RESPONSE OF IRRIGATION LEVEL AND BORON SPLITTING AS FOLIAR APPLICATION ON THE GROWTH AND YIELD OF LENTIL

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CERTIFICATE

*This is to certify that the thesis entitled "**RESPONSE OF IRRIGATION LEVEL AND BORON SPLITTING AS FOLIAR APPLICATION ON THE GROWTH AND YIELD OF LENTIL**" submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment 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 **SANCHITA PAUL**, REGISTRATION NO. **18-09035** 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:
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DEDICATED TO MY BELOVED

PARENTS

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RESPONSE OF IRRIGATION LEVEL AND BORON SPLITTING AS FOLIAR APPLICATION ON THE GROWTH AND YIELD OF LENTIL

ABSTRACT

A field experiment was conducted for evaluating the effect of irrigation and boron splitting as foliar spray on growth and yield of lentil at the research field of the Department of Agronomy, Sher-e- Bangla Agricultural University, Dhaka from November, 2018 to March, 2019. The experiment consisted of three levels of irrigation *viz*., I_0: Control, I_1: one irrigation at 25 days after sowing (DAS), I_2: two irrigations at 25 DAS and 40 DAS and boron was applied by four levels *viz*., B_0: Control, B_1: 80% recommended dose as basal + rest 20% as foliar spray (FS) at pre flowering (PF), B_2: 60% RD as basal + rest 40% as FS at PF, B_3: 40% RD as basal + rest 60% as FS at PF. The experiment was full set up in a split-plot design with three replications. Data recorded on the basis of plant length, leaves plant^{-1}, branches plant^{-1}, dry weight plant^{-1}, pods plant^{-1}, seeds pod^{-1}, 1000-seed weight, pod length, seed yield, stover yield and biological yield were found statistically variable with treatments. In case of irrigation result revealed that the highest dry weight plant^{-1} (4.44 g), 1000-seed weight (24.26 g) and seed yield (570.56 kg ha^{-1}) were obtained from I_2 (Irrigations at 25 and 40 DAS). On the other hand, the highest dry weight plant^{-1} (4.40 g), 1000-seed weight (22.87g) and seed yield (598.81 kg ha^{-1}) were recorded from B_3 (40% RD as basal + rest 60% as FS at PF). Result also showed that most of the treatment combinations gave the statistical similar results in case of seed yield where numerically the highest seed yield (638.23 kg ha^{-1}) was recorded in I_2B_3. Numerically the highest stover yield (751.26 kg ha^{-1}) and biological yield (1389.4 kg ha^{-1}) was recorded from I_2B_3 combinations. The combined use of irrigation and boron was preferable than their individual application. It may be concluded that I_0B_3 combinations may be suitable for lentil cultivation if the crop received at least 12.8 mm rainfall during its maximum vegetative stage.

Key words: Boron, irrigation, yield characteristics, lentil, foliar application, splitting etc.

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ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
Cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agriculturel Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Milligram
FS	=	Foliar spray
No.	=	Number
^oC	=	Degree Celceous
SAU	=	Sher-e-Bangla Agricultural University
PF	=	Pre flowering
WHO	=	World Health Organization
µg	=	Microgram
RD	=	Recommended Dose

CHAPTER I

INTRODUCTION

Legumes are considered the world's most essential food source after cereals, as they are the main protein and energy sources for humans. It can be a good alternative to animal protein at the moment. Bangladesh is an agricultural country where different types of pulse crops are cultivated, including lentil, chickpea, cowpea, blackgram, mungbean, field pea and grass pea. People of Bangladesh get their most of the vegetable proteins from pulse. It is cultivated in an area of 898 million ha in Bangladesh with 389 million tons of output and 434 kgha^{-1} of productivity (BBS, 2018). According to the recommendation of the FAO, (2013), a minimum pulse intake per capita should be 80 g per day, whereas in Bangladesh it is 17.92 g per day. Pulse is an essential food crop because it acts as an easily accessible source of high protein, amino acids such as isoleucine, leucine, lysine, valine, good taste, and easily digestible components. Because of nutritional values and economic importance, new methods to increase the production of pulses need to be created. One of these new methods is the use of foliar fertilization, including micronutrients, which is known to be more active on yield, protein content, and nitrogen fixation.

Lentil (*Lens culinaris* Medik) is one of the oldest annual pulse crops cultivated for over 8,000 years as a major food source. It belongs to the *Papilionaceae* suPFamily under the *Leguminosae* family. Lentil is the world's fourth largest pulse (legume) plant after bean (*Phaseolus vulgaris* L.), pea (*Pisum sativum* L.), and chickpea (*Cicer arietinum* L.). Longer shelf life, market availability with lower cost makes lentils as an affordable and easy addition to our pantry. Lentil have a great deal of nutritional value not only in the form of vitamins but also as minerals and protein. Lentil seed is rich in essential nutrients, mineral products and soluble and in soluble dietary fivers. Seed contains 25% protein, 1.1% fat and 59% carbohydrate. A significant amount of vitamin A and B is also provided by lentil. Lentil is a perfectly digestible source of protein that is lower than other legumes due to anti-nutritional factors such as haemaglutinins, flavones and oligosaccharides. Lentil plays a major role in cultivation rotation to maintain soil fertility by adding atmospheric nitrogen to their root nodules using symbiotic rhizobic material to achieve greater yields.

India, Turkey, Syria, Pakistan, Spain and Bangladesh are the main lentil growing countries in the world. Totally in Bangladesh, 176,633 metric tons of lentil from an area of 385399 million hectares were produced during 2017-2018 (BBS, 2018). Lentil can be successfully grown in Bangladesh due to favorable weather and soil. But the country's average production of lentil is low compared to the leading lentil growers of the world. The main reasons for lower lentil production are mainly due to marginal and weak soil fertility, management practices, insufficient irrigation, poor pests and diseases control measures and higher flower falling rate. Above all, poor fertilization is behaving one of the stronger causes for low production of lentils.

Moisture is the major factor in many parts of the world which limits crop production. Plant physiological processes for example photosynthesis, cellular growth and turgidity, etc. are directly or indirectly influenced by irrigation (Reddi and Reddi, 1995). Siliquae per plant, seed and oil yield decreased with higher water pressure (Rahnema and Bakhshandeh, 2006). A crop's response to water stress varies with plant species, stage of crop growth, type of soil, climate and season. Water stress also affects plant phenology, development of the leaf area, flowering, setting of the pod and results in low yield. Inadequate water supply in growing stage, may decrease quantity and quality of crop (Debaeke and Aboudrare, 2004). In contrary, nutrient leaching, reduced crop production and wastage of water are also reported (Pang *et al*. 1997; Sezen *et al*. 2006). Further irrigation can adversely affect plant quality. First irrigation should be provided at the planting stage 35-40 days and second at the filling phase. Pod formation followed by flower initiation is the most critical stage for moisture stress. Vegetative stage, pre-flowering stage and pod setting stage are crucial stages of lentil stages for water use. The substantial increase in the yield characteristics of lentils can be done by using irrigation water, even though most farmers in Bangladesh do not use irrigation water in pulses as well as lentil (Quah and Jafar, 1994).

Foliar application of nutrients can increase the use of nutrients and reduce pollution by lowering the amount of fertilizer applied to the soil directly (Abdo-F, 2001). In addition, foliar nutrient feeding could have facilitated absorption of nutrient through root leading to the improvement of root growth and nutrient absorption (El-Fouly and El-Sayed, 1997). Boron is an addictive substance in the growth, development and quality of plants (Pilbeam and Kirkby, 1983; Marschner, 1995; Brown *et al*. 1999; Dordas *et al*. 2007). Boron also plays a crucial role in sugar exchange, nitrogen fixation, protein synthesis, saccharose synthesis, cell wall formation, membrane stability and K^+ movement (Singh *et al*. 2014). B is also functionally related to one or more processes of calcium utilization, cellular division, flowering, fruiting, metabolism of carbohydrate and nitrogen, disease resistance, water relationships and triggering certain reactions (Sprague, 1951). Boron deficiency in soil is a major reason for reduced crop yields in Bangladesh, India, Nepal and China (Anantawiroon *et al.* 1997). Boron deficiency results in plant sterility due to reproductive tissue malformation that affects pollen germination, leading to increased flower fall and decreased fruit area (Subasinghe *et al*. 2003). Symptoms of widespread B deficiency in crop includes deformation or discoloration of fruit or grain, disruption of flowering and fruiting and poor yields (Shorrocks, 1991; Ho, 2000).

