.51 cm) was given by Binamasur-8. The plant height of BARI Masur-8 at harvest was almost same with the findings of Zaman *et al*. (2022) but the plant height of Binamasur-8 at harvest was lower than the findings of Khatun *et al.* (2021).

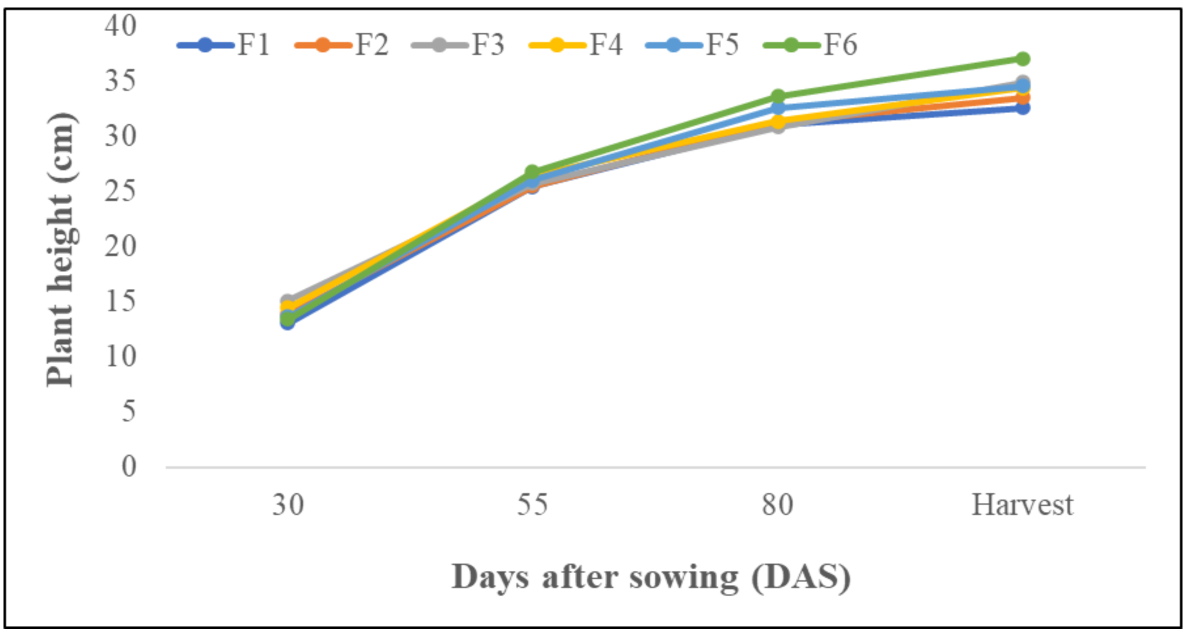



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 1.** Plant height of lentil as influenced by variety.

### 4.1.2 Effect of micronutrient management

The plant height of lentil was significantly influenced by fertilizers (Figure 2 and Appendix III) at 30, 80, and at harvest except 55 DAS. At 30 DAS, the highest plant height (15.14 cm) was recorded from $F_3$ which was statistically similar to $F_2$ (13.92 cm), and $F_4$ (14.46 cm) and the lowest plant height (13.11 cm) was recorded from $F_1$ which was statistically similar to $F_5$ (13.65 cm) and $F_6$ (13.46 cm). At 55 DAS, the numerically maximum plant height (26.81 cm) was recorded from $F_6$ and minimum plant height (25.48 cm) was recorded from $F_{1.}$ At 80 DAS, the highest plant height (33.70 cm) was recorded from $F_6$ which was statistically similar to $F_5$ (32.60 cm), $F_4$ (31.40 cm), $F_2$ (31.27 cm) and $F_1$ (31.12 cm) and the lowest plant height (30.90 cm) was recorded from $F_3$. At harvest, the highest plant height (33.70 cm) was recorded from $F_6$ which was statistically similar to $F_5$ (32.60 cm), $F_4$ (31.40 cm), $F_2$ (31.27 cm) and $F_1$ (31.12 cm) and the lowest plant height (32.60 cm) was recorded from $F_1$ which was statistically similar to $F_2$ (33.53 cm). Quddus *et al.* (2014) also found maximum plant height (29.1 cm) at harvest with $Zn_{1.0}B_{1.5}$ (kg $ha^{-1}$) combination which was much lower than our findings.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 2.** Plant height of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ at 30, 80 DAS and at harvest = 1.425, 2.588 and 3.424, respectively).

### 4.1.3 Interaction of variety and micronutrient management

Interaction of variety and micronutrient management showed statistically significant effect on the plant height at 30, 55, 80 DAS and at harvest (Table 1 and Appendix III). At 30 DAS, the tallest plant height (15.76 cm) was recorded from $V_1F_3$ which was statistically similar to $V_1F_4$ (15.06 cm), $V_1F_5$ (14.92 cm), $V_2F_3$ (14.53 cm), $V_1F_2$ (14.27 cm) and $V_2F_4$ (13.85 cm) and the shortest plant height (12.37 cm) was recorded from $V_2F_5$ which was statistically similar to all other interactions except $V_1F_3$, $V_1F_4$, $V_1F_5$ and $V_2F_3$. At 55 DAS, the tallest plant height (27.65 cm) was recorded from $V_1F_6$ which was statistically similar to all interactions except $V_2F_3$ that showed the shortest plant height $V_2F_3$ (24.61 cm). At 80 DAS, the tallest plant height (33.73 cm) was recorded from $V_2F_6$ which was statistically similar to all other interactions except $V_2F_2$ (29.67 cm) and $V_2F_3$ (29.00 cm) and the shortest plant height was recorded from $V_2F_3$. At harvest, the tallest plant height (38.45 cm) was recorded from $V_2F_6$ which was statistically similar to other interactions except $V_1F_1$ (32.67 cm), $V_2F_1$ (32.53 cm) and $V_2F_2$ (32.87 cm) and the shortest plant height (32.53 cm) was recorded from $V_2F_1$ which was statistically similar to all other interactions except $V_2F_6$ (38.45 cm). The result was findings of Zaman *et al*. (2022) and Quddus *et al*. (2014) study.

**Table 1**. Combined effect of variety and micronutrient management on plant height of lentil at different days after sowing

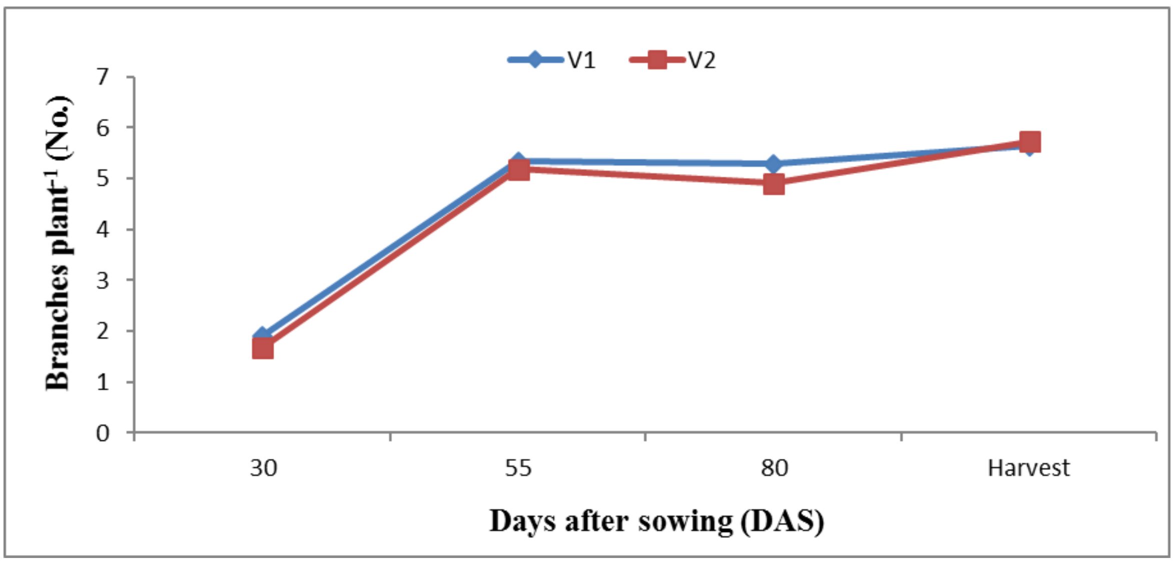
| Interactions | Plant height (cm) at | | | |
|---|---|---|---|---|
| | 30 DAS | 55 DAS | 80 DAS | Harvest |
| $V_1F_1$ | 13.37bcd | 25.52ab | 31.10abc | 32.67b |
| $V_1F_2$ | 14.27abcd | 25.30ab | 32.87ab | 34.20ab |
| $V_1F_3$ | 15.76a | 26.98ab | 32.80ab | 35.50ab |
| $V_1F_4$ | 15.06ab | 27.27ab | 31.63abc | 34.23ab |
| $V_1F_5$ | 14.92ab | 26.41ab | 33.47a | 35.07ab |
| $V_1F_6$ | 13.27bcd | 27.65a | 33.67a | 35.73ab |
| $V_2F_1$ | 12.86cd | 25.43ab | 31.15abc | 32.53b |
| $V_2F_2$ | 13.56bcd | 25.74ab | 29.67bc | 32.87b |
| $V_2F_3$ | 14.53abc | 24.61b | 29.00c | 34.40ab |
| $V_2F_4$ | 13.85abcd | 25.71ab | 31.17abc | 34.67ab |
| $V_2F_5$ | 12.37d | 25.65ab | 31.73abc | 34.13ab |
| $V_2F_6$ | 13.66bcd | 25.97ab | 33.73a | 38.45a |
| **LSD (0.05)** | 2.015 | 2.709 | 3.660 | 4.842 |
| **CV (%)** | 8.48 | 6.11 | 6.75 | 8.23 |

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8, $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

### 4.2 Number of branches plant$^{-1}$

#### 4.2.1 Effect of variety

There were no significant variations of the number of branches plant$^{-1}$ recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 3 and Appendix IV). At 30 DAS, the numerically maximum number of branches plant$^{-1}$ was recorded from BARI Masur-8 (1.91) as compared to Binamasur-8 (1.68). At harvest, the maximum number of branches plant$^{-1}$ (5.64) was observed from BARI Masur-8 and the minimum number branches plant$^{-1}$ (5.72) from Binamasur-8. Similar trend was also observed for other studied durations (55 and 80 DAS). Zaman *et al*. (2022) also found 3.2 branches plant$^{-1}$ for BARI Masur-8 and Khatun *et al.* (2021) found 3.27 branches plant$^{-1}$ for Binamasur-8 which was lower than the present findings.



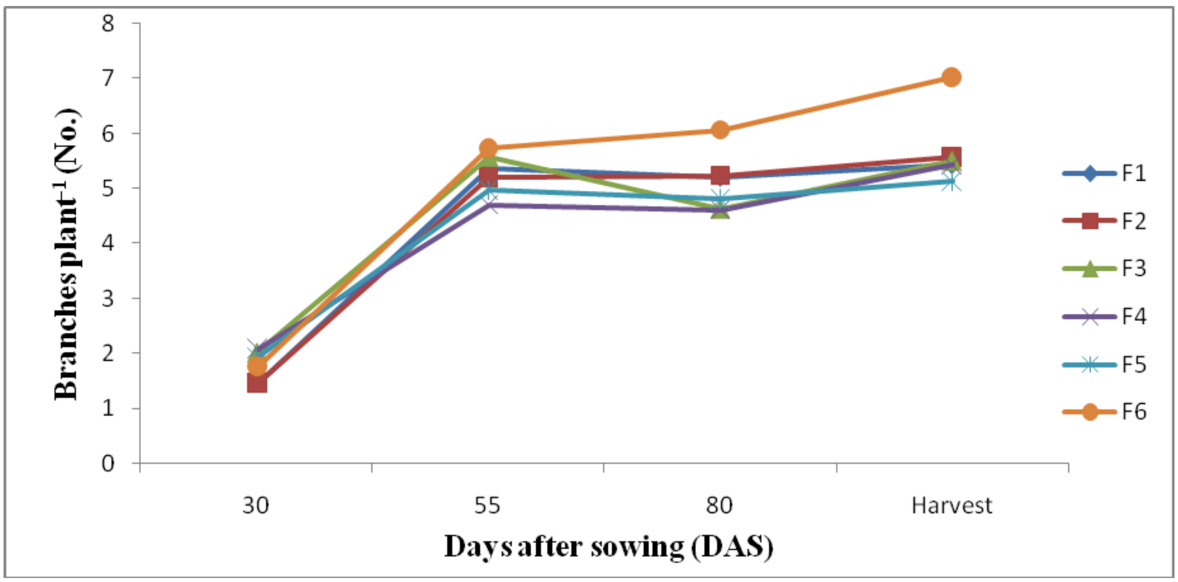

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 3**. Number of branches plant$^{-1}$ of lentil as influenced by variety.

#### 4.2.2 Effect of micronutrient management

The number of branches plant$^{-1}$of lentil was significantly influenced by micronutrient management (Figure 4 and Appendix IV) at 30, 80 DAS and at harvest and non-significant at 55 DAS. At 30 DAS, the highest number of branches plant$^{-1}$ (2.07) was recorded from $F_4$ which was statistically similar to $F_3$ (2.02), $F_5$ (1.93) and $F_6$ (1.75) and the lowest number of branches plant$^{-1}$ (1.45) was recorded from $F_1$ that statistically similar to $F_2$ (1.55) and $F_6$

(1.75). At 55 DAS, the maximum number of branches plant$^{-1}$ (5.73) was recorded from $F_6$ and minimum number of branches plant$^{-1}$ (4.70) recorded from $F_4$. At 80 DAS, the highest number of branches plant$^{-1}$ (6.07) recorded from $F_6$ which was statistically similar to $F_1$ (5.20) and $F_2$ (5.23) and the lowest number of branches plant$^{-1}$ (4.60) recorded from $F_4$ which was statistically similar to all other treatments except $F_6$ (6.07). At harvest, the highest number of branches plant$^{-1}$ (7.03) was recorded from $F_6$ and the lowest number of branches plant$^{-1}$ from $F_5$ (5.13) which was statistically similar to other treatments except $F_6$ (7.03). Paul *et al.* (2019) was found 5.73 branches plant$^{-1}$ at harvest which was lower than the present findings (7.03 branches plant$^{-1}$).




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 4.** Number of branches plant$^{-1}$of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ at 30, 80 DAS and at harvest = 0.39, 1.252 and 1.093, respectively).

### 4.2.3 Interaction of variety and micronutrient management

Interaction of variety and micronutrient management showed statistically significant variation on the number of branches plant$^{-1}$ at 30, 55, 80 DAS and at harvest (Table 2 and Appendix IV). At 30 DAS, the highest number of branches plant$^{-1}$ (2.30) was recorded from $V_1F_4$ that statistically similar to $V_1F_5$ (2.17), $V_1F_3$ (2.13), $V_2F_6$ (2.07), $V_2F_3$ (1.90) and $V_2F_4$ (1.83) and the lowest number of branches plant$^{-1}$ (1.20) recorded from $V_2F_1$ which statistically similar to $V_1F_1$ (1.70), $V_1F_2$ (1.70), $V_2F_5$ (1.70), $V_1F_6$ (1.43) and $V_2F_2$ (1.40). At 55 DAS, the highest number of branches plant$^{-1}$ (6.27) recorded from $V_1F_6$ which was statistically similar to $V_2F_3$ (6.00), $V_1F_5$ (5.60), $V_1F_1$ (5.47), $V_1F_2$ (5.40), $V_2F_5$ (5.27), $V_2F_4$ (5.27), $V_2F_6$ (5.20), $V_1F_3$ (5.13) and $V_2F_2$ (5.00) and the lowest number of branches plant$^{-1}$ (4.13) recorded from $V_1F_4$ which statistically similar to other interactions except $V_1F_6$ (6.27). At 80 DAS, the highest number of branches plant$^{-1}$ (6.40) was recorded from $V_1F_6$ that statistically similar to all other interaction except $V_2F_3$ (4.53), $V_2F_5$ (4.13) and $V_1F_4$ (4.07) and the lowest number of branches plant$^{-1}$ (4.07) recorded from $V_1F_4$ which statistically similar to other interaction except $V_1F_6$ (6.40). At harvest, the highest number of branches plant$^{-1}$ (7.40) recorded from $V_2F_6$ which statistically similar to $V_1F_6$ (6.67) and the lowest number of branches plant$^{-1}$ (4.80) recorded from $V_2F_5$ that statistically similar to other interactions except $V_2F_6$ (7.40) and $V_1F_6$ (6.67). The highest number of branches plant$^{-1}$ (7.40) recorded from $V_2F_6$ which was higher than the findings of Khatun *et al.* (2021) and Paul *et al.* (2019).