For maintaining production of lentil in a dry and nutrient deficient soil, irrigation and micronutrient like boron management is very important. By proper irrigation may results in lower root absorbing capacity in crop plants by significantly reducing transpiration levels and impaired active transport and membrane permeability. Foliar application of B at vegetative stage may important role in lentil growth, flowering and pod filling. So there is a great need for soil-based fertilizers and foliar application of boron. Poor and variable seed production is a major problem restricting the yield and fast growth of grain legumes, including tropical lentil. Severe attention needs to be paid to the serious problem like flower fall and bad seed setting.

Considering the above facts, the present work was carried out to examine the effect of boron and irrigation levels on growth and yield of lentil cv. BARI masur-6 with following objectives:

- **i.** to select the optimum irrigation level for the higher production of lentil .
- **ii.** to examine the yield advantage achieving after boron splitting and
- **iii.** to evaluate the promising interaction effect of irrigation level and boron splitting on the growth, yield and yield contributing characters of lentil.

CHAPTER II

RIVIEW OF LITERATURE

Around 2000 BC lentil was introduced first in the Indo-Gengetic plain after its domestication in Western Asia (Cubero, 1981). Lentil is one of Bangladesh's main pulse crops, along with many countries around the world.

Application of iron, zinc, molybdenum and boron has the potential effects over plant micro-nutrition. Boron and irrigation are the most important factors on their relation to maximize the growth; yield and quality contributing traits of lentil. For that studies related to yield and development of lentil have been carried out in our country as well as many other nations. So, the research as far done in Bangladesh is inadequate and inconclusive. Relevant research information regarding the effect of boron with irrigation, which are pertinent to the present experiment, have been discussed and presented in this chapter.

2.1 Effect of Irrigation on growth, yield attributes and yield

Irrigation can affect production, yield components, and lentil yield variables. Dastan and Aslam (1986) found that lentils responded positively to irrigation at 15 and 30 days after sowing in Delhi's sandy loam soil.

Pannu and Singh (1988) demonstrated that the total dry matter and grain yields were affected by moisture deficit in lentil.

Lopes *et al*. (1988) reported that moisture deficiency resulted in lower number of leaves, pods per plant, reduced plant length-root length ration in *Phaseolus vulgaris*.

2.1.1 Growth Parameters

Salter and Goode (1967) mentioned that for species like lentil, plant growth is physiologically more resistant to pressure from moisture than others.

Yadav *et al*. (1992) found that the moisture regime for lentils is relatively better than gram. One irrigation at flower initiation (50 DAS) was found to be most effective in the north-eastern plains (Faizabad); whereas in Central India (Jabalpur), two irrigations was found to be efficient at branching and flowering.

Rathi *et al*. (1995) showed that most critical growth stage for moisture deficit in lentil is pod formation followed by the initiation of flowering. In case of failure of winter rains, 1 to 2 irrigations were required for enhanced productivity of the crop. The importance of irrigation was increased under late planting of the crop due to poor root developments and higher depletion of soil moisture.

Pandey *et al*. (1984) reported that Mungbean is more vulnerable than other grain legumes to water deficits. Water deficit affects the development of the canopy and the overall phase of growth, but tolerance to water deficit is varied.

Krouma (2010) conducted an experiment on chickpea (*Cicer arietinum* L.) in a greenhouse for evaluating the effect of drought stress on plant growth, photosynthesis and water ties. A strong relationship was noticed between the growth of plants and the status of photosynthesis and leaf water. Compared to Chetoui and Kesseb, Amdoun showed the greatest growth of plants and photosynthetic development, the lowest index of drought severity, and major osmotic adjustment under drought pressure. Water use efficiency clearly differentiated the studied genotypes.

2.1.2 Yield Parameters

Giriappa (1998) contemplated that two irrigations of 6 cm depth, each at blooming and pod development stages, were the best for growth, dry matter production, grain yield and grain protein content of lentil cultivated in lateritic sandy loam soils,.

Pannu and Singh (1988) demonstrated that both the total dry matter and the cereal yield of the mungbean were affected by the moisture deficit in the lentil.

Petersen (1989) reported that water deficit reduced pods per plant and mean seed yield in *Phaseolus vulgaris*; whereas, pods per plant and seeds per pod in *Lens culinaris*.

Saxena and Yadov (1976); Mehrotra *et al*. (1977); Bisen *et al*. (1980); Verma and Kalra (1981) and Singh *et al.* (1981) claimed that higher seed production was observed in group of two irrigations compared to one irrigation or no irrigation. Saraf and Baitha, (1979) reported 52% increase of seed yield in lentil was due to increasing water supply from 115 mm to 228 mm.

Yusuf *et al.* (1979); Singh *et al*. (1979); Saraf and Baitha (1979); Verma and Kalra (1981); noted that pre-flowering (branching/maximum vegetative) and pod filling are crucial stages of moisture and, under conditions of inadequate soil moisture, an irrigation increased seed yield in lentils at these levels.

Saraf and Baitha (1979); Bisen *et al*. (1980); Verma and Kalra (1981) and Nema *et al*. (1984) reported that irrigation at pre-flowering stage (vegetative phase) and at the pod filling stage gave increased seed production in lentil.

Zhang *et al*. (2000) demonstrated a 70% increase in the yield of lentil grain with 1 or 2 irrigations at flowering or pod-filling stages.

For assessing the effect of supplementary irrigation and bio-fertilization on lentil yields, Attia and Barsoum (2013) conducted two field trials in Egypt. They tested three irrigation treatments without additional irrigation (rain-fed), an additional 45 mm irrigation and two additional 90 mm irrigation and suggested the application of two additional irrigations (90 mm) for higher lentil yields.

Lal *et al*. (1988) reported that drought at filling stage diminishes both the number of pods per plant and the number of seeds per pod brought about decreased yield of lentil.

Erskine and Ashkar (1993) and Hudak and Patterson (1995) claimed that irrigation during the lentil grain filling stage increases the yield.

Bhattacharya (2009), Hosseini *et al*. (2011) and Khourgami *et al*. (2012) also found the positive feedback of supplementary irrigation on lentil production.

Sarker *et al*. (2003) stated that irrigation increases the lentil yield during the reproductive stage.

Panahyan-e Kivi *et al.* (2009) set up a study utilizing various paces of irrigation and lentil cultivars with a minimum yield of 869 $kgha^{-1}$ and a total yield of 1340 $kgha^{-1}$.

Venkateswarlu and Ahlawat (1993) observed noticeable increase of lentil production because of irrigation. They found wet moisture regime (IW/CPE = 0.6) gave higher yield than the dry moisture regime (IW/CPE = 0.35) on sandy loam soils in Delhi.

Manjunath *et al*. (2010) expressed that irrigating lentil at blooming stage increased the grain yield significantly over no irrigation to the tune of 9.01 and 10.73% during 2005–06 and 2006–07, separately. They found a large number of pods per plant, grains per plant and 1000-grain weight under groups of crops treated with irrigation.

Kahraman *et al*. (2016) concluded that under semi-arid environment supplemental irrigation can improve lentil production.

Rad *et al.* (2010) conducted a study on eighteen selected genotypes of lentil to evaluate the effect of water stress on them. They stop irrigation in all plots with first flower appearance and then interrupt irrigation till harvest stage. With study of drought indices, stress tolerance index (STI) and geometric mean productivity (GMP) had positive and noteworthy relationship in 1% level with yield in drought and normal condition and on basis of both indices Naeen and Shiraz7 genotypes showed the highest resilience than other genotypes.

McKenzie and Hill (1990) conducted an experiment combining two lentil cultivars (Olympic and Titore) with two irrigation treatments. In 1985-86, Titore was sown on two dates, with four irrigation treatments. The 1985-86 season was wetter than average and seed yields were lower, ranging from 0.6 to 1.5 tha^{-1}. Seed yield ranged from 0.32 to 2.5 tha^{-1} under rain shelters. Same time in May sowing un-irrigated plots yielded 1.5 tha^{-1}, while all other plots yielded 0.8 tha^{-1}. In both seasons, there has been little positive response to irrigation. Plants having full irrigation produced 1.27 g DM and 0.72 g seed/m^2 per mm of water received. There was a strong connection between yield and actual evapotranspiration (ET) under the rain shelters. Efficiency in water use (WUE) ranged from 2.81 g DM /m^2 per mm ET in unirrigated plots to 0.69 g per mm ET plant.

Sionit and Kramer (1977) observed in soybean that, the maximum reduction in yield due to moisture deficit occurred during grain filling stage. Majumdar and Roy (1992) reported that the higher grain yield and positive effect on yield components due to irrigation application in summer sesame. Similar result was found in soybean (Rajput *et al*., 1991), in edible pea (Rahman, 2001), and in greengram (Pal and Jana, 1991).

Drastic yield reduction was also reported in mungbean due to water deficit Sadasivam *et al*. (1988); Hamid and Rahih (1990). Reduction of canopy development, inhibition of photosynthetic rate and lower dry matter production were acted as the primary causes of poor production of mungbean.

Hamid and Haque (2003) also showed a drastic yield reduction in mungbean due to water deficit.

Sadasivam *et al*. (1988) reported that water deficit during vegetative phase of mungbean reduces grain production by reducing size of plant, limiting their root growth, number of pods and harvest index.

Talukder (1987) found that wheat seed yield and harvest index were the most susceptible parameters relating to water deficit at flowering as well as pod developmental stages.

Oweis *et al.* (2004) reported that by raising supplemental irrigation (SI) from 1.04 tha^{-1} and 4.27 tha^{-1} (under rain-fed conditions) to 1.81 tha^{-1} and 6.2 tha^{-1} (under full SI conditions) separately improved the lentil grain and biomass yield values.

Dubtez and Mahalle (1998) found that water deficit reduced yield of bushbean by 53%, 71% and 35% when the deficit prevailed during pre-flowering, flowering and pod formation stages, respectively.

Rowe and Neilsen (2010) studied the effects of irrigation to spring sown forage turnips, Brassica rapa var. rapa cv. Barkant. In 1999–2000 and 2000–01 spring to summer seasons, yields, yield components and growth rates of turnips were studied during four stages of vegetative growth in two field experiments of north-west Tasmania. Increases in dry matter content as well as total yield was observed with increase of irrigation rates.

The results also show that in later periods, moisture deficits that limit yields did not restrict yield response to irrigation.

Cselotel (1980) emphasised over regular irrigation particularly at flowering and pod formation stage for producing a large sum of good quality snap beans. Higher number of dry pods per plant, increased seed weight and seed yield per hectare was found when irrigation water was supplied weekly. Haque (1998) reported similar results in peas and greengram, respectively.

Paramjit and Roy (2001) performed a field experiment during the 1998-99 Rabi season at CCS Haryana Agricultural University, Hisar, Agronomy Research Area. The experiment comprised four levels of irrigation i.e. I_0 (no irrigation), I_1 (one irrigation at tillering stage), I_2 (one irrigation at flag leaf stage) and I_3 (two irrigations first at tillering and second at flag leaf stage) and four levels of nitrogen (0, 30, 60 and 90 kg N ha^{-1}). In contrast with other irrigation procedures, the application of two irrigations (I_3) gave impressive results on absorption of nutrients.

The period at the beginning of the flowering stage is most sensitive to water shortage, while maximum yield and yield components were obtained with full irrigation, almost the maximum yield can be ensured by providing adequate irrigation during flowering and fruit formation periods for drought-prone environments (Blum, 2005).

Mustafa *et al*. (2008) concluded that highest number of pods per plant, number of seeds per pod, 100-seed weight of chickpea was obtained with irrigation scheduled at sowing, branching, flowering and pod filling stage when compared with irrigation at sowing, irrigation at sowing & pod filling and irrigation at sowing, branching & pod filling stages.

Abraham *et al*. (2010) found that two irrigations at pre flowering and pod formation stages of chickpea gave highest dry matter accumulation than single irrigation at pre flowering, pod formation and no irrigation.

Parmar *et al.* (2014) reported that 1.0 IW/CPE ratio gave the highest plant length (37.68 cm) in rajma.

Patidar *et al.* (2015) found the highest plant length (42.18 cm) of cowpea recorded under the irrigation at 0.8 IW:CPE ratio at 60 days after sowing.

Roy *et al*. (2016) reported that significant effect on number of pods per plant, seeds per pod, 1000-seed weight, shelling percentage, seed yield, stover yield, biological yield and harvest index of chickpea varieties were due to the different level of irrigation treatments.

Ray *et al*. (2001) conducted a field experiment during Rabi season in chickpea with four levels of irrigation (no irrigation, one irrigation at the branching stage, one irrigation at the branching stage plus one irrigation at the pod development stage, and two irrigations during the branching and pod development stages). The two irrigations group showed the most impressive result in relation to growth and water consumption.

Reddy and Ahlawat (1998) recorded significantly higher number of pods per plant of chickpea with two irrigations scheduled at branching and pod initiation compared to no irrigation, though two irrigations did not affect grains per pod and test weight.

Khade and Varma (1990) found highest number of pods (8.28) per plant, seeds (16.43) per pod and seed yield (1.03 tha^{-1}) with 3 irrigations in *Vicia* sp.

Decreased grain yield due to water deficit was also reported in chickpea, (Provakar and Suraf, 1991), soybean (Rajput *et al*., (1991), greengram and blackgram (Tripurari and Yadav, 1990) and fababean (Khade and Varma, 1990).

Ashraf *et al*. (2011) investigated the effect of different irrigation frequencies on pea seed yield and seed quality under field conditions, Pakistan during the years of 2005-06 and

2006-07. Two promising pea cultivars i.e. Meteor and Climax were tested along with four irrigation levels i.e. 8 irrigations up to flowering (I_1): 1_0 irrigations up to pod filling (I_2): 1_2 irrigations up to seed filling (I_3) and 1_3 irrigations up to seed maturity (I_4) were applied. The results indicated that cultivar Meteor produced significantly higher seed yield (2.5 $tonha^{-1}$) in treatment I_3 while Climax gave maximum yield (2.2 $tonha^{-1}$) in I_4.

Vitkov (1972) found that soil wetting up to 60 cm depth by sprinkler irrigation increased seed yield up 950 kg per hectare in French bean. It was also reported that field pea were most sensitive to water deficit during flowering and early pod filling stage (Lewis *et al*. 1974). They also reported that sorghum grain yield was reduced to 17.34% and 10% over control when water deficit occurred at late vegetative and booting stage respectively.

Bstawi *et al*. (2011) studied the effect of skipping one irrigation during different developmental stages on growth, yield, yield components and water use efficiency of wheat (*Triticum aestivum* L.) in two consecutive winter seasons (2008/09-2009/10) at the Demonstrated Farm, Sudan University of Science and Technology, Shambat, Sudan. Condor cultivar was grown under six irrigation treatments at developmental growth stage, in which one-irrigation was skipped at some of growth stages (seedling W_1, tillering W_2, booting W_3, dough W_4 and repining stage W_5) and irrigation without skipping with intervals of 10 days as control WS. The results showed that there were highly significant variations in all parameters tested due to missing irrigation in both seasons except for plant/m^2 and accumulation of plant length and dry matter in the both seasons in 45 days of reading (booting stage). During (control) irrigation every 10 days gave higher values (with few different stages of seedling and repining) than the other critical stages. In spite of the fact that the outcomes demonstrated an exceptionally good effect on the biomass, straw and grain production, harvest index, efficiency of water use and protein content of the parameters studied. In particular, the highest protein content, grain and straw yield and field water use efficiency was obtained by giving irrigation every 10 days with slightly different skipping on seedling and repining levels. It is necessary to avoid missing irrigation during the tillering and boot phase.

Latif (2006) studied on three irrigations (at 30, 50, 65 DAS) and four levels (at 0, 40.80 and 120 N kgha^{-1}) on growth and yield of rape seed. He observed that the plant length significantly increased with the increasing levels of irrigation and N.

2.2.1 Effect of Boron on growth, yield attributes and yield

Boron is an effective component required for the proper development of pollen grain and sugar translocation. Due to the application of boron, substantial variability was observed in different crops. Brenchley and Thornton (1925); Walter *et al*. (1982); Tripathy *et al*. (1999) observed that deficiency of boron drastically reduces nodulation, growth and yield of legumes due to inadequate supply of carbohydrates to root nodule bacteria and its insufficient conversion.

Anonymous (2009) confirmed that the application of Nitrogen, Phosphorus, Boron and Rhizobium inoculum vastly increased the growth and yield contributing factors of Lentil.

2.2.1 Growth Parameters

Pabitra *et al*. (2018) assessed the effects of boron as foliar applications on production, yield character attribution of lentil cultivated on sandy loam soil at Krishi Vigyan Kendra (KVK) Farm, Ashokenagar (North 24 Pargana), West Bengal as a field trial during the 2015-16 and 2016-17 Rabi season. The results revealed that the highest plant length of 38.86 cm was documented for the treatment of foliar spray with 0.5 % solution of borax at 15, 40 DAS and at flower initiation stage. All the foliar spray of boron at different interval along with soil application of NPK fertilizer gave higher plant length than the control (31.08 cm).

Dixit and Elamathi (2007) stated that the length of the crop, the number of per plant, dry weight per plant, 1000-seed weight, grain yield and haulm yield increased in the green gram by foliar application of boron (0.2%).