**Table 2**. Combined effect of variety and micronutrient management on the number of branches plant$^{-1}$of lentil at different days after sowing

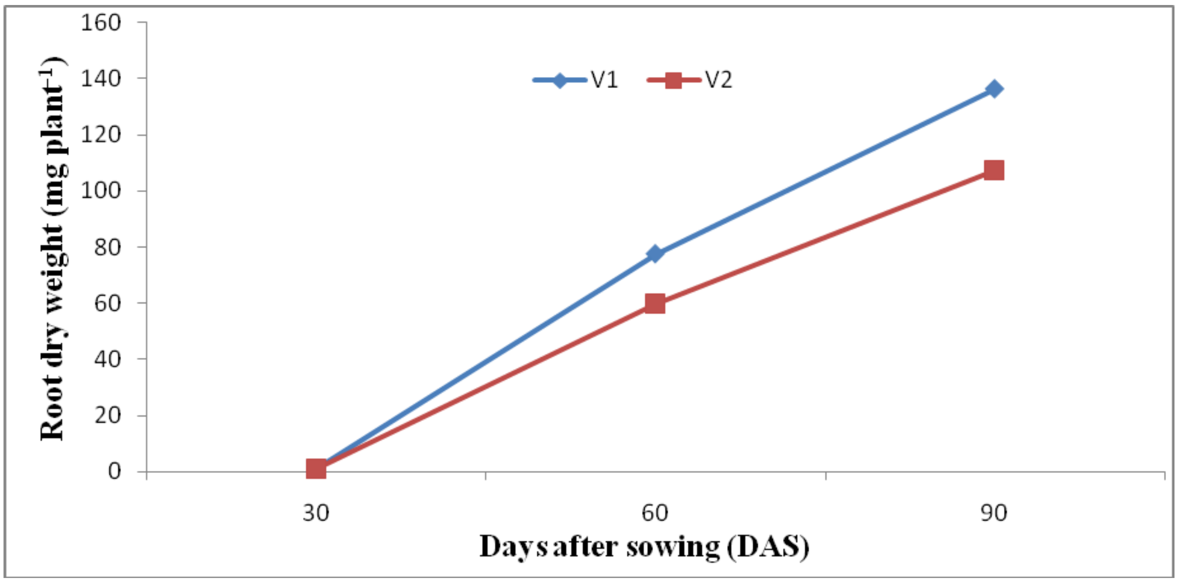
| Interactions | Number of branches plant$^{-1}$ at | | | |
|---|---|---|---|---|
| | **30 DAS** | **55 DAS** | **80 DAS** | **Harvest** |
| **$V_1F_1$** | 1.70bcd | 5.47abc | 5.67ab | 5.73bc |
| **$V_1F_2$** | 1.70bcd | 5.40abc | 5.33ab | 5.53bc |
| **$V_1F_3$** | 2.13abc | 5.13abc | 4.73ab | 5.20bc |
| **$V_1F_4$** | 2.30a | 4.13c | 4.07b | 5.27bc |
| **$V_1F_5$** | 2.17ab | 5.60abc | 5.47ab | 5.47bc |
| **$V_1F_6$** | 1.43cd | 6.27a | 6.40a | 6.67ab |
| **$V_2F_1$** | 1.20d | 5.27abc | 4.73ab | 5.13bc |
| **$V_2F_2$** | 1.40cd | 5.00abc | 5.13ab | 5.60bc |
| **$V_2F_3$** | 1.90abc | 6.00ab | 4.53b | 5.80bc |
| **$V_2F_4$** | 1.83abc | 5.27abc | 5.13ab | 5.60bc |
| **$V_2F_5$** | 1.70bcd | 4.33c | 4.13b | 4.80c |
| **$V_2F_6$** | 2.07ab | 5.20abc | 5.73ab | 7.40a |
| **LSD $_{(0.05)}$** | 0.557 | 1.662 | 1.770 | 1.546 |
| **CV (%)** | 18.24 | 18.57 | 20.43 | 15.97 |

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8, $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

### 4.3 Root dry weight

#### 4.3.1 Effect of variety

There were no significant variations of the dry weight of root plant$^{-1}$ between BARI Masur-8 and Binamasur-8 (Figure 5 and Appendix V). At 30 DAS, the numerically maximum root dry weight plant$^{-1}$ (0.94 mg) was observed from BARI Masur-8 and minimum from Binamasur-8 (0.81 mg). At 60 DAS, the numerically maximum root dry weight plant$^{-1}$ (77.56 mg) was observed from BARI Masur-8 and minimum from Binamasur-8 (59.78 mg). At 90 DAS, the maximum root dry weight plant$^{-1}$ (136.25 mg) was observed from BARI Masur-8 and minimum from Binamasur-8 (107.22 mg).

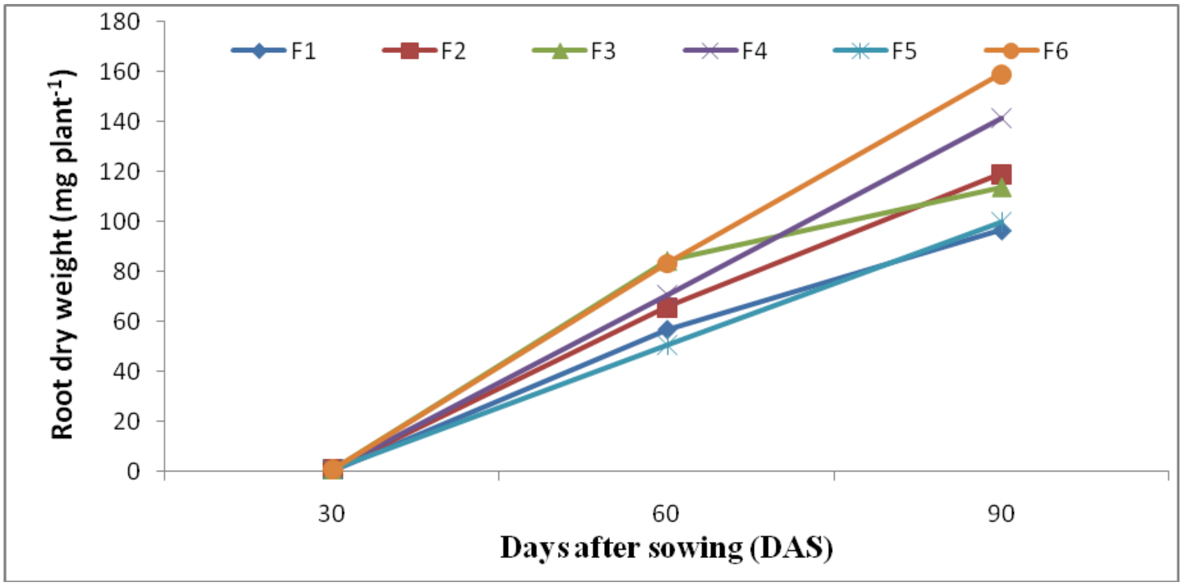



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 5**. Root dry weight ( mg plant$^{-1}$) of lentil as influenced by variety.

#### 4.3.2 Effect of micronutrient management

The root dry weight plant$^{-1}$ of lentil was significantly influenced by micronutrient management (Figure 6 and Appendix V) at 30 and 90 DAS but non-significant at 60 DAS. At 30 DAS, the highest root dry weight (0.99 mg plant$^{-1}$) was recorded from $F_4$ which was statistically similar to $F_3$ (0.98 mg plant$^{-1}$), $F_5$ (0.89 mg plant$^{-1}$) and $F_6$ (0.84 mg plant$^{-1}$) and the lowest weight (0.76 mg plant$^{-1}$) recorded from $F_1$ that statistically similar to $F_2$ (0.78 mg plant$^{-1}$), $F_5$ (0.89 mg plant$^{-1}$) and $F_6$ (0.84 mg plant$^{-1}$). At 60 DAS, the maximum root dry weight (84.33 mg plant$^{-1}$) recorded from $F_3$ and minimum root dry weight (50.67 mg plant$^{-1}$) recorded from $F_5$. At 90 DAS, the highest root dry weight (159.17 mg plant$^{-1}$) was recorded from $F_6$ which statistically similar to $F_2$ (119.17 mg plant$^{-1}$), $F_3$ (113.75 mg plant$^{-1}$) and $F_4$ (141.67 mg plant$^{-1}$) and the lowest root dry weight (96.67 mg plant$^{-1}$) recorded from $F_1$ which statistically similar to $F_5$ (100.00 mg plant$^{-1}$), $F_2$ (119.17 mg plant$^{-1}$), $F_3$ (113.75 mg plant$^{-1}$) and $F_4$ (141.67 mg plant$^{-1}$). Singh and Bhatt (2013) also found variation of root dry weight from 1.87 to 2.45 g plant$^{-1}$ using different concentration of zinc.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 6.** Root dry weight of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ at 30, 60 and 90 DAS = 0.208, 36.086 and 52.768, respectively).

### 4.3.3 Interaction of variety and micronutrient management

Interaction of variety and micronutrient management showed statistically significant effect on the root dry weight of lentil at 30, 60 and 90 DAS (Table 3 and Appendix V). At 30 DAS, the highest root dry weight (1.17 mg) plant$^{-1}$ recorded from $V_1F_4$ which statistically similar to $V_1F_1$ (0.91 mg), $V_1F_3$ (1.00 mg), $V_1F_5$ (0.97 mg) and $V_2F_3$ (0.96 mg) and the lowest root dry weight (0.61 mg) plant$^{-1}$ recorded from $V_2F_1$ which statistically similar to $V_1F_2$ (0.76 mg), $V_1F_6$ (0.82 mg), $V_2F_2$ (0.80 mg), $V_2F_4$ (0.81 mg), $V_2F_5$ (0.81 mg), and $V_2F_6$ (0.86 mg). At 60 DAS, the highest root dry weight (114.67 mg) plant$^{-1}$ recorded from $V_1F_6$ which statistically similar to $V_1F_2$ (65.33 mg), $V_1F_3$ (97.33 mg), $V_1F_4$ (70.00 mg), $V_2F_2$

(66.00 mg), $V_2F_3$ (71.33 mg) and $V_2F_4$ (72.00 mg) and the lowest root dry weight (44.67 mg) plant$^{-1}$ recorded from $V_2F_5$ that statistically similar to other treatments $V_1F_3$ (97.33 mg) and $V_1F_6$ (114.67 mg). At 90 DAS, the highest root dry weight (176.67 mg) plant$^{-1}$ recorded from $V_1F_6$ which statistically similar to $V_1F_1$ (110.00 mg), $V_1F_2$ (122.50 mg), $V_1F_4$ (121.67 mg), $V_1F_4$ (175.83 mg), $V_1F_5$ (110.83 mg), $V_2F_2$ (115.83 mg), $V_1F_3$ (105.83 mg), $V_1F_4$ (107.50 mg) and $V_2F_6$ (141.67 mg) and the lowest root dry weight (83.33 mg) plant$^{-1}$ was recorded from $V_2F_1$ which statistically similar to $V_2F_5$ (89.17 mg) and other treatments except $V_1F_6$ (176.67 mg) and $V_1F_4$ (175.83 mg).

**Table 3**. Combined effect of variety and micronutrient managements on the root dry weight plant$^{-1}$of lentil at different days after sowing

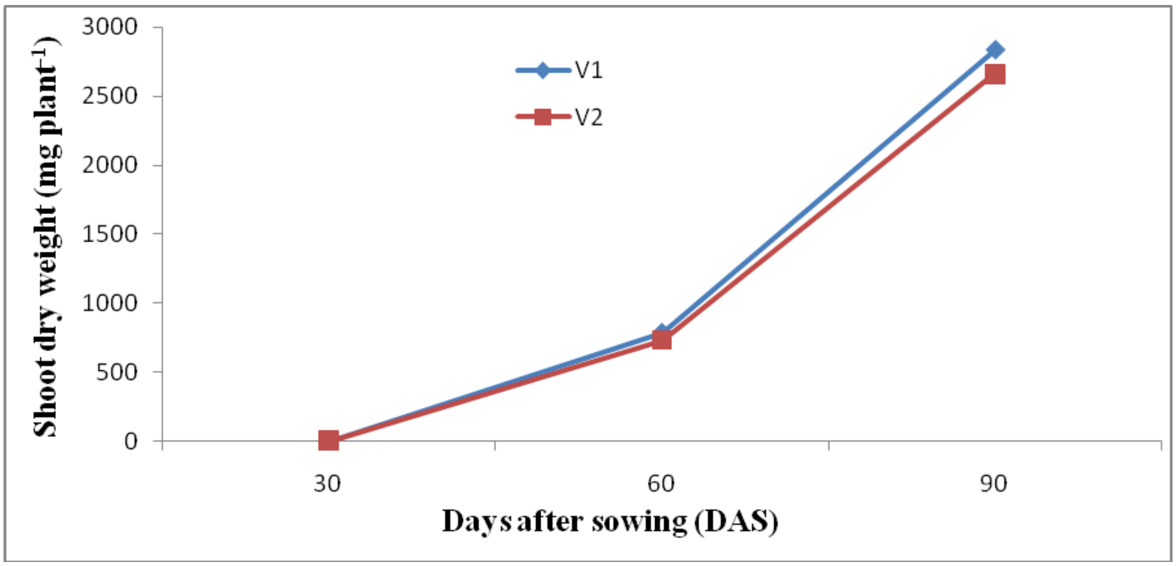
| Interactions | Root dry weight (mg) plant$^{-1}$ | | |
|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS |
| $V_1F_1$ | 0.91ab | 61.33bc | 110.00ab |
| $V_1F_2$ | 0.76bc | 65.33abc | 122.50ab |
| $V_1F_3$ | 1.00ab | 97.33ab | 121.67ab |
| $V_1F_4$ | 1.17a | 70.00abc | 175.83a |
| $V_1F_5$ | 0.97ab | 56.67bc | 110.83ab |
| $V_1F_6$ | 0.82bc | 114.67a | 176.67a |
| $V_2F_1$ | 0.61c | 52.67bc | 83.33b |
| $V_2F_2$ | 0.80bc | 66.00abc | 115.83ab |
| $V_2F_3$ | 0.96ab | 71.33abc | 105.83ab |
| $V_2F_4$ | 0.81bc | 72.00abc | 107.50ab |
| $V_2F_5$ | 0.81bc | 44.67c | 89.17b |
| $V_2F_6$ | 0.86bc | 52.00bc | 141.68ab |
| LSD $_{(0.05)}$ | 0.295 | 51.033 | 74.62 |
| CV (%) | 62.59 | 43.64 | 35.99 |

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8, $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

### 4.4 Shoot dry weight

#### 4.4.1 Effect of variety

There were no significant variations of the shoot dry weight plant$^{-1}$ recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 7 and Appendix VI). At 30 DAS, the numerically maximum shoot dry weight plant$^{-1}$ was found in BARI Masur-8 (0.94 mg) that followed by Binamasur-8 (0.81 mg). At 60 DAS, the numerically maximum shoot dry weight plant$^{-1}$ (785.89 mg) was found in BARI Masur-8 that followed by Binamasur-8 (733.89 mg). At 90 DAS, the numerically maximum shoot dry weight plant$^{-1}$ (2837.17 mg) found in BARI Masur-8 that followed by Binamasur-8 (2665.83 mg).

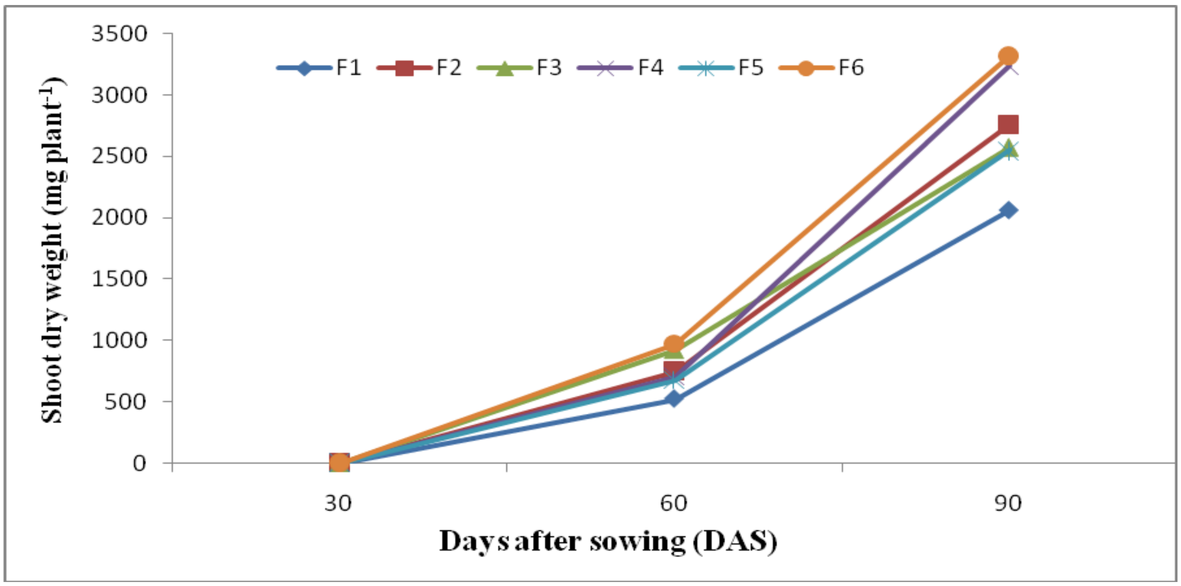



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 7**. Shoot dry weight (mg plant$^{-1}$) of lentil as influenced by variety.

#### 4.4.2 Effect of micronutrient management

The shoot dry weight plant$^{-1}$ (mg) of lentil was significantly influenced by the variation of fertilizers (Figure 8 and Appendix VI) at 30, 60 and 90 DAS. At 30 DAS, the highest shoot dry weight plant$^{-1}$ (0.99 mg) was recorded from $F_4$ which statistically similar to $F_3$ (0.98 mg), $F_5$ (0.89 mg) and $F_6$ (0.84 mg) and the lowest shoot dry weight plant$^{-1}$ (0.76 mg) was recorded from $F_1$ that statistically similar to $F_2$ (0.78 mg), $F_5$ (0.89 mg) and $F_6$ (0.84 mg). At 60 DAS, the highest shoot dry weight plant$^{-1}$ (973.67 mg) recorded from $F_6$ which statistically similar to $F_2$ (749.67 mg), $F_3$ (924.67 mg), $F_4$ (707.67 mg) and $F_5$ (677.00 mg) and lowest shoot dry weight plant$^{-1}$ (526.67 mg) was recorded from $F_1$ which statistically similar to other treatments except $F_6$ (973.67 mg). At 90 DAS, the highest shoot dry weight plant$^{-1}$ (3319.33 mg) recorded from $F_6$ which statistically similar to $F_2$ (2762.50 mg), $F_3$ (2575.67 mg), $F_4$ (3238.33 mg) and $F_5$ (2548.00 mg) and the lowest shoot dry weight plant$^{-1}$ (2065.17 mg) recorded from $F_1$ which statistically similar to other treatments except $F_6$ (3319.33 mg). Singh and Bhatt (2013) also reported that shoot dry weight varied from 3.23 to 4.37 g plant$^{-1}$ using different concentrations of zinc whereas present experiment found shoot dry weight varied from 2.07 to 3.32 g plant$^{-1}$ using different micronutrient management.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 8.** Shoot dry weight plant$^{-1}$ of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ at 30, 60 and 90 DAS = 0.208, 342.941 and 1158.84, respectively).

**4.4.3 Interaction of variety and micronutrient management**

Interaction of variety and micronutrient management showed statistically significant effect on the shoot dry weight plant$^{-1}$ at 30, 60 DAS but non-significant at 90 DAS (Table 4 and Appendix VI). At 30 DAS, the highest shoot dry weight plant$^{-1}$ (1.10 mg) recorded from $V_1F_4$ which statistically similar to $V_1F_1$ (0.90 mg), $V_1F_3$ (0.99 mg), $V_1F_5$ (0.91 mg), $V_1F_6$ (0.83 mg), $V_2F_3$ (0.97 mg), $V_2F_4$ (0.91 mg), $V_2F_5$ (0.88 mg) and $V_2F_6$ (0.85 mg) and the lowest shoot dry weight plant$^{-1}$ (0.62 mg) recorded from $V_2F_1$ that statistically similar except $V_1F_2$ (0.77 mg) and $V_2F_2$ (0.79 mg). At 60 DAS, the highest shoot dry weight plant$^{-1}$ (1239.33 mg) was recorded from $V_1F_6$ which statistically similar to $V_1F_3$ (960.67 mg), $V_2F_2$ (7786.67 mg), $V_2F_3$ (888.67 mg) and $V_2F_4$ (786.00 mg) and the lowest shoot dry weight plant$^{-1}$ (515.33 mg) was recorded from $V_2F_1$ which statistically similar to other interactions except $V_1F_6$ (1239.33 mg). At 90 DAS, the numerically maximum dry weight of shoot plant$^{-1}$ (3552.33 mg) was recorded from $V_1F_6$ and the minimum dry weight of shoot plant$^{-1}$ (1934.00 mg) from $V_1F_1$.

**Table 4.** Combined effect of variety and micronutrient management on the shoot dry weight of lentil at different days after sowing

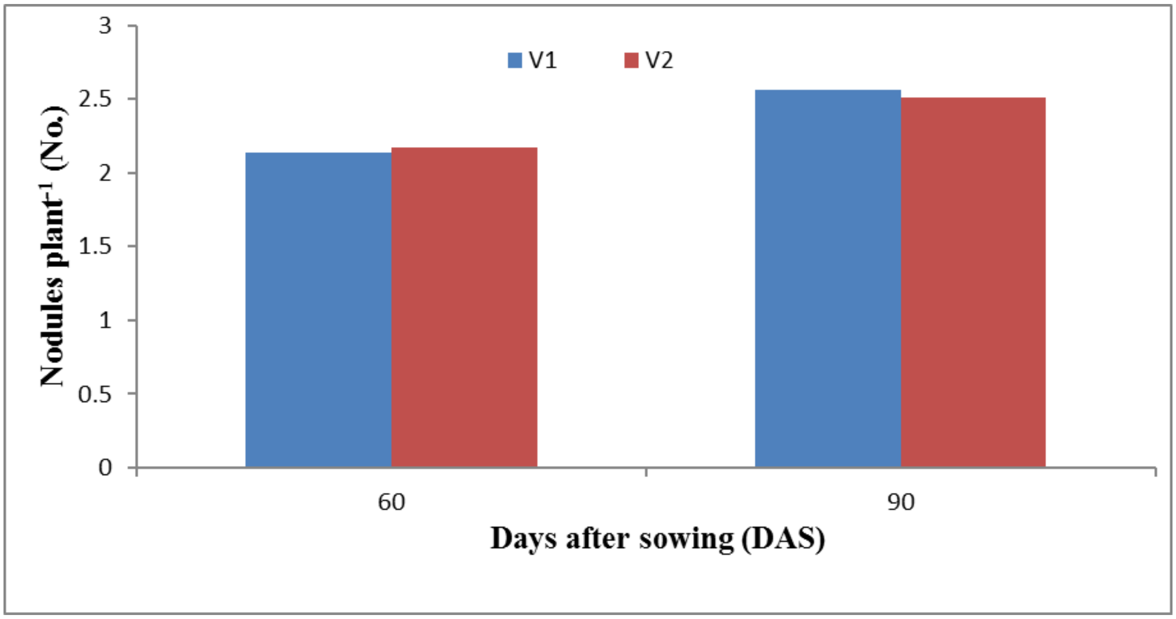
| Interactions | Shoot dry weight plant$^{-1}$ (mg) | | |
|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS |
| **$V_1F_1$** | 0.90abc | 538.00b | 1934.00 |
| **$V_1F_2$** | 0.77bc | 712.67b | 2348.33 |
| **$V_1F_3$** | 0.99ab | 960.67ab | 2815.67 |
| **$V_1F_4$** | 1.10a | 629.33b | 3318.00 |
| **$V_1F_5$** | 0.91abc | 635.33b | 3054.67 |
| **$V_1F_6$** | 0.83abc | 1239.33a | 3552.33 |
| **$V_2F_1$** | 0.62c | 515.33b | 2196.33 |
| **$V_2F_2$** | 0.79bc | 786.67ab | 3176.67 |
| **$V_2F_3$** | 0.97ab | 888.67ab | 2335.67 |
| **$V_2F_4$** | 0.91abc | 786.00ab | 3158.67 |
| **$V_2F_5$** | 0.88abc | 718.67b | 2041.33 |
| **$V_2F_6$** | 0.85abc | 708.00b | 3086.33 |
| **LSD $_{(0.05)}$** | 0.295 | 484.99 | NS |
| **CV (%)** | 62.59 | 37.47 | 34.97 |

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8, $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

### 4.5 Number of nodules plant$^{-1}$

#### 4.5.1 Effect of variety

There were no significant variations of the number of nodules plant$^{-1}$ recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 9 and Appendix VII). At 60 DAS, the maximum number of nodules plant$^{-1}$ was found in Binamasur-8 (2.17) followed by BARI Masur-8 (2.14). At 90 DAS, the maximum number of nodules plant$^{-1}$ was found in BARI Masur-8 (2.56) and Binamasur-8 (2.51).

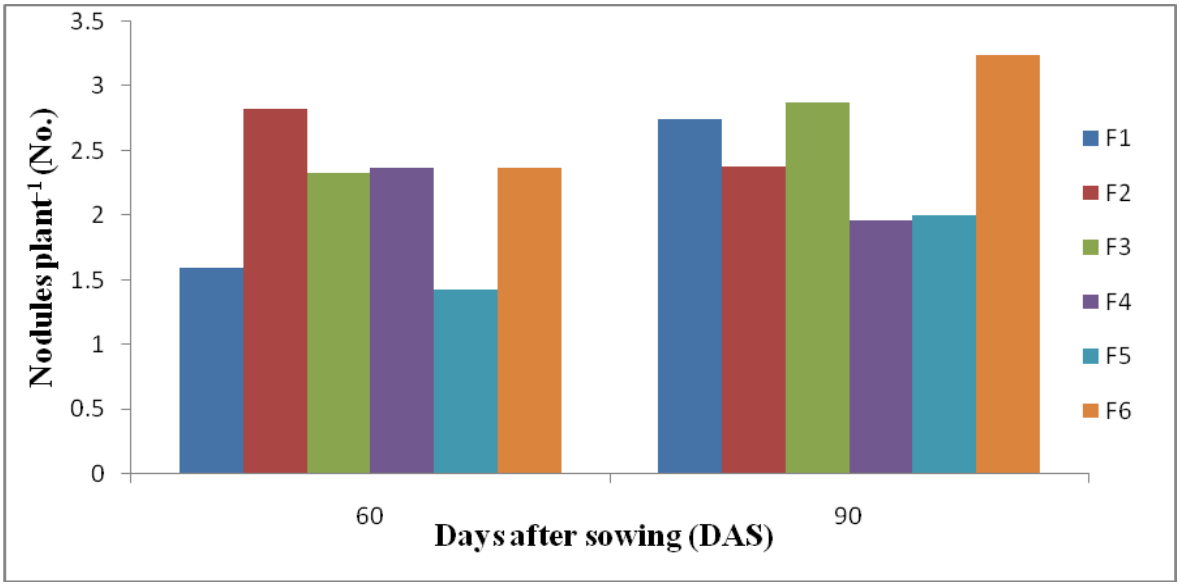



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 9**. Number of nodules plant$^{-1}$ of lentil as influenced by variety.

### 4.5.2 Effect of micronutrient management

The number of nodules plant$^{-1}$ of lentil was significantly influenced by micronutrient management (Figure 10 and Appendix VII) at 60 DAS and non-significant at 90 DAS. At 60 DAS, higher number of nodules plant$^{-1}$ (2.83) was recorded from $F_2$ which statistically similar to $F_1$ (1.60), $F_3$ (2.33), $F_4$ (2.37) and $F_6$ (2.37) and the lowest number of nodules plant$^{-1}$ (1.43) recorded from $F_5$ that statistically similar to other treatments except $F_2$ (2.83). At 90 DAS, the maximum number of nodules plant$^{-1}$ (3.24) was recorded from $F_6$ and minimum number of nodules plant$^{-1}$ (1.96) from $F_4$. Singh and Bhatt (2013) also reported variation of nodules plant$^{-1}$ for different zinc concentrations.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 10.** Number of nodules plant$^{-1}$ of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ at 60 DAS = 1.386).

### 4.5.3 Interaction of variety and micronutrient management

Interaction of variety and micronutrient management showed statistically significant effect on the number of nodules plant$^{-1}$ at 90 DAS but non-significant at 60 DAS (Table 5 and Appendix VII). At 60 DAS, the maximum number of nodules plant$^{-1}$ (3.33) was recorded from $V_1F_2$ and the minimum number of nodules plant$^{-1}$ (1.13) recorded from $V_1F_5$. At 90 DAS, the highest number of nodules plant$^{-1}$ (4.33) was recorded from $V_1F_6$ which statistically similar to $V_1F_2$ (2.25), $V_1F_3$ (3.17), $V_2F_1$ (3.92), $V_2F_2$ (2.50), $V_2F_3$ (2.58) and $V_2F_6$ (2.15) and the lowest number of nodules plant$^{-1}$ (1.58) from $V_1F_1$ that statistically similar to other interactions except $V_1F_6$ (4.33) and $V_2F_1$ (3.92).

**Table 5**. Combined effect of variety and micronutrient management on the number of nodules plant$^{-1}$ of lentil at different days after sowing

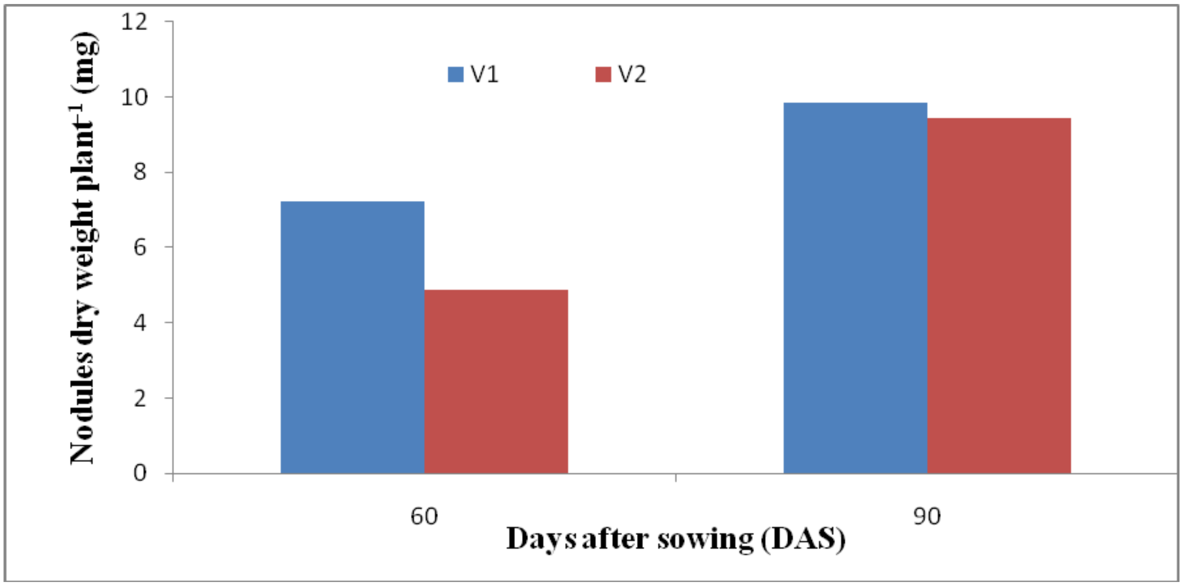
| Interactions | Number of nodule plant$^{-1}$ | |
|---|---|---|
| | 60 DAS | 90 DAS |
| $V_1F_1$ | 1.53 | 1.58c |
| $V_1F_2$ | 3.33 | 2.25abc |
| $V_1F_3$ | 1.87 | 3.17abc |
| $V_1F_4$ | 2.33 | 2.00bc |
| $V_1F_5$ | 1.13 | 2.00bc |
| $V_1F_6$ | 2.67 | 4.33a |
| $V_2F_1$ | 1.67 | 3.92ab |
| $V_2F_2$ | 2.33 | 2.50abc |
| $V_2F_3$ | 2.80 | 2.58abc |
| $V_2F_4$ | 2.40 | 1.92bc |
| $V_2F_5$ | 1.73 | 2.00bc |
| $V_2F_6$ | 2.07 | 2.15b |
| LSD $_{(0.05)}$ | NS | 2.259 |
| CV (%) | 53.40 | 52.37 |

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8, $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

### 4.6 Nodules dry weight plant$^{-1}$

#### 4.6.1 Effect of variety

There were no significant variations of the dry weight of nodules plant$^{-1}$ was recorded for variety of BARI Masur-8 followed by Binamasur-8 (Figure 11 and Appendix VIII). At 60 DAS, the maximum dry weight of nodules plant$^{-1}$ (7.22 mg) of BARI Masur-8 and minimum from Binamasur-8 (4.89 mg). At 90 DAS, the highest dry weight of nodules plant$^{-1}$ (9.86 mg) of BARI Masur-8 and lowest from Binamasur-8 (9.46 mg).

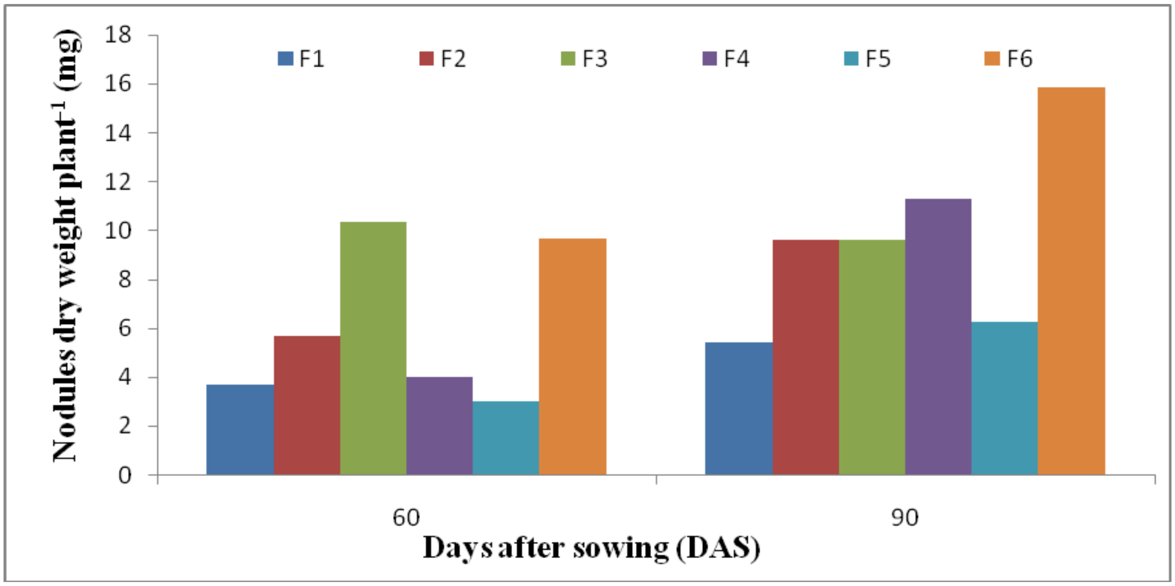



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 11**. Dry weight of nodules plant$^{-1}$ of lentil as influenced by variety.

### 4.6.2 Effect of micronutrient management

The dry weight of nodule plant$^{-1}$ of lentil was significantly influenced by micronutrient management (Figure 12 and Appendix VIII) at 60 DAS and non-significant at 90 DAS. At 60 DAS, the highest dry weight of nodules plant$^{-1}$ (10.33 mg) was recorded from $F_3$ which statistically similar to $F_1$ (3.67 mg), $F_2$ (5.67 mg), $F_4$ (4.00 mg) and $F_6$ (9.67 mg) and the lowest dry weight of nodules plant$^{-1}$ (3.00 mg) from $F_5$ that statistically similar to other treatments except $F_3$ (10.33 mg). At 90 DAS, the maximum dry weight of nodules plant$^{-1}$ (15.83 mg) was recorded from $F_6$ and minimum dry weight of nodules plant$^{-1}$ (5.42 mg) from $F_1$. Singh and Bhatt (2013) also found variation of nodules plant$^{-1}$ with different zinc concentrations.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 12.** Dry weight of nodules plant$^{-1}$ of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ at 60 DAS = 100.04).