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

Vimalan *et al*. (2017) performed a pot experiment to determine the response of green gram (CO 8) after soil application of different levels of B in a boron-deficient soil on the basis of plant length, number of leaves and branches per plant, number of pods per plant, number of seeds per pod, 1000-seed weight, seed yield and protein content (%). Results concluded that B applied (1.5 $kgha^{-1}$) gave significant improvement of all parameters than the control group (0 kg of B ha^{-1}) which gave the poorest performance in respect of yield and protein content of green gram seed.

Padma *et al*. (1989) reported that a field trial performed on French bean cv in Andhra Pradesh. At the boron difference level (2.5 or 5.0 ppm borax) was applied individually and in combination as a two-stage foliar spray (20 and 40 DAS). Improvement of plant length (35 cm), number of per plant (4.3) branches, tap root length (20.4 cm), leaf area (94.12 cm^2), leaf area index (0.60) and dry matter production (62.8 g $plant^{-1}$) were gained from that trial.

Verma *et al*. (1999) came to find that plant length (56.6 cm) with borax @ 10 $kgha^{-1}$ (basal applied flowering), number of branches of per plant (4.6) and dry matter per plant (12.82 g) both with borax @ 5 $kgha^{-1}$ (basal applied in flowering) and number of per plant (12.0) leaves with borax @ 10 (basal applied) were significantly highest in French bean maturity regulation.

Kalyani *et al*. (1993) and Bolanos *et al*. (1994) concluded that the plant length, growth rate and leaf area index in pigeon pea were increased significantly after foliar application of boron as boric acid at rate of 200, 300 and 400 ppm.

Rahman and Alam (1998) observed that apply of B (1.5 $kgha^{-1}$) developed significantly 10.17 percent higher per plant branches in groundnut over control.

Dutta *et al*. (1984) claimed that the application of B (1 $kgha^{-1}$) in mungbean increased the ratio of leaf area, leaf area index, crop growth rate, number of branches per plant, number of pod per plant, seed weight per pod and a decrease in chlorophyll content and net assimilation speed, but the relative growth rate, total dry matter and seed yield and some other growth attributes were not affected.

Abdo (2001) performed two field experiments on morphological, physiological and anatomical parameters of two mungbean (*Vigna radiata*) cultivars V-2010 (Giza-1) and VC-1000 at Giza Experimental Station, ARC, Egypt, during the 1998 and 1999 seasons. In addition to distilled water as command, Zn (0.2 or 0.4 g/l), Mn (1.5 or 2.0 g/l), B (3.0 or 5.0 g/l) and a combination of Zn, Mn and B (0.2, 1.5 and 3.0 g/l, respectively) was sprayed once at 35 DAS. The analysis showed that the applied concentration for Zn, Mn or B foliar spray alone or in a combination, most growing parameters in both seasons substantially increased. Application of Zn (0.2 g/l) along with a mixture of micronutrients results in improved parameters of morphology and physiology. It was observed that mungbean cv. VC-1000 surpassed cv. V-2010 in all parameters under investigation in both seasons. The effect of spraying with low level of Zn, Mn, B and their mixture on the internal structure of the vegetative growth of mungbean cv. VC-1000 was investigated.

Kaisher *et al*. 2010 concluded that Boron (5 $kgha^{-1}$) has impressive effect on plant length, number of branches per plant, number of pods per plant, number of seeds per pod, weight of 1000-seed and yield of mungbean seed after completing their study in sandy loam boron-deficient soil in Bangladesh.

Marschner (1990) reported that Boron toxicity symptoms in most crops are defective symptoms of certain boron-sensitive crops such as legumes, brassica, beets, celery, grapes and fruit trees showing chllorosis and young leaves drying, killed growing points, deformed blossom production, burning of leaf tips and reduced root growth.

Agarwala *et al.* (1981) found that the direct effects of boron were expressed in the close relationship between the availability of boron and the anther's capacity to produce pollen and the viability of pollen grains.

2.2.2 Yield Parameters

Wojcik *et al*. (1999) stated that Boron application directly on soil or as foliar fertilizer is a commonly used technique for raising production (pollination), fruit quality, fruit storage capacity and abiotic stress tolerance i.e. reduction of reactive oxygen species (ROS).

Sakal *et al*. (1999) conducted a field study in calcareous soils for finding the direct and residual impact of varying levels of B on the maize-lentil cropping process. They showed that increasing levels of B application significantly increased maize and lentil yield to 16 kg borax ha^{-1}. It has been found that lentil is more reactive to B.

During the 2010 and 2012 Rabi seasons, Quddus *et al*. (2014) conducted a two-year field experiment at Regional Pulses Research (RPRS), Madaripur to test the impact of Zinc (Zn) and Boron (B) on lentil (*Lens culinaris* Medic) yield and yielding characteristics. The results showed that the yield of seed and stove ranged from 896-1040 $kgha^{-1}$ to 1997-2349 $kgha^{-1}$, respectively.

The highest seed yield 1040 $kgha^{-1}$ was recorded with B level 1.5 $kgha^{-1}$ which was statistically identical with B level 1.0 $kgha^{-1}$ but remarkably higher than that of others. In comparison with the control the production rate was increased 13.8% with boron level 1.5 $kgha^{-1}$.

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

Anonymous (2009) recorded a notable increase in the lentil yield over control by balanced application of N, P, K, S, Zn and B.

The findings of Mondal *et al*. (2010); Bhuiyan *et al*. (2008); Singh *et al*. (2004) agreed with the results obtained in this study. Yielding characteristics of lentil such as plant length, plant pods, seeds per pod and 1000-seed weight showed significant variability due to different boron rates. Highest plant length (28.7 cm) was observed in the group treated with B 1.5 $kgha^{-1}$ followed by B 1.0 $kgha^{-1}$. In contrast, the control group showed the lowest value (25.6 cm).

Pabitra *et al*. (2018) stated a highly significant effect of treatment with boron on the number of pods per plant compared to control in lentil. Number of pods per plant ranged from 29.60 in control plots compared to 45.40 in foliar spray treated group where borax 0.5% solution was given at 15, 40 DAS and at the initiation stage of the seed. While the numbers of pods (42.80 per plant) produced by the treatment of (T_3) 0.5 % solution of borax at 15 and 40 DAS was statistically at par with the foliar spray of 0.5 % solution of borax in to three splits.

Schon and Blevins (1990) noted that foliar split application of B twice at the time of flowering, improved the number of pods per branch, and a total of 0.56 $kgha^{-1}$ was recorded as optimal for the increase of pods per branch.

Rerkasem *et al*. (1990) recorded a great increase in the grain yield of green gram using boron. Though, early growth of crop in boron deficit soil was poor due to the presence of large percentage of abnormal seedling but increasing boron content to 0.36 mg B kg^{-1} of soil eliminates any such abnormal seedlings irrespective of the seed boron content.

Roy *et al*. (2011) carried out an experiment where foliar or soil plus foliar methods of B fertilization increased yield attributes including seed per pod, pod per plant, 1000-seed weight, both seed and straw yield and uptake of B in green gram over control irrespective of genotypes. The maximum increase in all parameters studied was found in the soil plus foliar application method.

Prakash and Dey (1997) reported that black gram sprayed with 0, 0.01 %, 0.02 % or 0.03 % B solutions (as borax) had a beneficial effect on pollen germination, relative growth rate (RGR), leaf area index (LAI), number of flowers per plant, leaf nitrate reductase activity (NRA), number of pods per plant, seed yield per plant, seed yield per hector, 1000-seed weight and harvest index in field trials during Kharif season.

Pandey *et al*. (2013) studied that at 0.1 percent foliar application of boron, helped to increase the production ascribing variable such as number of pods, pod length, number of seeds per pod and yield in black gram at Lucknow.

Ceyhan and Onder (2007) studied the impact of boron on yield and yield components of five genotypes of chickpea (*Cicerarietinum*), namely Akc, in-91, Population, Go'kc, e, I'zmir-92, and Menemen-92 in calcareous soils in central Anatolian Turkey. They reported that significant increase of grain production in all genotypes (except for Go'kc.e) due to application of B @ 1 $kgha^{-1}$.

In B deficient soils, Wallenhammar (2013) investigated the impact of soil and foliar applied boron (B) on flower growth, nectar production, seed yield and germination in organic red clover. The results showed that there is a greater increase in seed yield when B is applied to the soil compared with foliar application.

Singh *et al*. (1992) found that without B, the number, size and weight of nodules decreased a lot and nodular development pattern changed leading to an inhibition of nitrogenase activity in French bean.

Srivastava *et al*. (2005) noted that no pods were formed in B deficit group, compared to a yield of 300 $kgha^{-1}$ with full nutrient treatment in chickpea. They also found that when B was removed leaves became yellowish showing signs of 'little plant'. For the chickpea shoot tips, a critical concentration range of 15-20 ppm B was found.

Schon and Blevins (1987) reported that increased chickpea yields with increasing levels of B from 0 to 2.5 $kgha^{-1}$. Similar outcomes were also observed by Rerkasem *et al*. (1987) in black-gram and green-gram.

Bharti *et al*. (2002) carried out a study in Bihar, India during winter season of 1997-98 to observe the effect of B (0, 1.5 and 2.5 $kgha^{-1}$) apply on yield and nutrition status of chickpea (cv. BG256). They found that the mean seed yield increased with the increasing Zn and B content, whereas stover yield decreased with the increasing B and Zn rate.

Chowdhury *et al*. (2000) also reported a great increase in cowpea seed yield as the implementation of boron was risen.

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

Vrema and Mishra (1999) carried out a pot experiment with mungbean cv. PDM 54; where boron was applied by seed treatment, soil application or foliar spraying. Increased production and growth parameters and seed yield per plant was observed when B was applied at the equivalent of 5 $kgha^{-1}$ during flowering.

Maqbool *et al*. (2018) performed two years of field experiment to assess the effect of boron application and water stress on the production, yield and protein content of mungbean at vegetative and flowering stages. The experiment comprised three water stress levels (regular irrigation, water stress at vegetative stage and water stress at reproductive phase) and four boron levels (0, 2, 4 and 6 $kgha^{-1}$). The improvement of production was mainly due to greater plant length, number of pods bearing branches, number of pods per plant, number of seeds per pod and 1000-grain weight. Boron application at 4 $kgha^{-1}$ caused 17%, 10% and 4% increase in grain yield under regular irrigation, stress at vegetative stage and water stress at reproductive phase, respectively. Protein contents were also increased (9-16%) at same boron treatment. At a higher dose (6 kg ha^{-1}) of boron, most parameters showed a marked decrease. In conclusion, the application of boron in clay-loam soil at a level of 4 $kgha^{-1}$ has done the best to improve mungbean production, yield and seed protein under both normal and water stressed conditions. So, boron is considered important to improve the drought resistance, yield and protein contents of pulses.

Mondal *et al*. (2012) reported that treatment combination involving three branching, pre-flowering and pod-filling irrigations with a foliar operation of 0.2% borax at the flowering stage listed a maximum yield of mung bean seed (898 $kgha^{-1}$) that was relatively higher than other combinations of treatment.

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

Islam and Sarkar (1993) found higher number of seed per pod of mustard due to application of B @ 1.5 $kgha^{-1}$ and above and below of this rate hampered the seed set.

Malewar *et al*. (2001) reported that with increasing levels of borax up to 10 kg Borax ha^{-1}, stover yield increased from 9.47 to 14.41 per cent and seed yield increased from 6.54 to 10.21 per cent in mustard.

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

Harmankaya *et al*. (2008) found that the loss of production of common bean (*Phaseolus vulgaris* L.) was because of B deficiency when the susceptible cultivars were grown in calcareous B deficient soils. In boron-applied genotypes (Sehirali-90, Yunus-90, Karacasehir-90, Onceler-90, Goy niik-98, and Akman-98) the yield was obtained higher than control.

In cereal-clover rotation, Dear and Lipsett (1987) recorded yields of underground clover herbage increased by 25 percent with application B but seed yield increased 21-fold with application B. Increasing boron levels have increased berseem dry matter yield up to 2 ppm.

Patil *et al*. (1993) carried out an experiment to evaluate the effect of boron application on groundnut yield and found that both soil and foliar application of B increased the pod yield significantly.

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

Patel and Golakiya (1996) conducted a pot experiment and found that B at 2 ppm gave the highest pod yield in groundnut.

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

Sherrell (1983) carried out that applying boron at (3 ppm) increased Lucerne seed production.

Singh and Singh (1984) observed that signs of boron toxicity in lentil plants first arose at a rate of 8 ppm. The main symptoms 12 are yellowing of the lower leaf leaflets followed by browning and scorching.

Wang *et al*. (1996) reported a limited risk of B toxicity due to the recommended levels of boron fertilizer in rapeseed-rice crop rotations in south-eastern China at up to 4 to 8 times. The low risk of B toxicity can be attributed to relatively high B removal in harvested seed, seed and stubble, the redistribution of fertilizer B by leaching in the 0 to 60 cm layer and to boron absorption.

From reviewed information it was found that in the case of lentil, the combined application of two irrigation and different levels of boron at different stage improving the growth and yield contributing characters of lentil.

Irrigation and Boron application both have particular positive impact over growth, yield and yield attributing factors not only in Lentil but also over other crops. The time and level of irrigation is very important in case of production of Lentil. On the other hand, administration of boron on soil and as foliar application both have strong constructive feedback on yield attributing factors of Lentil. The effects of irrigation level and application of boron in Lentil production has been studied on different varieties all over the world however, the studies were very scant. In addition, the response of level of irrigation, boron application as foliar spray along with their combined response on *BARI masur-6* variety has not been studied yet in our country. For this, the assessment of these treatments both as single as well as in combination over Lentil production is urgently needed. Because, this experiment will open a new avenue where higher Lentil production will be secured by limited application of irrigation as well as fertilizer.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 3, 2018 to March 9, 2019 to study the effect of irrigation and boron on the yield and quality of lentil (BARI mushur-6). The details of the materials and methods have been presented below:

Description of the experimental site

3.1 Location

The field experiment was done from November 2018 to March 2019 at the Agronomy Farm at Sher-e-Bangla Agricultural University, Dhaka. The experimental field is placed at 23 ° 46 ' N latitude and 90 ° 22 ' E longitude at an elevation of 8.2 m above sea level belonging to the Madhupur Tract Agro-ecological Zone ' AEZ-28 ' (BBS, 2012). The location of the experimental site has been shown in Appendix I.

3.2 Soil

The research field soil is slightly acidic with a low content of organic matter. The selected site was above flood level and sufficient sunshine was available during the experimental period with proper irrigation and drainage system. Soil samples were collected from the experimental field from depths of 0-15 cm. Soil Resources Development Institute (SRDI), Dhaka, performed the soil analysis. Also the experimental plot is high ground and the experimental site soil was clay loam with a pH of 5.45-5.61. Appendix III provides the physicochemical properties and soil nutrient status of the experimental plots.

3.3 Climate and weather

The local climate is subtropical, with high temperatures and heavy rainfall during the Kharif season (April-September) and low rainfall during the Rabi season (October-

March). Information of the meteorological information on air temperature, relative humidity, precipitation and sunshine during the experiment time were obtained from Bangladesh Weather Station, Sher-e-Bangla Nagar. Appendix II provided comprehensive meteorological information on air temperature, relative humidity, total rainfall and soil temperature reported by the Bangladesh Weather Station, Sher-e-Bangla Nagar, Dhaka during the study period.

3.4 Plant materials

BARI Masur-6 is a recommended cross variety of lentil. It grows in Rabi season and was released in 2006. The variety is resistant to diseases, insects and other pests. It is also resistant to stemphylium blight and mosaic virus. There is no tendril at the tip of the leaf. Plant length remains 35-40 cm and bushy type plant. Seed color deep brown. Flower color is violet. Maximum seed yield is 2.2-2.3 t ha^{-1}. Life cycle of the crop is 110-115 days (Krishi Projocti Hatboi 7^{th} edition-2017)

3.5 Experimental treatments

The experiment was consisted of two treatment factors as follows:

3.5.1 Factor A: Irrigation level- 3

I_0 = No irrigation

I_1 = One irrigation at 25 days after sowing (DAS)

I_2 = Two irrigations at 25 and 40 DAS

3.5.2 Factor B: Boron level-4

a. B_0 = 0 kg B/ha (Control)
b. B_1 = **80% recommended dose of B as basal + Rest 20% as foliar spray at pre flowering**: Boron was applied to the experiment plot as boric acid. Boric acid @ 80% recommended dose was applied as basal and rest amount (20%) was applied as foliar application pre flowering stage.

c. B_2 = **60% RD of B as basal + Rest 40% as FS at PF**: Boron was applied to the experiment plot as boric acid. Boric acid @ 60% recommended dose was applied as basal and rest amount (40%) was applied as foliar application pre flowering stage.

d. B_3 = **40% RD of B as basal + Rest 60% as FS at PF**: Boron was applied to the experiment plot as boric acid. Boric acid @ 40% recommended dose was applied as basal and rest amount (60%) was applied as foliar application pre flowering stage.