### 4.6.3 Interaction of variety and micronutrient management

Interaction of variety and micronutrient management showed statistically significant effect on the dry weight of nodules plant$^{-1}$ at 60 but non-significant at 90 DAS (Table 6 and Appendix VIII). At 60 DAS, the highest dry weight of nodules plant$^{-1}$ (26.00 mg) recorded from $V_1F_3$ which statistically similar to $V_1F_1$ (10.00 mg) and $V_1F_6$ (10.00 mg) and the lowest dry weight of nodules plant$^{-1}$ was recorded from $V_1F_4$ (2.00 mg), $V_2F_1$ (2.00 mg), $V_2F_3$ (2.00 mg) and $V_2F_5$ (2.00 mg) which statistically similar to other interactions except $V_1F_3$ (26.00 mg). At 90 DAS, the maximum dry weight of nodules plant$^{-1}$ (18.33 mg) recorded from $V_1F_4$ and the minimum dry weight of nodules plant$^{-1}$ (4.17 mg) was recorded from $V_1F_1$.

**Table 6**. Combined effect of variety and micronutrient management on the dry weight of nodules plant$^{-1}$ of lentil at different days after sowing

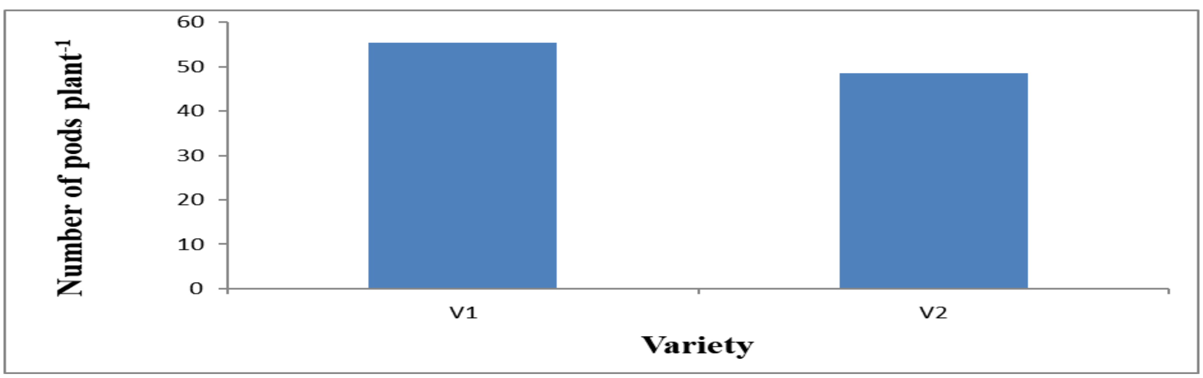
| Interactions | Nodules dry weight plant$^{-1}$ (mg) | |
|---|---|---|
| | 60 DAS | 90 DAS |
| $V_1F_1$ | 10.00ab | 4.17 |
| $V_1F_2$ | 8.00b | 6.67 |
| $V_1F_3$ | 26.00a | 9.17 |
| $V_1F_4$ | 2.00b | 18.33 |
| $V_1F_5$ | 4.00b | 5.83 |
| $V_1F_6$ | 10.00ab | 15.00 |
| $V_2F_1$ | 2.00b | 6.67 |
| $V_2F_2$ | 6.00b | 12.50 |
| $V_2F_3$ | 2.00b | 10.00 |
| $V_2F_4$ | 6.00b | 4.25 |
| $V_2F_5$ | 2.00b | 6.67 |
| $V_2F_6$ | 6.00b | 16.67 |
| LSD $_{(0.05)}$ | 17.644 | NS |
| CV (%) | 100.04 | 91.69 |

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8, $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

### 4.7 Number of pods plant$^{-1}$

#### 4.7.1 Effect of variety

There were no significant variations of the number of pods plant$^{-1}$ recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 13 and Appendix IX). The maximum number of pods plant$^{-1}$ (55.42) was found in BARI Masur-8 and minimum from Binamasur-8 (48.54). Variation of pods plant$^{-1}$ in BARI Masur-8 and Binamasur-8 was also reported by Zaman *et al*. (2022) and Khatun *et al.* (2021).

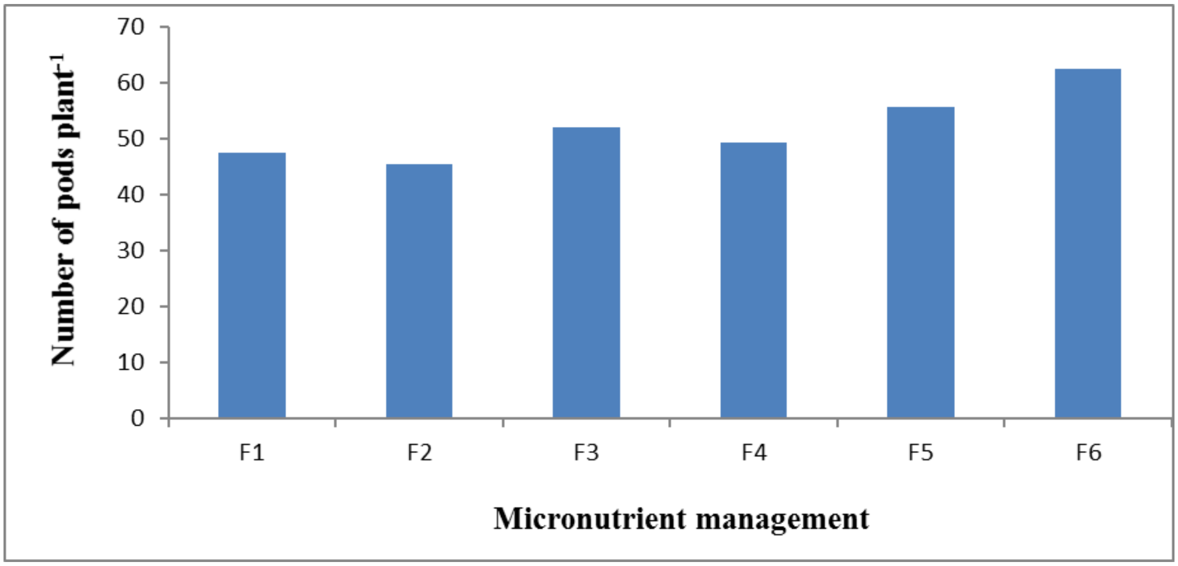



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 13**. Number of pods plant$^{-1}$ of lentil as influenced by variety.

### 4.7.2 Effect of micronutrient management

The number of pods plant$^{-1}$ of lentil was significantly influenced by micronutrient management (Figure 14 and Appendix IX). The highest number of pods plant$^{-1}$ (62.37) was recorded from $F_6$ that statistically similar to $F_5$ (55.53), $F_3$ (52.00), $F_4$ (49.17) and $F_1$ (47.53) and the lowest number of pods plant$^{-1}$ (45.30) recorded from $F_2$ which statistically similar to other treatments except $F_6$ (62.37). Quddus *et al.* (2014) also found variation of pods plant$^{-1}$ with different zinc and boron concentrations.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 14.** Number of pods plant$^{-1}$ of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ = 15.439).

### 4.7.3 Interaction of variety and micronutrient management

The interaction between variety and micronutrient management significantly affected the number of pods plant$^{-1}$ of lentil (Table 7 and Appendix IX). The highest number of pods plant$^{-1}$ (63.20) of lentil was obtained from combination of $V_2F_6$ that similar to $V_1F_1$ (48.40), $V_1F_2$ (50.53), $V_1F_3$ (61.00), $V_1F_4$ (53.93), $V_1F_5$ (57.13), $V_1F_6$ (61.53), $V_2F_1$ (46.67), $V_2F_3$ (43.00), $V_2F_4$ (44.40), and $V_2F_5$ (53.93). The lowest number of pods plant$^{-1}$ (40.07) of lentil was found from combination of $V_2F_2$ which similar to other interactions except $V_2F_6$ (63.20). Quddus *et al.* (2014) also found around similar number of pods plant$^{-1}$ using $Zn_{3.0}B_{1.5}$ (kg ha$^{-1}$) combination.

**Table 7.** Combined effect of variety and micronutrient management on the number of pods plant$^{-1}$, length of pod, number of seeds pod$^{-1}$ and 1000-seed weight of lentil

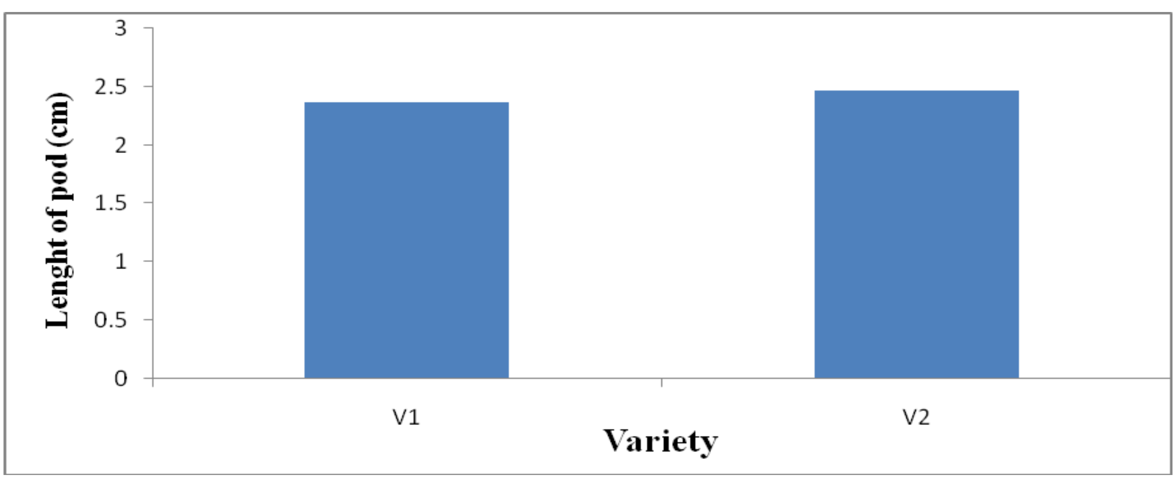
| Interactions | Number of pods plant$^{-1}$ | Length of pod (cm) | Number of seeds pod$^{-1}$ | 1000-seed weight (g) |
|---|---|---|---|---|
| **$V_1F_1$** | 48.40ab | 1.20 | 1.62ab | 34.87a |
| **$V_1F_2$** | 50.53ab | 1.16 | 1.70ab | 34.57abc |
| **$V_1F_3$** | 61.00ab | 1.16 | 1.67ab | 33.30c |
| **$V_1F_4$** | 53.93ab | 1.15 | 1.70ab | 34.77ab |
| **$V_1F_5$** | 57.13ab | 1.20 | 1.77ab | 33.93abc |
| **$V_1F_6$** | 61.53ab | 1.17 | 1.79ab | 33.50bc |
| **$V_2F_1$** | 46.67ab | 1.18 | 1.83a | 28.33de |
| **$V_2F_2$** | 40.07b | 1.21 | 1.73ab | 28.80d |
| **$V_2F_3$** | 43.00ab | 1.17 | 1.73ab | 27.13e |
| **$V_2F_4$** | 44.40ab | 1.15 | 1.53b | 28.37de |
| **$V_2F_5$** | 53.93ab | 1.18 | 1.80ab | 28.80d |
| **$V_2F_6$** | 63.20a | 1.17 | 1.77ab | 28.25de |
| **LSD (0.05)** | 21.835 | NS | 0.273 | 1.313 |
| **CV (%)** | 24.66 | 6.73 | 29.46 | 2.47 |

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8, $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

### 4.8 Length of pod

#### 4.8.1 Effect of variety

There were no significant variations of pod length recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 15 and Appendix IX). The numerically maximum pod length (1.17 cm) was recorded from BARI Masur-8 and minimum from Binamasur-8 (1.18 cm).

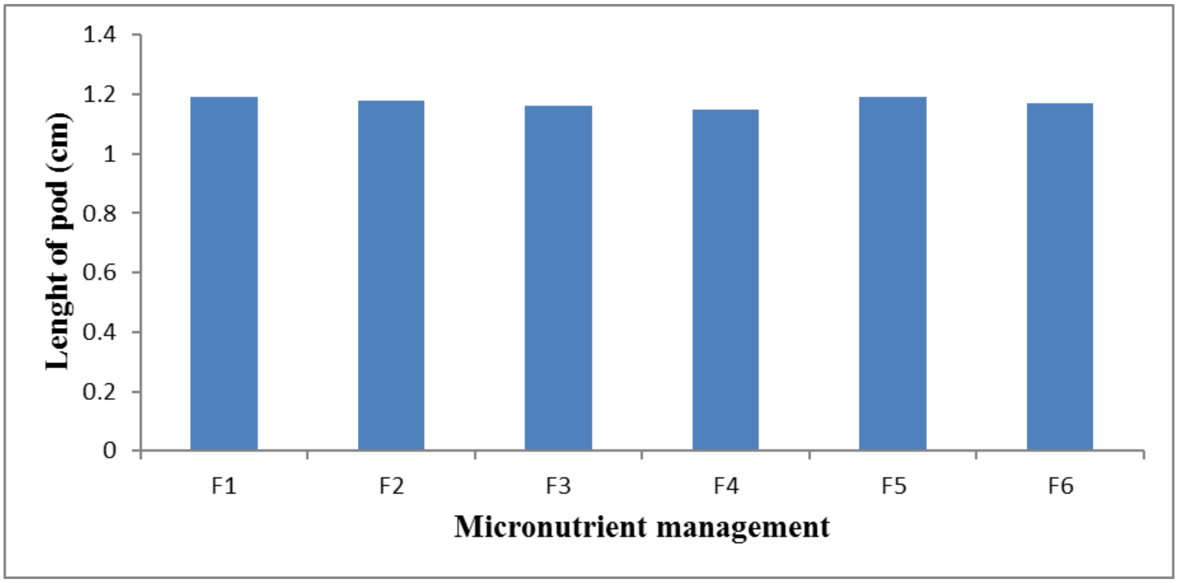



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 15**. Pod length of lentil as influenced by variety.

### 4.8.2 Effect of micronutrient management

The pod length of lentil was not significantly influenced by micronutrient management (Figure 16 and Appendix IX). The maximum pod length was recorded from $F_1$ (1.19 cm) and $F_5$ (1.19 cm) whereas the minimum pod length from $F_4$ (1.15 cm).




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 16**. Pod length of lentil as influenced by zinc and boron management.

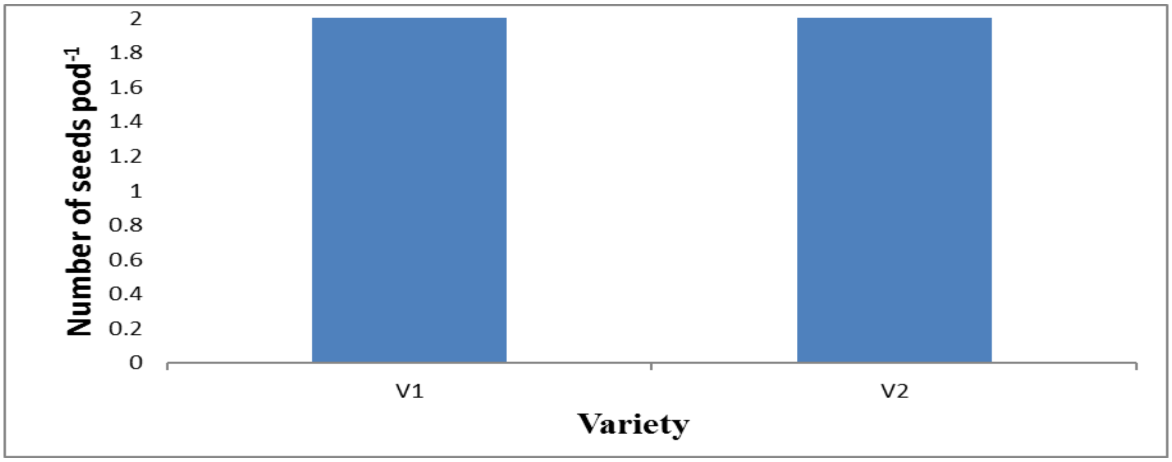
### 4.8.3 Interaction of variety and micronutrient management

The interaction between variety and micronutrient management were not significantly affected the pod length of lentil (Table 7 and Appendix IX). Numerically the maximum pod length (1.21 cm) of lentil was obtained from interaction of $V_2F_2$. The minimum pod length of lentil was found from treatment combination of $V_1F_4$ (1.15 cm) and $V_2F_4$ (1.15 cm).

## 4.9 Number of seeds pod$^{-1}$

### 4.9.1 Effect of variety

There were no significant variations of number of seeds pod$^{-1}$ recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 17 and Appendix IX). The maximum number of seeds pod$^{-1}$ was found from BARI Masur-8 (1.71) and minimum from Binamasur-8 (1.73) whereas Khatun *et al*. (2021) also found 1.86 seeds pod$^{-1}$ from Binamasur-8 which was similar to the present findings.