3.6 Experimental design and layout

The two factors experiment was laid out in Split-Plot Design with three replications of irrigation was in main plot and boron in sub plot. The experiment was consisted of 12 treatments. The treatment combinations were allocated at random with three replication. There were 36 unit plots altogether in the experiment. The size of the each unit plot was 2.5m × 1.5m. The distance maintained between two blocks and plots were 0.5m and 0.3m, plant to plant distance 6cm. The layout of the experiment has been shown in Appendix IV.

3.7 Land preparation

Power tiller was used for the preparation of the experimental field. Then it was exposed to the sunshine for 5/6 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed and deep ploughing was due to obtained good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of the crop. Breaking the soil clods into small pieces after each ploughing was ensured by laddering. The experimental field was made free from all kinds of weeds and stubbles. The plots were spaded one day before sowing.

3.8 Fertilizer application

The calculated entire amount of all fertilizers were applied during final plot preparation. Spading was done to mix the fertilizers properly with the soil in the plot.

Table 1. Fertilizer application

Fertilizers	Dose ($kgha^{-1}$)
Urea	50
TSP	90
MoP	40
Boric acid	8.5

Source: Krishi Projocti Hatboi 7th edition-2017

Total Urea, TSP and MoP were applied as basal dose. Boron was applied as boric acid as basal dose and rest amount were applied as foliar application at pre flowering stage.

3.9 Sowing of seed in the field

Seeds of BARI masur 6 were hand sown in the experimental plot. Seeds were sown on 3 November 2018. The seeds were treated with Autostin® 50 WDG (Carbendazim group) before sowing the seeds to control the seed born diseases. The seeds were sown in rows in the furrows having a depth of 2-3 cm. Row to Row distance was 30 cm.

3.10 Intercultural operations

3.10.1 Thinning

Seedling emergence was completed within 10 days of sowing. First thinning was done following 15 days of sowing to remove unhealthy and lineless seedlings and maintaining the distance from plant to plant is about to 6 cm.

3.10.2 Weeding

The crop was infested with some weeds during the early stages of crop establishment. The crop was weeded thrice; first weeding was done at 15 DAS, second weeding was done at 25days after sowing (DAS) and third weeding was done at 35 DAS.

3.10.3 Irrigation

Irrigation was applied in the experiment field at two times {25 days after sowing (DAS) and 40 (DAS)}. First irrigation was applied at vegetative stage and second irrigation at flowering stage.

3.10.4 Disease and pest management

The research field looked nice with normal green plants. Time to time, the field was observed to detect visual variations between treatments and any form of infestation. The experimental crop was infected with foot and root rot disease and Autostin® 50 WDG (Carbendazim group) was used to control the disease.

3.11 Harvesting and threshing

The plant was harvested after 100 days of sowing for data collection when approximately 80% of the pods reached maturity. The morphological, growth and yield attributes crop sampling was done at harvest stage. For average results, harvesting data were collected on $1m^2$ of the middle portion of each map. Each treatment's harvested plants were brought to the cleaned threshing floor and hand-separated pods from shoes, enabling them to dry well under bright sunlight.

3.12 Crop sampling and data collection

Data of the various lentil parameters were collected from three randomly selected plant samples. Harvesting data were collected from $1m^2$ of each the plot's. The harvested plants had been stored for yield. The sample plants were carefully removed from the soil with khurp so that no seeds were dropped into the soil and then washed, dried on the ground and separated by hand from the pants. Finally, Grain weights were taken at 12% moisture content on an individual plot basis and converted to kg ha-1. Dry weight stover yield has also been taken. At harvest point, data were reported on growth and yield parameters. Information on some morpho-physiological, plant and yield components were also obtained at the final harvest.

3.13 Recording of data

3.13.1 Crop growth parameters

a. Plant length (cm) at 35, 50, 65 DAS and at harvest
b. Number of leaves plant^{-1} at 35, 50, 65 DAS and at harvest
c. Number of branches plant^{-1} at 35, 50, 65 DAS and at harvest
d. Total dry weight plant^{-1} (g) at 35, 50, 65 DAS and at harvest
e. Days to flowering and Days to maturity

3.13.2 Yield contributing characters

a. Number of pods plant^{-1} at 50, 65 DAS and at harvest
b. Number of seeds pod^{-1} at harvest
c. Pod length (cm) at harvest
d. 1000-seed weight plant^{-1} (g)

3.13.3 Yield and harvest index

a) Seed yield (kg ha$^{-1)}$
b) Stover yield (kg ha$^{-1)}$
c) Biological yield (kg ha$^{-1)}$
d) Harvest index (%)

3.14 Procedure of recording data

3.14.1 Plant length (cm)

Different days after sowing (DAS) the plant length was recorded in centimeters (cm). Data were recorded as the average of three (3) plants randomly selected from each plot's inner rows. The length from the ground level to the tip of the leaves was assessed.

3.14.2 Number of leaves plant^{-1}

After sowing the crop duration, the number of leaves plant^{-1} was counted at different days. From pre-selected 3 plant samples from each plot, leaves number plant^{-1} was counted and the mean was calculated.

3.14.3 Number of branches plant^{-1}

The branches were counted from three (3) randomly selected plant at Number of leaves plant^{-1} was counted at different days after sowing of crop duration. Leaves number plant^{-1} were counted from pre-selected 3 plants samples from each plot and mean was calculated.

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

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

3.14.5 Days to flowering

Days to flowering was counted from the date of sowing to the date of 80% of plants flowered in each plot.

3.14.6 Days to maturity

Days to 80% pod maturity were measured by counting the number of days required after sowing to attain maturity of 80% pods. Maturity was measured on the basis of brown colour of leaves including stem and dark grey colour of pods.

3.14.7 Number of pods plant^{-1}

Total number of pods of three (3) plants in each plot was noted and the mean number was expressed per plant basis.

3.14.8 Number of seeds pod^{-1}

Total number of seeds of three (3) plants selected at random from each sampled plants was noted and the mean number was expressed per pod basis.

3.14.9 Pod length (cm)

Length of seeds selected from (3) selected plants from each plot was noted and the mean number was expressed per pod basis.

3.14.10 Weight of 1000-seeds (g)

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

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

The plants of the central 1.0 m^2 area plot were harvested for measuring seed yield. The seed were threshed from the plants, cleaned, dried and then weighed (kgha^{-1}).

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

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

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

Grain yield and stover yield together were regarded as biological yield. The biological yield was calculated and recorded as kg ha^{-1}.

3.14.14 Harvest index (%)

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

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

3.15 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the different level of irrigations and boron and also their interaction. The mean values of all the characters were calculated and analysis of variance (ANOVA) was performed. The significant differences among the treatment means were estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984) and mean value was determined.

CHAPTER IV
RESULTS AND DISCUSSION

Irrigation and Boron are the most important factors on their relation to maximum to growth; yield and parameters contributing to yield of any crops as well as lentil. The experiment was done to evaluate the effect of irrigation and boron on yield, parameters contributing to yield and quality of lentil. Plant length (cm), number of leaves, number of branches, dry matter weight (g), number of pods, number of seeds, seed length, 1000-seed weight, seed yield, stover yield, biological yield and harvest index have been presented in different tables and figures as yield and yield contributing characters. The analyses of variance in respect of all the characters under study have been presented in Appendix V-X11. The detailed experimental findings have been explained and discussed below with supporting references wherever possible.