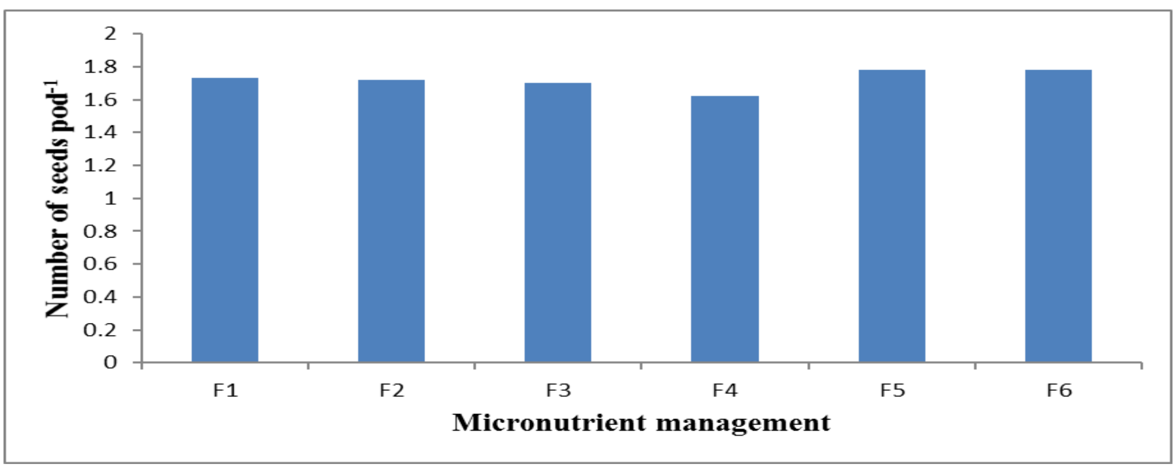



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 17**. Number of seeds pod$^{-1}$of lentil as influenced by variety.

### 4.9.2 Effect of micronutrient management

The number of seeds pod$^{-1}$ of lentil was not significantly influenced by micronutrient management (Figure 18 and Appendix IX). The maximum number of seeds pod$^{-1}$ (1.78) was recorded from $F_5$ followed by $F_6$ and the minimum number of seeds pod$^{-1}$ (1.62) from $F_4$. The highest 1.74 and 1.80 seeds pod$^{-1}$ was reported by Quddus *et al.* (2014) by using different amount of zinc and boron.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 18.** Number seeds pod$^{-1}$ of lentil as influenced by zinc and boron management.

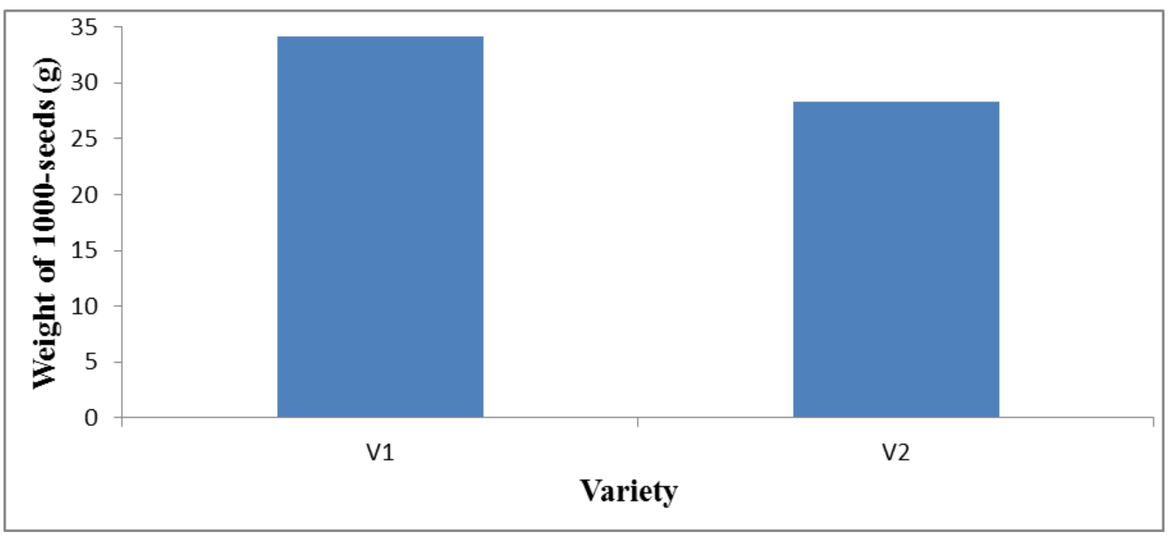
### 4.9.3 Interaction of variety and micronutrient management

The interaction between variety and micronutrient management significantly affected the number of seeds pod$^{-1}$ of lentil (Table 7 and Appendix IX). The highest number of seeds pod$^{-1}$ (1.83) of lentil was obtained from treatment combination of $V_2F_1$ which similar to $V_1F_1$ (1.62), $V_1F_2$ (1.70), $V_1F_3$ (1.67), $V_1F_4$ (1.70), $V_1F_5$ (1.77), $V_1F_6$ (1.79), $V_2F_2$ (1.73), $V_2F_3$ (1.73), $V_2F_6$ (1.77), and $V_2F_5$ (1.80). The lowest number of seeds pod$^{-1}$ (1.53) of lentil was found from treatment combination of $V_2F_4$ that similar to all other interactions except $V_2F_1$ (1.83). Similar number of seeds pod$^{-1}$ was also reported by Quddus *et al.* (2014) using $Zn_{3.0}$ $B_{1.0}$ and $Zn_{3.0}$ $B_{1.5}$.

## 4.10 1000-seed weight

### 4.10.1 Effect of variety

There were significant variations of 1000-seed weight recorded from two varieties (Figure 19 and Appendix IX). The higher 1000-seed weight was recorded from BARI Masur-8 (34.16 g) compared to that Binamasur-8 (28.28 g). Variation of 1000-seed weight of lentil varieties was also found by Zaman *et al.* (2022) and Khatun *et al*. (2021).

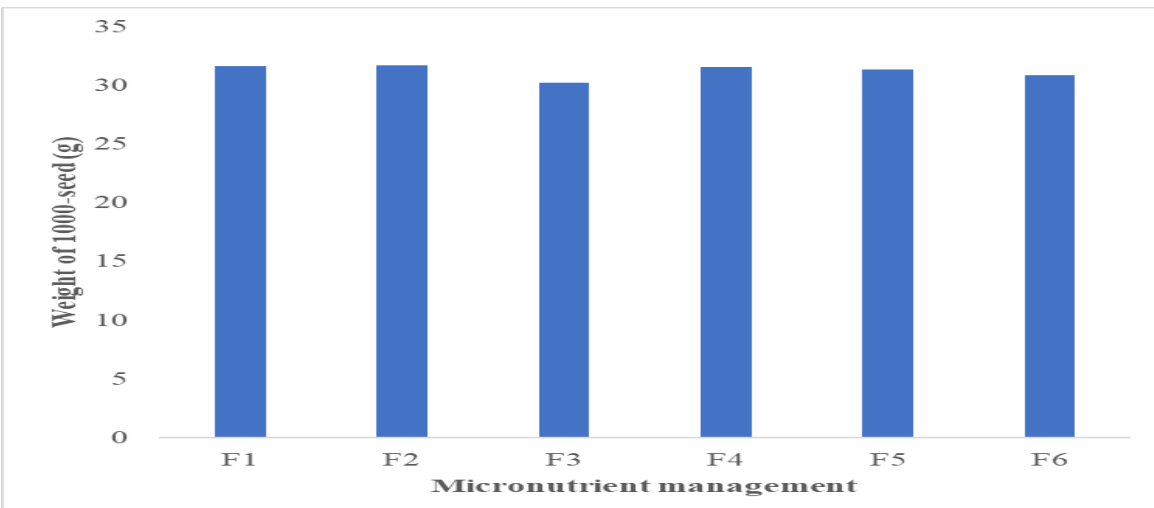



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 19**. 1000-seed weight of lentil as influenced by variety (LSD $_{(0.05)}$ = 3.129).

### 4.10.2 Effect of micronutrient management

The 1000-seed weight of lentil was significantly influenced by micronutrient management (Figure 20 and Appendix IX). The highest 1000-seed weight (31.68 g) was recorded from $F_2$ which was similar to $F_1$ (31.60 g), $F_4$ (31.57 g), $F_1$ (31.37 g) and $F_6$ (30.88 g) and the lowest 1000-seed weight (30.22 g) recorded from $F_3$ which was similar to $F_6$ (30.88 g). The maximum 1000-seed weight (16 g) was found by Quddus *et al.* (2014) and 25 g by Singh and Bhatt (2013) for variation of zinc micronutrient. Similarly different amount of boron showed maximum 1000-seed weight (16.2 g) as reported by Quddus *et al.* (2014). Various combinations of boron and zinc also showed varied 1000-seed weight of lentil as reported by Quddus *et al.* (2014).




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 20.** 1000-seed weight of lentil as influenced zinc and boron management (LSD $_{(0.05)}$ = 0.928).

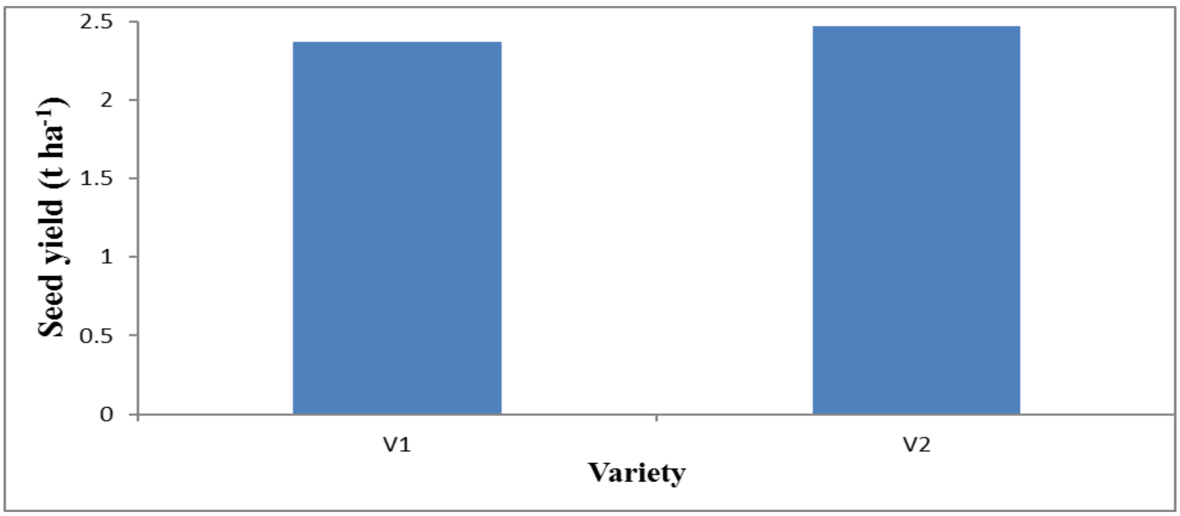
### 4.10.3 Interaction of variety and micronutrient management

The interaction between variety and micronutrient management significantly affected the 1000-seed weight of lentil (Table 7 and Appendix IX). The highest 1000-seed weight of lentil (34.87 g) was obtained from treatment combination of $V_1F_1$ which similar to $V_1F_2$ (34.57 g), $V_1F_4$ (34.77 g) and $V_1F_5$ (33.93 g). The lowest 1000-seed weight of lentil (27.13 g) was found from treatment combination of $V_2F_3$ that similar to $V_2F_1$ (28.33 g), $V_2F_4$ (28.37 g) and $V_2F_6$ (28.25 g).

### 4.11 Seed yield

#### 4.11.1 Effect of variety

There were no significant variations of seed yield recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 21 and Appendix X). The numerically maximum seed yield recorded from BARI Masur-8 (2.37 t $ha^{-1}$) and minimum from Binamasur-8 (2.47 t $ha^{-1}$). Similar variation of seed yield for lentil variety was also found by Zaman *et al.* (2022) and Khatun *et al*. (2021).

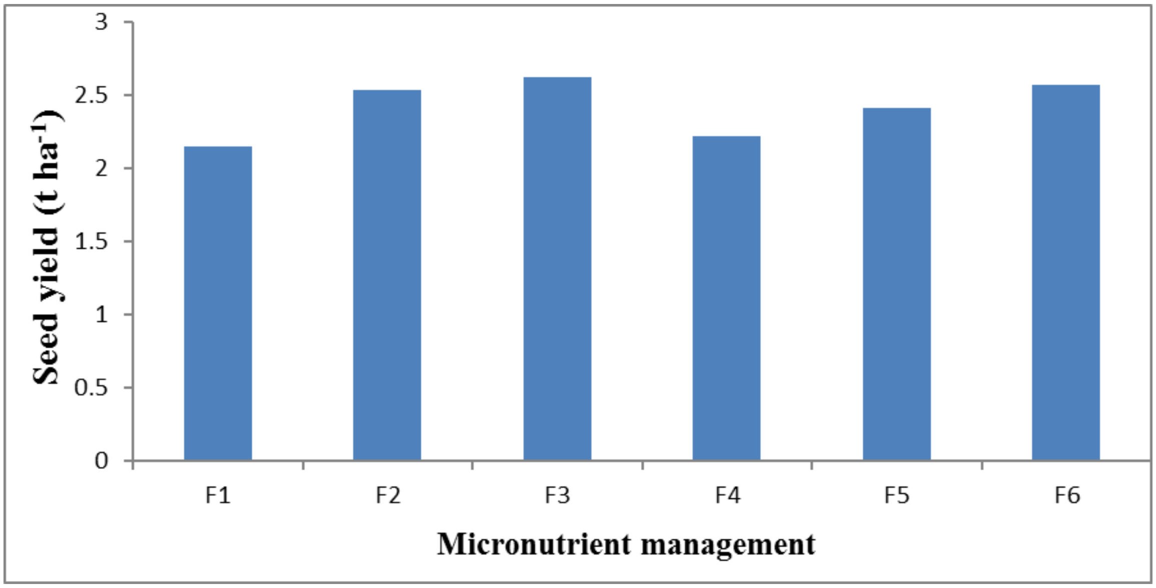



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 21**. Seed yield of lentil as influenced by variety.

#### 4.11.2 Effect of micronutrient management

Seed yield of lentil was significantly influenced by micronutrient management (Figure 22 and Appendix X). The highest seed yield (2.62 t $ha^{-1}$) was recorded from $F_3$ which similar to $F_2$ (2.53 t $ha^{-1}$), $F_5$ (2.41 t $ha^{-1}$) and $F_6$ (2.57 t $ha^{-1}$) and the lowest seed yield (2.15 t $ha^{-1}$) from $F_1$ which similar to $F_4$ (2.22 t $ha^{-1}$) and $F_5$ (2.41 t $ha^{-1}$). Hossain *et al.* (2020) showed highest yield (1.81 $tha^{-1}$) by using combination of Zn @ 3 kg $ha^{-1}$+B @ 2 kg $ha^{-1}$+Mo @ 1 kg $ha^{-1}$. Quddus *et al.* (2014) showed highest yield (1.16 $tha^{-1}$) by using combination of Zn @ 3 kg $ha^{-1}$+B @ 1.5 kg $ha^{-1}$.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 22.** Seed yield of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ = 0.358).

### 4.11.3 Interaction of variety and micronutrient management

The interaction between variety and micronutrient management significantly affected the seed yield of lentil (Table 8 and Appendix X). The highest seed yield of lentil (2.91 t $ha^{-1}$) was obtained from treatment combination of $V_2F_6$ which similar to $V_1F_2$ (2.64 t $ha^{-1}$), $V_1F_3$ (2.79 t $ha^{-1}$), $V_1F_5$ (2.48 t $ha^{-1}$), $V_2F_2$ (2.41 t $ha^{-1}$), $V_2F_3$ (2.45 t $ha^{-1}$) and $V_2F_4$ (2.48 t $ha^{-1}$). The lowest seed yield of lentil (1.96 t $ha^{-1}$) was found from treatment combination of $V_1F_4$ that similar to $V_1F_1$ (2.09 t $ha^{-1}$).

**Table 8.** Combined effect of variety and micronutrient management on seed yield, straw yield, biological yield and harvest index of lentil

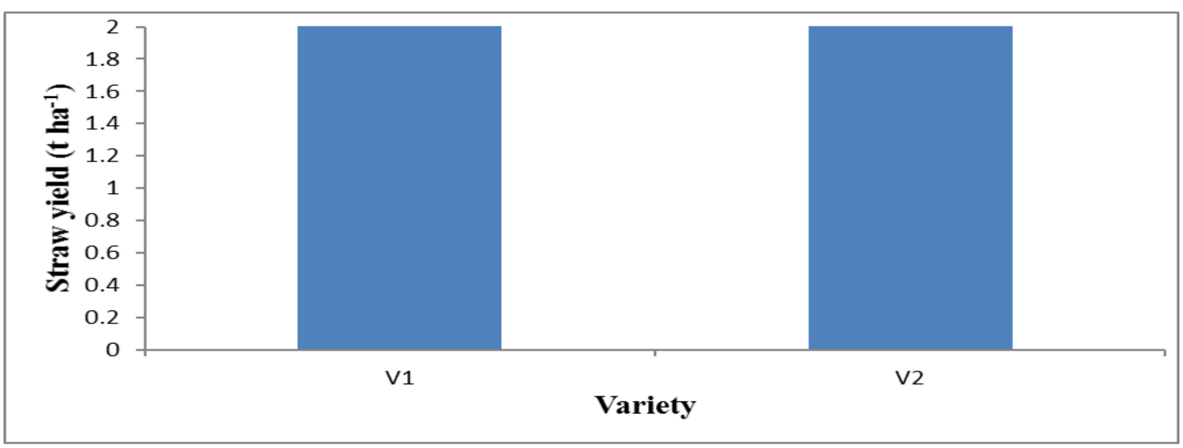
| Interactions | Seed yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest Index (%) |
|---|---|---|---|---|
| **$V_1F_1$** | 2.09de | 1.79abc | 3.89bc | 53.73a-d |
| **$V_1F_2$** | 2.64abc | 2.13ab | 4.78a | 55.62a-d |
| **$V_1F_3$** | 2.79ab | 2.22a | 5.02a | 55.52a-d |
| **$V_1F_4$** | 1.96e | 1.74bc | 3.69c | 53.32bcd |
| **$V_1F_5$** | 2.48a-d | 1.79abc | 4.27abc | 58.36ab |
| **$V_1F_6$** | 2.24cde | 1.96abc | 4.20abc | 53.16cd |
| **$V_2F_1$** | 2.20cde | 1.63c | 3.83bc | 58.03abc |
| **$V_2F_2$** | 2.41a-e | 1.89abc | 4.29abc | 56.07a-d |
| **$V_2F_3$** | 2.45a-e | 2.01abc | 4.46abc | 54.91a-d |
| **$V_2F_4$** | 2.48a-d | 2.07abc | 4.56ab | 54.83a-d |
| **$V_2F_5$** | 2.35cde | 2.15ab | 4.49abc | 53.13d |
| **$V_2F_6$** | 2.91a | 2.05abc | 4.96a | 58.65a |
| **LSD $_{(0.05)}$** | 0.506 | 0.478 | 0.884 | 5.087 |
| **CV (%)** | 38.91 | 45.44 | 11.88 | 5.39 |

$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8, $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

### 4.12 Straw yield

#### 4.12.1 Effect of variety

There were no significant variations of straw yield recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 23 and Appendix X). The maximum straw yield was given by BARI Masur-8 (1.94 t ha$^{-1}$) and minimum by Binamasur-8 (1.97 t ha$^{-1}$).

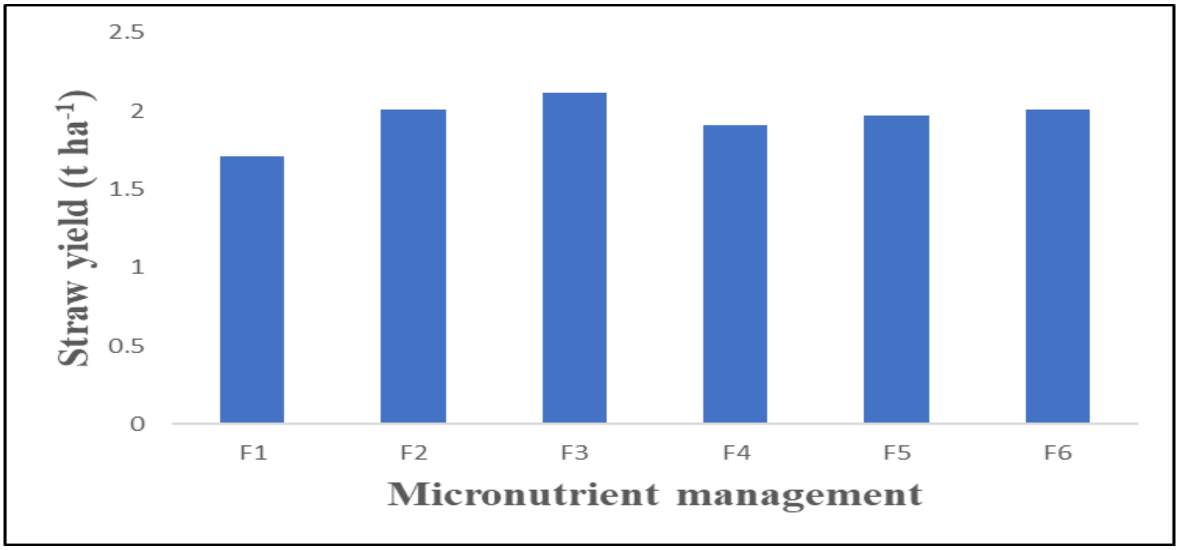



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 23**. Straw yield of lentil as influenced by variety.

### 4.12.2 Effect of micronutrient management

Straw yield of lentil was significantly influenced by micronutrient management (Figure 24 and Appendix X). The highest straw yield (2.12 t $ha^{-1}$) was recorded from $F_3$ which similar to $F_2$ (2.01 t $ha^{-1}$), $F_4$ (1.91 t $ha^{-1}$), $F_5$ (1.97 t $ha^{-1}$) and $F_6$ (2.01 t $ha^{-1}$) and the lowest straw yield (1.71 t $ha^{-1}$) from $F_1$ that similar to other treatments except $F_3$ (2.12 t $ha^{-1}$). Khurana *et al.* (2012) and Quddus *et al.* (2014) showed highest yield (3.6 t $ha^{-1}$) and (2.4 t $ha^{-1}$) respectively.




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 24.** Straw yield of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ = 0.338).

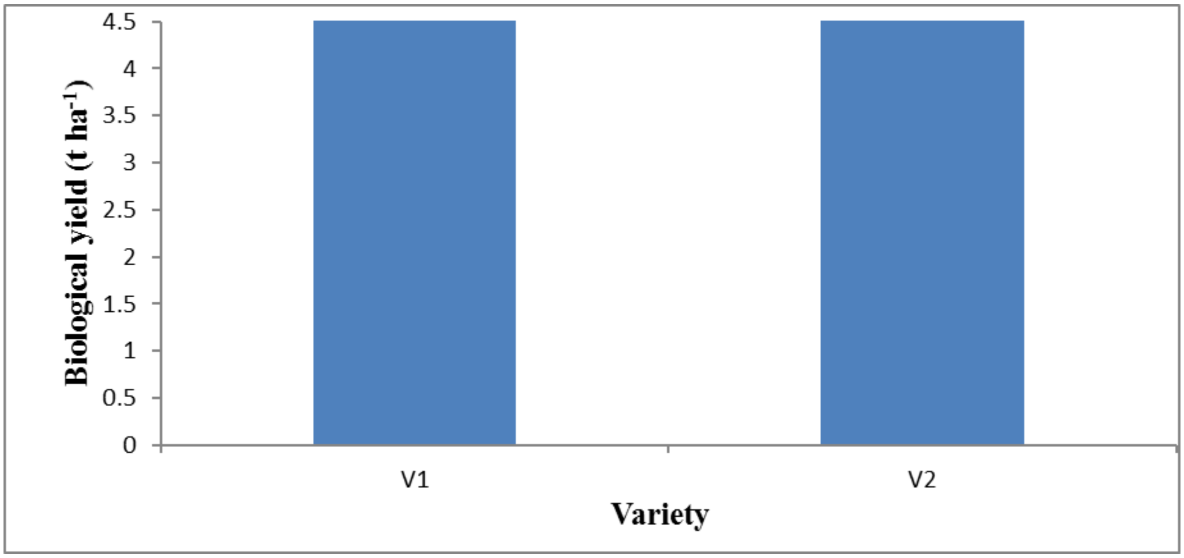
### 4.12.3 Interaction of variety and micronutrient management

The interaction between variety and micronutrient management significantly affected the straw yield of lentil (Table 8 and Appendix X). The highest straw yield (2.22 t $ha^{-1}$) of lentil was obtained from treatment combination of $V_1F_3$ which similar to $V_1F_1$ (1.79 t $ha^{-1}$), $V_1F_2$ (2.13 t $ha^{-1}$), $V_1F_5$ (2.79 t $ha^{-1}$), $V_1F_6$ (1.96 t $ha^{-1}$), $V_2F_2$ (1.89 t $ha^{-1}$), $V_2F_4$ (2.07 t $ha^{-1}$), $V_2F_6$ (2.05 t $ha^{-1}$), $V_2F_5$ (2.15 t $ha^{-1}$) and $V_2F_3$ (2.01 t $ha^{-1}$). The lowest straw yield (1.63 t $ha^{-1}$) of lentil was found from treatment combination of $V_2F_1$ which was similar to all other treatments except $V_1F_3$ (2.22 t $ha^{-1}$), $V_1F_2$ (2.13 t $ha^{-1}$) and $V_2F_5$ (2.15 t $ha^{-1}$).

### 4.13 Biological yield

### 4.13.1 Effect of variety

There were no significant variations of biological yield recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 25 and Appendix X). The maximum biological yield obtained from BARI Masur-8 (4.31 t ha$^{-1}$) and minimum from Binamasur-8 (4.43 t ha$^{-1}$).

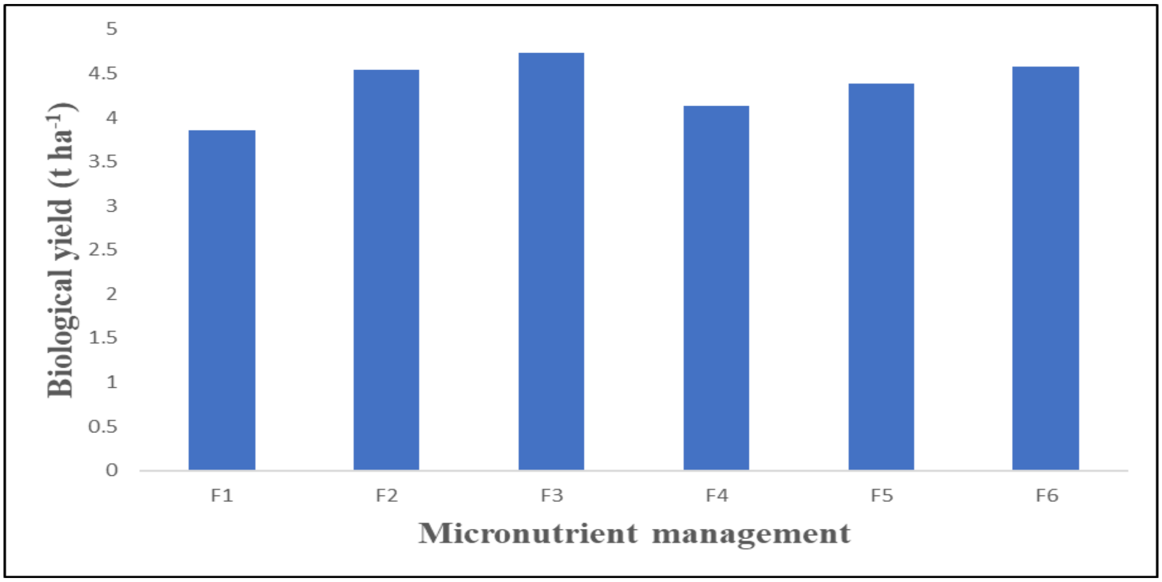



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 25**. Biological yield of lentil as influenced by variety.

### 4.13.2 Effect of micronutrient management

Biological yield of lentil was significantly influenced by micronutrient management (Figure 26 and Appendix X). The highest biological yield (4.74 t ha$^{-1}$) was recorded from $F_3$ which similar to $F_2$ (4.54 t ha$^{-1}$), $F_4$ (4.13 t ha$^{-1}$), $F_5$ (4.38 t a$^{-1}$) and $F_6$ (4.58 t ha$^{-1}$) and the lowest biological yield (3.86 t ha$^{-1}$) recorded from $F_1$ that similar to $F_4$ (4.13 t ha$^{-1}$) and $F_5$ (4.38 t ha$^{-1}$). Khurana and Sanjay (2012) showed highest biological yield (4.9 t ha$^{-1}$) whereas Quddus *et al.* (2014) showed highest biological yield (3.44 t ha$^{-1}$).




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 26.** Biological yield of lentil as influenced by zinc and boron management (LSD $_{(0.05)}$ = 0.625).

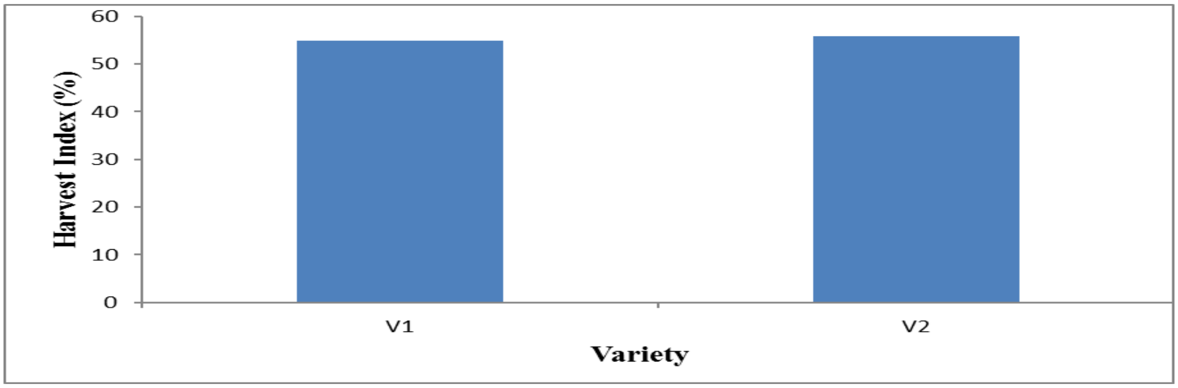
### 4.13.3 Interaction of variety and micronutrient management

The interaction between variety and micronutrient management significantly affected the biological yield of lentil (Table 8 and Appendix X). The highest biological yield of lentil (5.02 t $ha^{-1}$) was obtained from treatment combination of $V_1F_3$ which similar to $V_1F_2$ (4.78 t $ha^{-1}$), $V_1F_5$ (4.27 t $ha^{-1}$), $V_1F_6$ (4.20 t $ha^{-1}$), $V_2F_2$ (4.29 t $ha^{-1}$), $V_2F_3$ (4.46 t $ha^{-1}$), $V_2F_4$ (4.56 t $ha^{-1}$ $tha^{-1}$), $V_2F_5$ (4.49 t $ha^{-1}$) and $V_2F_6$ (4.96 t $ha^{-1}$). The lowest biological yield of lentil (3.69 t $ha^{-1}$) was found from treatment combination of $V_1F_4$ that similar to all other interactions except $V_1F_3$ (5.02 t $ha^{-1}$), $V_2F_6$ (4.96 t $ha^{-1}$), $V_1F_2$ (4.78 t $ha^{-1}$) and $V_2F_4$ (4.56 t $ha^{-1}$).

### 4.14 Harvest Index

#### 4.14.1 Effect of variety

There were no significant variations of harvest index recorded for variety of BARI Masur-8 and Binamasur-8 (Figure 27 and Appendix X). The maximum harvest index was given by Binamasur-8 (55.77 %) and minimum from BARI Masur-8 (54.95 %).

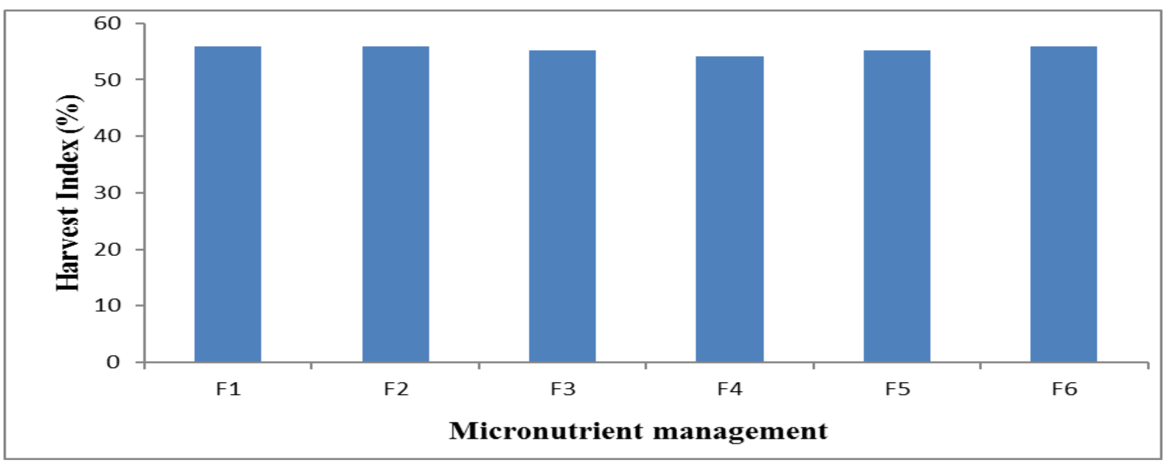



$V_1$ = BARI Masur-8, $V_2$ = Binamasur-8

**Figure 27**. Harvest index of lentil as influenced by variety.

#### 4.14.2 Effect of micronutrient management

Harvest index of lentil was not significantly influenced by micronutrient management (Figure 28 and Appendix X**)**. The numerically maximum harvest index was recorded from $F_6$ (55.90 %) and the minimum from $F_4$ (54.08 %).




$F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray

**Figure 28.** Harvest index of lentil as influenced by zinc and boron management.

### 4.14.3 Interaction of variety and micronutrient management

The interaction between variety and micronutrient management significantly affected the harvest index of lentil (Table 8 and Appendix X). The highest harvest index of lentil (58.65 %) was obtained from treatment combination of $V_2F_6$ which similar to $V_1F_1$ (53.73 %), $V_1F_2$ (55.62 %), $V_1F_3$ (55.52 %), $V_1F_5$ (58.36 %), $V_2F_1$ (58.03 %), $V_2F_2$ (56.07 %), $V_2F_3$ (54.91 %) and $V_2F_4$ (54.83 %). The lowest harvest index of lentil (52.13 %) was found from treatment combination of $V_2F_5$ which was similar to all other interactions except $V_2F_6$ (58.65 %) $V_1F_5$ (58.36 %) and $V_2F_1$ (58.03 %).

# Chapter V

# Summary and Conclusion

# SUMMARY AND CONCLUSION

The experiment was carried out in Sher-e-Bangla Agricultural University, Dhaka during the period from November 2021 to March 2022 to evaluate the influence of variety and micronutrient (zinc and boron) on growth and yield of lentil.