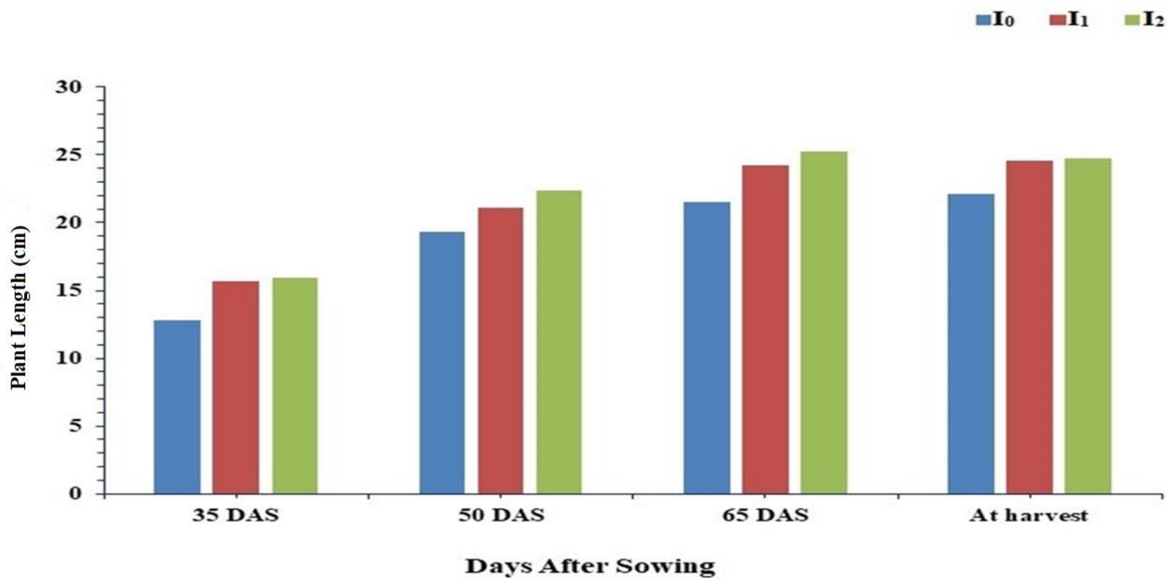
4.1 Growth parameters

4.1.1 Plant length (cm)

Effect of irrigation

At vegetative stage 25 DAS (Days after Sowing) and at flowering stage 40 DAS (Appendix V and fig.1), the plant length of lentil was highly influenced by irrigation. Results showed that the highest plant length (15.91, 22.38, 25.22 and 24.72 cm at 35, 50, 65 DAS and at harvest respectively) was obtained from I_2 (25 DAS and 40 days after sowing) followed by I_1 (25 DAS) level of irrigation. Similarly, the shortest plant length (12.84, 19.35, 21.55 and 22.09 cm at 35, 50, 65 DAS and at harvest) was recorded from I_0 (no irrigation). No significant difference was found between the treatment I_1 and I_2. Results revealed that plant length increased with increasing irrigation levels irrespective of growing period up to at harvest. Similar results was also found by Latif (2006) and Kibria (2013). Paul and Begum (1993) also found that one irrigation at bud initiation stage gave maximum plant length at harvest in mustard plant. Siag *et al*. (1993), Piri *et al*.

(2011) and Hossain *et al*. (2013) showed maximum plant length when two irrigations were applied during branching and silique development stage.

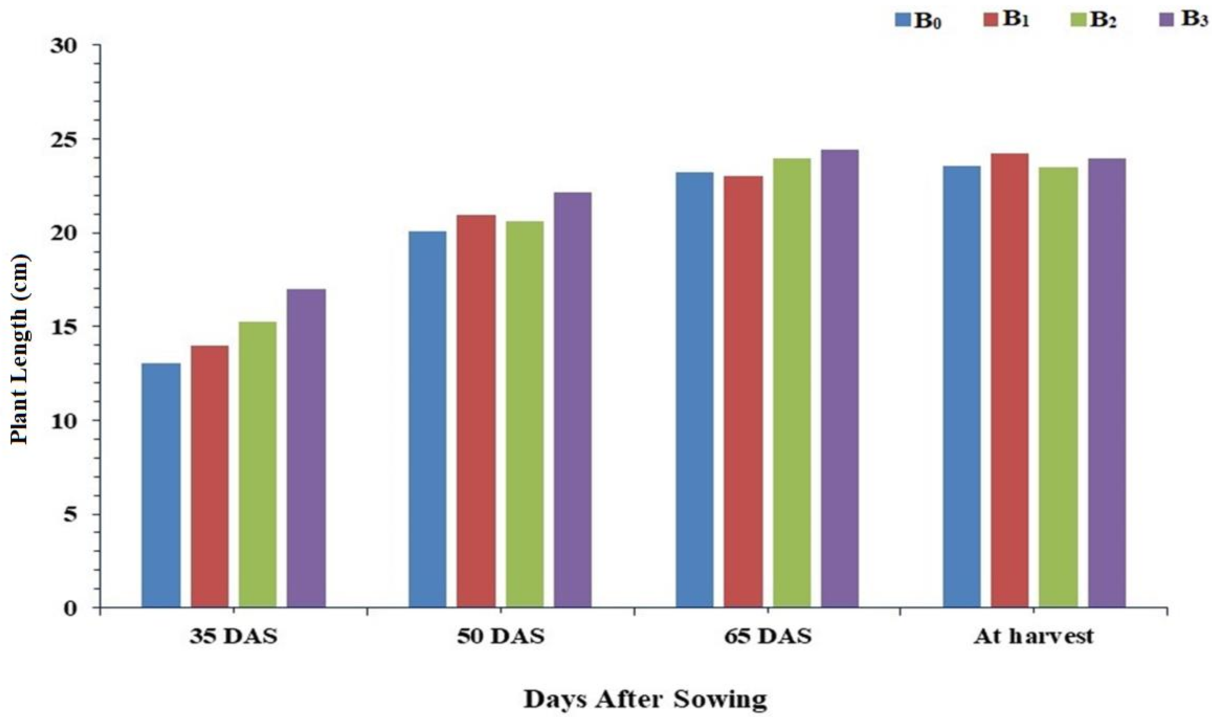


Note: I_0 = No irrigation, I_1= Irrigation at 25 DAS I_2 = Irrigation at 25 and 40 DAS

Fig.1. Response of irrigation on plant length of Lentil at different days after sowing (SE = 1.0735, 0.6354, 0.5148, 0.503 at 35, 50, 65 DAS and at harvest respectively)

Effect of Boron

Lentil plant length also differed considerably due to different treatments of boron on different days after sowing (Appendix V and Fig. 2). Result showed that the highest plant length (16.98, 22.12, 24.39 and 23.97 cm at 35, 50, 65 DAS and at harvest, was obtained from B_3 (40% recommended dose as basal + rest 60% as flower spray at pre flowering) followed by B_2 (60% RD as basal + rest 40% as FS at PF) and B_1 (80% RD as basal + rest 20% as FS at PF) and without boron produce the lowest plant length (13.06, 20.05, 23.24, 23.14 cm at 35, 50, 65 DAS at harvest) respectively was obtained from B_0 (control). Comparable results was additionally found by Vimalan *et al*. (2017). It seemed that 1.5 kg B ha^{-1} vastly increased plant length and control (B_0) had the lowest quality of plant length in lentil.



Note: B_0 = control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3= 40% RD as basal + rest 60% as FS at PF

Fig.2. Response of boron on plant length of Lentil at different days after sowing (SE= 0.6906, 0.8538, 0.9341, 0.9525 at 35, 50, 65 DAS and at harvest respectively)

Interaction effect of irrigation and boron on plant length (cm)

Interaction effect of different levels of irrigation and boron application in terms of plant length also exposed significant variation at different days after sowing (Appendix V and Table 2). Result indicated that the highest plant length (19.74, 22.54, 27.02 and 25.59 cm at 35, 50, 65 DAS and at harvest) was recorded from I_2B_3 (Irrigations at 25 and 40 DAS and Boron at 40% recommended dose as basal + rest 60% as foliar spray at pre flowering) which was statistically similar to I_2B_2. Correspondingly, the lowest plant length (12.71, 19.44, 23.99 and 23.30 cm at 35, 50, 65 days after sowing and control had the lowest plant length in lentil and at harvest respectively was recorded from I_0B_0 which was statistically identical to I_0B_1, I_0B_2. The treatment combination of I_2B_1, I_2B_0, I_2B_2 and I_2B_1 also gave comparatively higher plant length but significantly different from all other treatment combinations.