The experiment was laid out in split-plot design with variety in the main plot and micronutrient in the sub-plot. Two micronutrients, viz. zinc (Zn) and boron (B) with variations in method (recommended fertilizer dose (RFD) and organic manure) had been used for both BARI Masur-8 ($V_1$) and Binamasur-8 ($V_2$) varieties to determine the effect of zinc and boron on its growth and yield. The micronutrient management systems were as follows: $F_1$ = Control (No fertilizer), $F_2$ = Recommended fertilizer dose of NPKS (RFD) with Zn as basal dose, $F_3$ = RFD with Zn as foliar spray, $F_4$ = RFD with Zn & B as foliar spray, $F_5$ = 50 % RFD + 50 % cowdung, $F_6$ = 50 % RFD + 50 % cowdung + Zn & B as foliar spray.

Data on different growth parameters, yield components and yield of plants were recorded. The collected data were statistically analyzed using CropStat software and the differences among the means were evaluated by LSD at 5 % level of significance.

Significant effect was found on plant height, number of branches, root dry weight, shoot dry weight, number of nodules, weight of nodules, number of pods, length of pod, number of seeds pod$^{-1}$, 1000-seed weight, seeds yield, straw yield, biological yield and harvest index in different micronutrient management and interaction of variety with fertilizer throughout the cropping season. No significant effect had found for variety except 1000-seed weight.

The highest plant height (37.09 cm) was observed at $F_6$ micronutrient management and the lowest plant height (32.60 cm) observed at $F_1$. In case of interaction, the highest plant height (38.45 cm) recorded at $V_2F_6$ and the lowest plant height (32.53 cm) at $V_2F_1$.

The highest number of branches plant$^{-1}$ (7.03) was found at $F_6$ micronutrient management and the lowest number of branches plant$^{-1}$ (5.13) at $F_5$. In case of interaction, the highest number of branches plant$^{-1}$ (7.40) was found at $V_2F_6$ micronutrient management and the lowest number of branches plant$^{-1}$ (4.80) at $V_2F_5$.

The highest dry weight of root plant$^{-1}$ (159.17 mg) was found at $F_6$ micronutrient management and the lowest dry weight of root plant$^{-1}$ (96.67 mg) at $F_1$. In case of interaction, the highest dry weight of root plant$^{-1}$ (176.67 mg) was found at $V_1F_6$ interaction and the lowest dry weight of root plant$^{-1}$ (83.33 mg) at $V_2F_1$.

The highest dry weight of shoot plant$^{-1}$ (3319.33 mg) was found at $F_6$ micronutrient management and the lowest dry weight of shoot plant$^{-1}$ (2065.17 mg) was observed at $F_1$. In case of interaction, the result was non-significant.

The highest number of nodules plant$^{-1}$ (2.83 at 60 DAS) was found at $F_2$ micronutrient management and the lowest number of nodules plant$^{-1}$ (1.43 at 60 DAS) was observed at $F_5$. In case of interaction, the result was non-significant.

The highest weight of nodules plant$^{-1}$ (10.33 mg at 60 DAS) was found at $F_3$ micronutrient management and the lowest weight of nodules plant$^{-1}$ (3.00 mg at 60 DAS) at $F_5$. In case of interaction, the highest weight of nodules plant$^{-1}$ (26.00 mg at 60 DAS) was found at $V_1F_3$ micronutrient management and the lowest weight of nodules plant$^{-1}$ (2.00 mg at 60 DAS) at $V_1F_4$, $V_2F_1$, $V_2F_3$, $V_2F_5$.

The highest number of pods plant$^{-1}$ (62.37) was found at $F_6$ micronutrient management and the lowest number of pods plant$^{-1}$ (45.30) at $F_2$. In case of interaction, the highest number of pods plant$^{-1}$ (63.20) was found at $V_2F_6$ micronutrient management and the lowest number of pods plant$^{-1}$ (40.07) at $V_2F_2$. The length of pod was showed non-significant for micronutrient management and interaction.

The number of seeds pod$^{-1}$ showed non-significant result for micronutrient management. In case of interaction, the highest number of seeds pod$^{-1}$ (1.83) was found at $V_2F_1$ micronutrient management and the lowest number of seeds pod$^{-1}$ (1.53) at $V_2F_4$.

The highest 1000-seed weight (31.68 g) was found at $F_2$ and the lowest 1000-seed weight (30.22 g) at $F_3$. In case of interaction, the highest 1000-seed weight (34.87 g) was found at $V_1F_1$ combination and the lowest 1000-seed weight (27.13 g) at $V_2F_3$.

The highest seed yield (2.62 t $ha^{-1}$) was found at $F_3$ and the lowest seed yield (2.15 t $ha^{-1}$) at $F_1$. In case of interaction, the highest seed yield (2.91 t $ha^{-1}$) was found at $V_2F_6$ combination and the lowest seed yield (1.96 t $ha^{-1}$) at $V_1F_4$.

The highest straw yield (2.12 t $ha^{-1}$) was found at $F_3$ and the lowest straw yield (1.71 t $ha^{-1}$) was observed at $F_1$. In case of interaction, the highest straw yield (2.22 t $ha^{-1}$) was found at $V_1F_3$ combination and the lowest straw yield (1.63 t $ha^{-1}$) at $V_2F_1$.

The highest biological yield (4.74 t $ha^{-1}$) was found at $F_3$ and the lowest biological yield (3.86 t $ha^{-1}$) was observed at $F_1$. In case of interaction, the highest biological yield (5.02 t $ha^{-1}$) was found at $V_1F_3$ combination and the lowest biological yield (3.69 t $ha^{-1}$) at $V_1F_4$.

Harvest index showed non-significant result for micronutrient management. In case of interaction, the highest harvest index (58.65 %) was found at $V_2F_6$ combination and the lowest harvest index (52.13 %) at $V_2F_5$.

So, the two studied varieties showed similar performance on yield. Foliar application of Zn has the potentiality to increase seed yield. Application of Zn is important for lentil cultivation. The variety Binamasur-8 with 50 % RFD + 50 % cowdung + Zn & B ($F_6$) as foliar spray could bring maximum yield (2.91 t $ha^{-1}$) of lentil that also similar with $F_2$, $F_3$ and $F_4$. Variety BARI Masur-8 gave the highest seed yield (2.79 t $ha^{-1}$) with $F_3$ that similar with $F_2$ and $F_5$.

As the experiment was conducted on one year and in one AEZ, it is suggested to conduct more study in longer period of times and in different AEZ before final Recommendation.

# References

# REFERENCES

Adhikary, P., Giri, S., Hansda, A., Saren, S. and Tudu, B. (2018). Effect of Boron on growth and yield of lentil in Alluvial Soil. *Intl. J. Pure App. Biosci*. **6**(5): 1171-1175.

Agarwala, S.C., Sharma, N.P., Chatterjee, C. and Sharma. C.P. (1981). Development and enzymatic changes during pollen development in boron deficient maize plants. *Plant Nutr*. **3**: 329-336.

Alloway, B.J. (2004). Zinc in Soils and Crop Nutrition. PubI. of international Zinc Association.

Anonymous. (2004). Annual Report of the Coconut Research Institute (CRI) of Sri Lanka. Lunuwila: CRI.

Anonymous. (2009). 25 Years of Pulses Research at IIPR, 1984-2009 (Eds. Shiv Kumar and Mohan Singh), Published by: Indian Institute of Pulses Research, Kanpur 208024, India.

Arif, M., Chohan, M.A., Ali, S. and Khan, S. (2006). Response of wheat to foliar application of nutrients. *J. Agric. Biol. Sci.* **1**: 30-34.

BARC. (2018). Fertilizer Recommendation Guide, Published by Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

BARI. (2017). BARI Masur-8, Developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh.

BBS. (2021). Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Bhatty, R.S. (1988). Composition and quality of lentil (*Lens culinaris* Medik.): A review. *Canadian Inst. Food Sci. Technol. J.* **21**: 144-160.

BINA. (2014). Binamasur-8, Developed by Bangladesh Institute of Nuclear Agriculture (BINA), BAU Campus Mymensingh.

Broadly, M.R., White, P.J., Hamnod, J.P., Zelko, I. and Lux, A. (2007). Zinc in plants. *New Phytol*. **173**: 677-702

Cakmak, I. (2000). Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phytol.* **14**(1): 185-205.

Cakmak. (2008). Enrichment of cereal grains with zinc: agronomic or genetic biofortification*.* *J. Plant Soil* **30**: 185-205

Chakraborty, A. (2009). Growth and yield of lentil (*Lens culinaris* L.) as affected by Boron and Molybdenum application in lateritic soil. *J. Crop and Weed*. **5**(1): 88-91.

Cheng, C. and Rerkasem, B. (1993). Effects of boron on pollen viability in wheat. *Plant Soil*. **155/156**: 313-315.

Dugger, W.M. (1983). Boron in Plant Metabolism. In: Encyclopedia of *Plant Physiology*, New Series (A. Lauchli and R.L. Bicleski, eds). Springer-Vetlng, Berlin. New York. **15**: 626-650.

Dunn, D., Stevers G. and Kendig A. (2005). Boron fertilization of rice with soil and foliar applications on line crop management. *Plant Soil*. **60**: 357.

Grzebisz, W., Wronska, M., Diatta, J.B. and Dullin, P. (2008). Effect of Zn foliar application at early stages of maize growth on patterns of nutrients and dry matter accumulation by the canopy. Part I. Zinc uptake patterns and its redistribution among maize organs. *J. Elementol*. **13**: 17-28.

Gupta, U.C. (1979). Boron nutrition of crops. *Adv. Agron*. **3**: 273-307.

Hossain, M.A., Quddus, A., Alam, K., Naser, H.M., Anwar, B., Khatun, F., Rashid, H., Khatun, F. and Siddiky, A. (2020). Application of zinc, boron, and molybdenum in siol increases lentil productivity, nutrient uptake, and apparent balance, *Canadian* J. Soil Sci., https://doi.org/10.1139/cjss-2019-0141.

ICARDA. (2015). 'BARIMASUR-8': A New Micronutrient-Rich Lentil Variety Released in Bangladesh, Published by ICARDA Communication Team.

Islam, M.M., Karim, M.R., Oliver, M.M.H., Urmi, T.A., Hossain, M.A. and Haque, M.M. (2018). Impacts of trace element addition on lentil (*Lens culinaris* L.). *Agron*. 8(**7**): 100.

Islam, M.R., Riasat, T.M. and Jahiruddin, M. (1997). Direct and residual effects of S, Zn and B on yield and nutrient uptake in a rice-mustard cropping system. *J. Indian Soc. Soil Sci.* **45**: 126-129.

Itoh, S., Tokumaga. Y. and Yumura, Y. (1978). Concentration of heavy metals contained in the soil solution and the contamination of vegetable crops by the excessive absorption of heavy metals, Bull. *Veg. Ornamental Crops Rex. Sm*. **511**: 545.

Jackson, J.F. and Chapman, S.M. (1975). The role of boron in plants. *In Trace Elements in Soil Plant Animal Systems*, (D.T.D. Nicholas and A Esau Ed.) Pub. London. pp. 119-121.

Jahiruddin, M., Haque, M.S., Haque, A.K.M.M. and Ray, P.K. (1992). Influence of boron, copper and molybdenum on grain formation in wheat. *Crop Res.* **5**: 35-42.

Karan, D., Singh, S. B. and Ram, K. (2019). Effect of Zinc and Boron application on Yield of Lentil and Nutrient Balance in the Soil under Indo-Gangetic Plain Zones*. J. Agri Sci.* **1**(4): 206-209.

Kasim. W.A. (2007). Physiological consequences of structural and ultra-structural changes induced by Zn stress in Phaseolus vulgaris. Growth and photosynthetic apparatus. *Int. J. Bot.* **3**(1): 15-22

Khatun, S., Khalil, M.I. and Roknuzzaman, M. (2021). Yield performance of BINA developed Lentil varieties, Bangladesh *J. Nuclear Agric*. **35**: 183-187.

Khurana, M.P.S. and Sanjay, A. (2012). Comparative efficiency of borax and granubor as boron fertilizers for lentil and soybean grown on alluvial alkaline soils. *J. Plant Nutr.* **35**(14): 2145-2155.

Lewis, D.H. (1980). Boron. Are there inter-relations between the metabolic role of boron, synthesis of phenolic phyloalexins and the germination of pollen. *New phytol*. **84**: 264-270.

Li, W.H., Kui, K.C., Chao, N.S., Jem, M.P., Li, C.R., Chu, W.J. and Wang, C.L. (1978). Studies on the cause of sterility in wheat. *J. Northeastern Agri. Coilege.* **3**: 1-8.

Liu, P.P., Koizuba, N., Martin, R.C. and Nonogaki, H. (2005). The BME3 (Blue Micropylar End 3) GAlA zinc finger transcription factor is a positive regulator of Arabidopsis seed germination. *Plant J*. **44**: 960-971.

Marschner, H. (1995). Mineral nutrition of higher plants. 2nd Edition. Academic Press, San Diego. 889 p.

McLean, E., Cogswell, M., Egli, I., Wojdyla, D. and Benoist, B. (2009). Worldwide prevalence of anaenia, WHO Vitamin and Mineral Nutrition Information System, 1993-2005. *Public Health Natr.* **12**: 444-454.

Miller. W.R. and Donahue. L.R. (1997). Soils in our environment. Prentice- Hall of India Nt. Ltd., New Delhi, India. 7th edn. pp. 302-315.

Nambiar. K.K.M. and Motiramani, D.P. (1981). Tissue Fe/Zn ratio as diagnostic tool of *Viciafaba. Phytomorphol.* **45**: 169-173

Nasiri, Y., Zehtab-Salmasi, S., Nasrullahzadeh, S., Najafi, N. and Ghassemi-Golezani, K. (2010). Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.). *J. Med. Plants* Res. **4:** 1733 -1737.

Oktem, A. G. (2019). Effects of different zinc levels on grain yield and some phenological characteristics of red lentil (*Lens culinaris* Medik.) under arid conditions. *Turkish J. Agric. Forestr*. **43**: 1811-1817.

Pandey, N., Gupta, M. and Sharma, C.P. (1995). SEM studies on Zn deficient pollen and Stigma of *Viciafaba. Phytomorphol.* **45**: 169-173.

Pandey, N., Pathak, G.C. and Sharma, C.P. (2006). Zinc is critically required for pollen thnction and fertilization in lentil. *J. Trace Elem. Biol*. **20**: 89-96.

Pandey, N., Pathak, G.C. and Sharma, C.P. (2009b). Impairment in reproductive development is a major factor limiting seed yield of black gram under zinc deficiency. *Biol Plant*. **53**: 723-727.

Pandey, N., Pathak, G.C., Pandey, O.K. and Pandey, R. (2009a). Heavy metals, Co, Ni, Cu, Zn and Cd, produce oxidative damage and evoke differential antioxidant responses in spinach. *Braz. J. Plant Physiol*. **21**: 103-111.

Panhwar, Q.A., Radziah, O., Khanif, Y.M. and Nahar (2011). Application of boron and zinc in the tropical soils and its effect on maize (*Zea mays* L.) growth and soil microbial environment. *Aust. J. Crop. Sci.* **5**: 1649-1654.

Pathak, G.C. and Pandey, N. (2010). Improving Zn density and seed yield of green gram by foliar application of Zn at early reproductive phase. *Indian J. Plant Physiol.* **15**: 338-342.

Paul, S., Roy, T.S., Chakraborty, R., Roy, M. and Sarker, S.C. (2019). Growth performance of lentil by the effect of irrigation and boron splitting as foliar application, *Bangladesh Agron. J*. 22(**2**): 139-150.

Pilbeani, D.J. and Kirkby, E.A. (1983). The physiological role of boron in plants. *J. Plant Nutr*. **6**: 563-582.

Potarzycki, J. and Grzebisz, W. (2009). Effect of Zn foliar application on grain yield of maize and its yielding components. *Plant Soil Environ*. **55**: 519-527.

Quddus, M.A., Naser, H.M., Hossain, M.A. and Hossain, M.A. (2014). Effect of zinc and boron on yield and yield contributing characters of lentil in low ganges river floodplain soil at Madaripur, Bangladesh. *Bangladesh J. Agril. Res*. 39(**4**): 591-603.

Rahman, A., Jahiruddin, M. and Mian, M.H. (1993). Response of two mustard varieties to added sulphur and boron in Old Brahmaputra Floodplain Soils. Bangladesh *J. Nucl. Agric.* **9**: 15-28.

Ray, H., Bett, K., Tar'an, B., Vandenberg, A., Thavarajah, D. and Warkentin, T. (2014). Mineral micronutrient content of cultivars of field pea, chickpea, common bean, and lentil grown in Saskatchewan, Canada. *Crop Sci*. **54**: 1698–1708.

Read, S.A., Obeid, S., Ahlenstied, C. and Ahlenstiel, G. (2019). The role of zinc in antiviral immunity. *Adv. Nutr. Int. J.* **10**: 696-710.

Rerkasem, B., Netsangtip, R., Lordkaew, S. and Cheng, C. (1993). Grain set failure in boron deficient plant. *Plant Soil*. **155/156**: 309-312.

Saha, G., Ghosh, M., Nath, R., Gunri, S.K., Roy, K. and Saha, B. (2018). Effect of boron and zinc on growth, yield and economics of lentil (*Lens culinaris*) in New Alluvial Zone of West Bengal. *Indian J. Agron.* **63**(3): 391-393.

Sharma, P.N., Chatterjee, C., Agarwala, S.C. and Sharma, C.P. (1990). Zinc deficiency and pollen fertility in maize plant. *Indian J. Agron.* **124**: 221-225.

Singh, A.K. and Bhatt, B.P. (2013). Effect of foliar application of zinc on growth and seed yield of late-sown lentil (*Lens culinaris*). *Indian J. Agric. Sci.* **83**(6): 622-626.

Smith, M.R. and MUERS, S.S. (2018). Impact of anthropogenic $CO_2$ emissions on global human nutrition. *Nat. Clim. Change,* **8**: 834-839.

Smith, R.I.I. and Johnson, W.C. (1969). Effect of boron on wheat nectar production. *Crop Sci*. **9**: 75-76.

Tavallali, V., Rahemi, M., Eshgi, S., Kholdebarin, B. and Ramezanian, A. (2010). Zinc alleviates salt stress and increases antioxi-dant enzyme activity in the leaves of pistachio (*Pistacia vera* L. Badami) seedlings. *Turk J. Agri. Food*. **34**: 349-359.

Thavarajah, D., Thavarajah, P., Wejesuriya, A., Rutzke, M., Glahn, R. P., Combs, G. F., and Vandenberg, A. (2011). The potential of lentil (*Lens culinaris* L.) as a whole food for increased selenium, iron, and zinc intake: Preliminary results from a 3 year study. *Euphytica*, **180**: 123-128.

Tisdale, W.L. and Nelson, J.D. (1994). Zinc in Soil Fertility and Fertilizers (Fourth ed) Macmillan Publishing Company, New York, pp. 382-391.

Togay, N., Togay, Y., Erman, M. and Cig, F. (2015). Effect of Fe (iron) and Mo (molybdenum) application on the yield and yield parameters of lentil (*Lens culinaries* Medik.) *Legume Res*. **38**(3): 358-362.

Vaughan, A.K.F. (1977). The relation between the concentration of boron in the reproductive organs of maize plants and their development. *Rhodesian J. Agric. Res*. **15**: 163-170.

Wei, Y., Shohag, M.J.I. and Yang, X. (2012). Biofortification and Bioavailability of rice grain zinc as affected by different forms of foliar zinc fertilization. *PLOS ONE.* **7**: e45428.

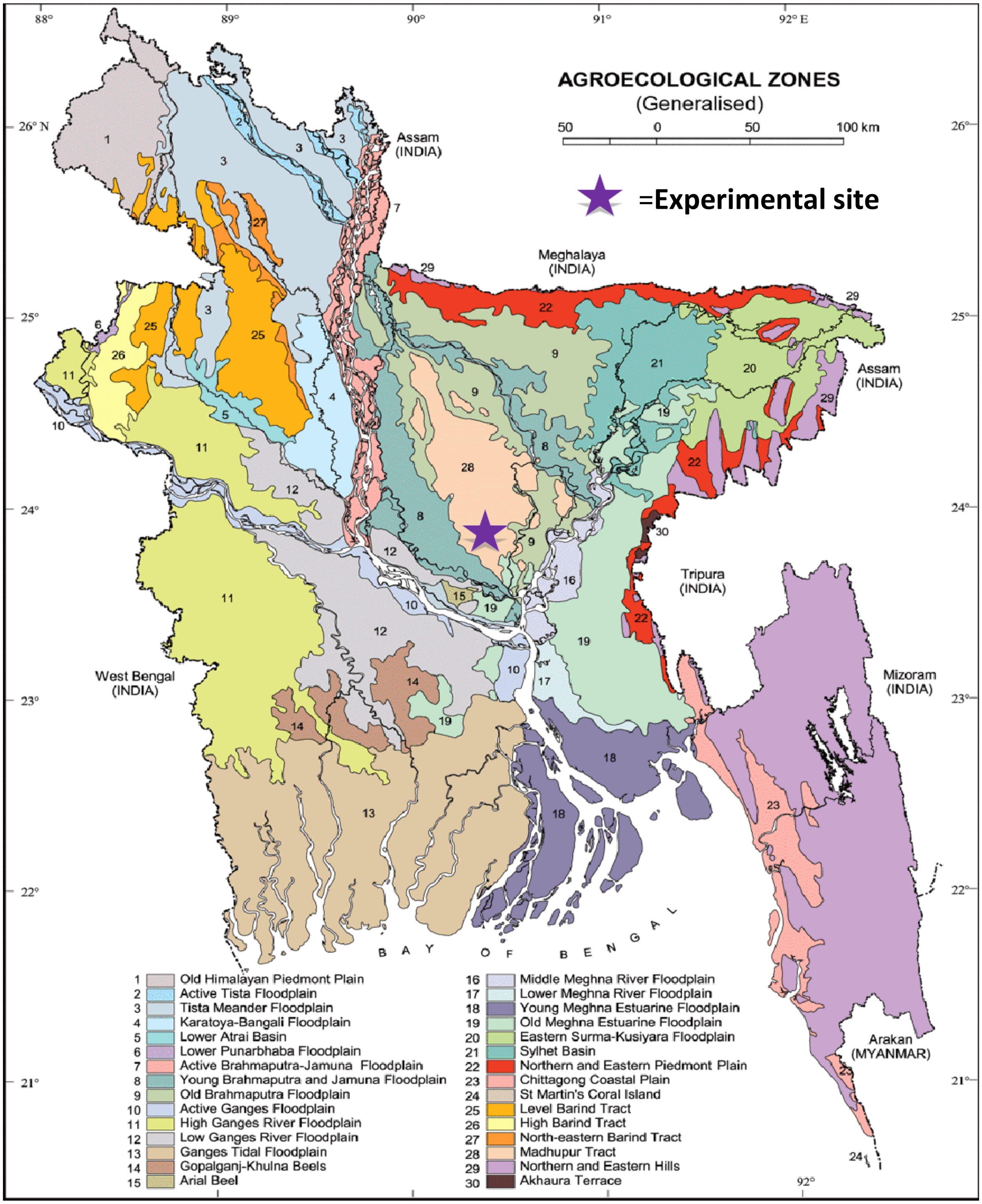
Wessells, K.R. and Brown, K.H. (2012). Estimating the Global prevalence of zinc Deficiency: Results Based on zinc Availability in National Food Supplies and the Prevalence of Stunting. *PLOS ONE.* **7**: e50568.

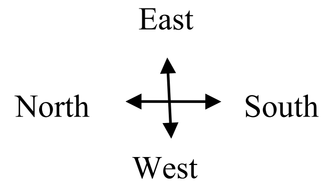
Zaman, M.S.U., Hossain, M.A., Alam, M.J., Alam, A.K.M.M., Ali, M.O., Sarker, D. and Sarker, A. (2022). 'BARI Masur-8': A high-yielding and biofortified lentil cultivar in Bangladesh, *J. Plant Regist*: 1–7.

# Appendices

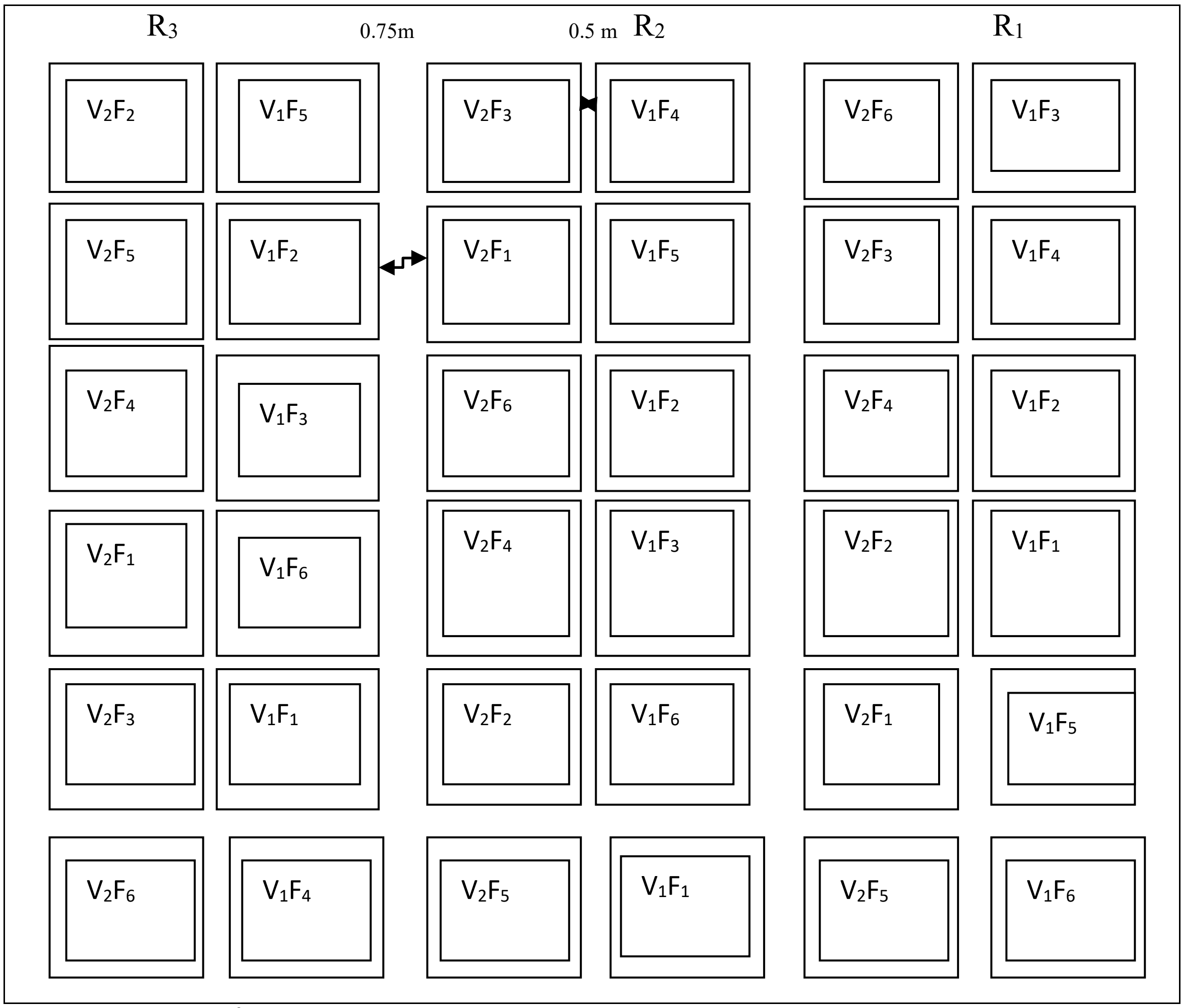
# APPENDICES

## Appendix I. Map showing the experimental sites under study






**Appendix II. Layout of the experimental at field**




Plot size (4.5 × 2) $m^2$, Distance of plot to plot 0.5 m, Replication to replication distance 0.75 m, total land area (29.5 × 14.5) $m^2$.

**Appendix III. Means square values for plant height of lentil at different growth stages**

| Sources of variation | Degrees of freedom | Means square values for plant height at | | | |
|---|---|---|---|---|---|
| | | 30 DAS | 55 DAS | 80 DAS | Harvest |
| Replication | 2 | 5.506 | 0.933 | 7.096 | 11.824 |
| Variety (V) | 1 | 8.517NS | 9.010NS | 20.642NS | 0.03063NS |
| Error (a) | 2 | 1.421 | 1.926 | 12.393 | 10.609 |
| Fertilizer managements (F) | 5 | 3.251* | 1.719NS | 7.148* | 13.761* |
| V X F | 5 | 1.425* | 1.683* | 4.244* | 3.427* |
| Error (b) | 20 | 1.4002 | 2.529 | 4.619 | 8.082 |

* Significant at 5% level, NS = non-significant

**Appendix IV. Means square values for number of branches plant$^{-1}$ of lentil at different growth stages**

| Sources of variation | Degrees of freedom | Means square values for number of branches plant$^{-1}$ at | | | |
|---|---|---|---|---|---|
| | | 30 DAS | 55 DAS | 80 DAS | Harvest |
| Replication | 2 | 0.0578 | 0.8411 | 0.8011 | 1.9600 |
| Variety (V) | 1 | 0.4444NS | 0.2178NS | 1.2844NS | 0.0544NS |
| Error (a) | 2 | 0.1878 | 0.6078 | 1.5011 | 0.7644 |
| Fertilizer managements (F) | 5 | 0.3878* | 0.8791NS | 1.8231* | 2.7566* |
| V X F | 5 | 0.2804* | 1.4498* | 1.0364* | 0.5344* |
| Error (b) | 20 | 0.1071 | 0.9524 | 1.0804 | 0.8236 |

* Significant at 5% level, NS = non-significant

**Appendix V. Means square values for dry weight of root plant$^{-1}$ of lentil at different growth stages**

| Sources of variation | Degrees of freedom | Means square values for dry weight of root plant$^{-1}$ at | | |
|---|---|---|---|---|
| | | 30 DAS | 60 DAS | 90 DAS |
| Replication | 2 | 0.00000836 | 846.333 | 2298.09 |
| Variety (V) | 1 | 0.00157344NS | 2844.44NS | 7583.50NS |
| Error (a) | 2 | 0.00006969 | 482.111 | 1678.30 |
| Fertilizer managements (F) | 5 | 0.00059404* | 1122.13NS | 3563.51* |
| V X F | 5 | 0.00045644* | 879.111* | 694.34* |
| Error (b) | 20 | 0.00029923 | 897.822 | 1919.86 |

* Significant at 5% level, NS = non-significant

**Appendix VI. Means square values for dry weight of shoot plant$^{-1}$ of lentil at different growth stages**

| Sources of variation | Degrees of freedom | Means square values for dry weight of shoot plant$^{-1}$ at | | |
|---|---|---|---|---|
| | | 30 DAS | 60 DAS | 90 DAS |
| Replication | 2 | 0.00000836 | 140127 | 0.168093E+07 |
| Variety (V) | 1 | 0.00157344NS | 24336NS | 264196NS |
| Error (a) | 2 | 0.00006969 | 197281 | 381860 |
| Fertilizer managements (F) | 5 | 0.00059404* | 164337* | 0.132353E+07* |
| V X F | 5 | 0.00045644* | 92626.2* | 623584NS |
| Error (b) | 20 | 0.00029923 | 81088 | 925901 |

* Significant at 5% level, NS = non-significant

**Appendix VII. Means square values for the number of nodules plant$^{-1}$ of lentil at different growth stages**

| Sources of variation | Degrees of freedom | Means square values for the number of nodules plant$^{-1}$ at | |
|---|---|---|---|
| | | 60 DAS | 90 DAS |
| Replication | 2 | 0.3478 | 15.4077 |
| Variety (V) | 1 | 0.0044NS | 0.01778NS |
| Error (a) | 2 | 3.8544 | 3.7855 |
| Fertilizer managements (F) | 5 | 1.6924* | 1.5667NS |
| V X F | 5 | 0.7831NS | 3.1828* |
| Error (b) | 20 | 1.3251 | 1.7599 |

* Significant at 5% level, NS = non-significant

**Appendix VIII. Means square values for the dry weight of nodules plant$^{-1}$ of lentil at different growth stages**

| Sources of variation | Degrees of freedom | Means square values for the dry weight of nodules plant$^{-1}$ at | |
|---|---|---|---|
| | | 60 DAS | 90 DAS |
| Replication | 2 | 38.1111 | 202.293 |
| Variety (V) | 1 | 49.0000NS | 1.4601NS |
| Error (a) | 2 | 60.3333 | 55.9392 |
| Fertilizer managements (F) | 5 | 60.9111* | 84.5017NS |
| V X F | 5 | 25.533* | 72.5434NS |
| Error (b) | 20 | 39.48889 | 78.4497 |

* Significant at 5% level, NS = non-significant

**Appendix IX. Means square values for the number of pods plant$^{-1}$, length of pod, number of seeds pod$^{-1}$ and 1000-seed weight of lentil**

| Sources of variation | Degrees of freedom | Mean square values of | | | |
|---|---|---|---|---|---|
| | | Number of pods plant$^{-1}$ | Length of pod | Number of seeds pod$^{-1}$ | 1000-seed weight |
| Replication | 2 | 145.923 | 0.009836 | 0.01805 | 4.398 |
| Variety (V) | 1 | 425.734NS | 0.0000694NS | 0.00588NS | 310.641NS |
| Error (a) | 2 | 75.921 | 0.0016028 | 0.003219 | 4.760 |
| Fertilizer managements (F) | 5 | 231.383* | 0.001496NS | 0.02228NS | 1.952* |
| V X F | 5 | 76.990* | 0.000856NS | 0.02255* | 0.524* |
| Error (b) | 20 | 164.361 | 0.006259 | 0.02569 | 0.595 |

* Significant at 5% level, NS = non-significant

**Appendix X. Means square values for seed yield, straw yield, biological yield and harvest index of lentil**

| Sources of variation | Degrees of freedom | Mean square values of | | | |
|---|---|---|---|---|---|
| | | Seed yield | Straw yield | Biological yield | Harvest index |
| Replication | 2 | 0.135 | 0.2008 | 0.60137 | 12.607 |
| Variety (V) | 1 | 0.089NS | 0.00588NS | 0.14314NS | 6.068NS |
| Error (a) | 2 | 0.0139 | 0.1593 | 0.19030 | 28.727 |
| Fertilizer managements (F) | 5 | 0.225* | 0.1138* | 0.63092* | 2.983NS |
| V X F | 5 | 0.261* | 0.1113* | 0.54646* | 25.870* |
| Error (b) | 20 | 0.0884 | 0.07874 | 0.26913 | 8.921 |

* Significant at 5% level, NS = non-significant

# Plates

# List of Plates


**Plate 1**. Experimental site

**Plate 2**. Nodules at 60 DAS


**Plate 3**. Field view of experimental plot at harvest


**Plate 4**. Seeds of BARI Masur-8