Table 2: Interaction effect of irrigation and boron on plant length (cm) of Lentil at different days after sowing

Treatment combinations	Plant length (cm) at			
	35 DAS	**50 DAS**	**65 DAS**	**At Harvest**
I_0B_0	12.71 bc	19.44 ab	23.99 a-d	23.30
I_0B_1	11.53 c	18.07 b	19.81d	21.38
I_0B_2	13.28 bc	20.17 ab	21.12 cd	21.56
I_0B_3	13.84 bc	20.23 ab	21.28 cd	22.11
I_1B_0	14.49 bc	21.66 ab	23.54 a-d	24.50
I_1B_1	15.31 a-c	21.35 ab	24.12 a-d	25.34
I_1B_2	15.57a-c	19.66 ab	24.26 a-d	24.40
I_1B_3	17.37 ab	21.72 ab	24.88 a-c	24.21
I_2B_o	11.98 c	19.57 ab	22.20 b-d	22.95
I_2B_1	15.05 bc	23.45 a	25.10 a-c	25.85
I_2B_2	16.88 ab	22.10 ab	26.55 ab	26.56
I_2B_3	19.74 a	22.54 ab	27.02 a	27.59
SE	1.1962	1.4789	1.6179	NS
CV (%)	13.98	12.3	11.85	12

NS = Non significant

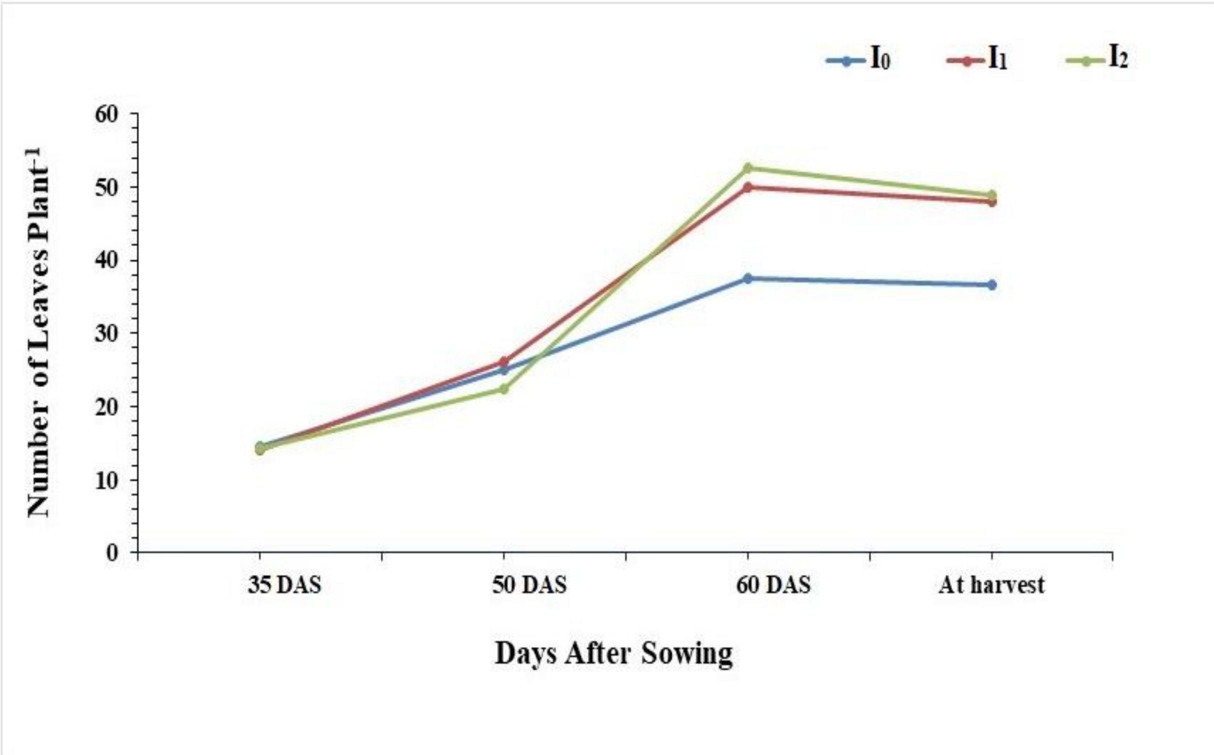
Note: I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

4.1.2 Number of leaves plant^{-1}

Effect of irrigation

The number of leaves plant^{-1} differed considerably due to different treatments of irrigations on different days after the planting. (Figure 3 and Appendix VI). The greatest number of leaves plant^{-1} was obtained at different stages of growth (14.23, 24.35, 52.58 and 48.88 at 35, 50, 65 DAS and at harvest) from I_2 (25 days after sowing and 40 DAS).The lowest number leaves per plant (14.44, 24.99, 37.54 and 36.65 at 35, 50, 65 DAS and at harvest) was obtained from I_0 (control) respectively.

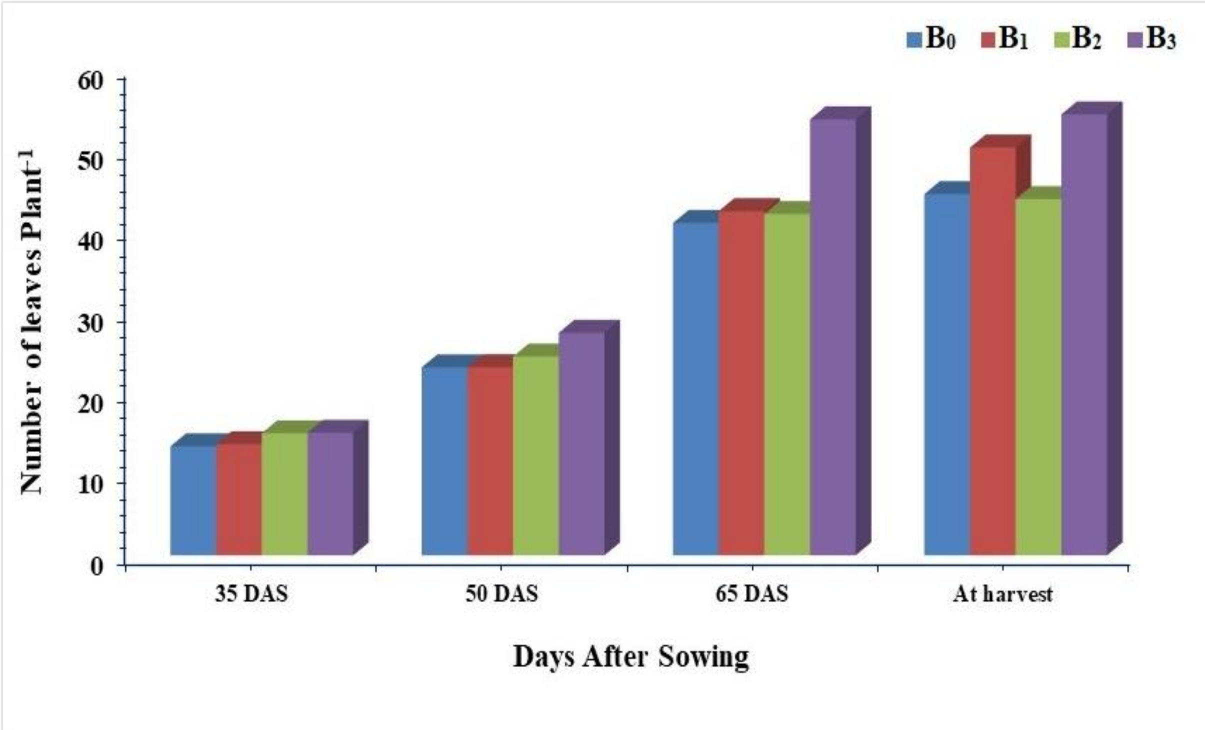


Note: I_0 = No irrigation, I_1= 25 DAS I_2 = 25 & 40 DAS

Fig. 3. Response of irrigation on number of leaves plant^{-1} of Lentil at different days after sowing (SE=0.3887, 1.3164, 7.9574, 4.475 at 35, 50, 65 DAS and at harvest respectively)

Effect of boron

Boron fertilizer had a major effect on the number of leaves plant^{-1} (Appendix VI and Table 3). Result showed that the highest number of leaves plant^{-1} (15.08, 27.37, 53.63 and 43.81 at 35, 50, 65 DAS and at harvest respectively) was obtained from B_3 (40% recommended dose as basal + rest 60% as foliar spray at pre flowering) which was statistically different with B_2 (60% RD as basal + rest 40% as FS at PF) and B_1 (80% RD as basal + rest 20% as FS at PF) and without boron produce the lower number of leaves plant^{-1} (13.41, 23.11, 40.89 and 44.43 at 35, 50, 65 DAS and at harvest) was recorded from B_0 (control).



Note: B_0 =control; B_1 = 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

Fig. 4: Response of boron on number of leaves plant^{-1} of Lentil at different days after sowing (SE=0.5633, 1.4268, 7.1379, 7.3402 at 35, 50, 65 DAS and at harvest respectively)

Interaction effect of irrigation and boron on leaves plant^{-1}

Interaction effect of different levels of irrigation and boron application in terms of leaves plant^{-1} also exposed significant variation at different days after sowing (Appendix VI and Table 3). The highest number of leaves plant^{-1} (45.19, 53.22 and 55.23 at 50, 65 DAS and at harvest) was produced from the interaction of I_2B_3 (Irrigations at 25 and 40 DAS and Boron at 40% recommended dose as basal + rest 60% as foliar spray at pre flowering) which was statistically similar with I_2B_2. The lowest number of leaves plant^{-1} was produced from the interaction of I_0B_0 (control) which was statistically similar with I_0B_1, I_0B_2, I_0B_3, I_1B_0, I_1B_1 and I_1B_3 combinations.

Table 3. Interaction effect of irrigation and boron on the number of leaves plant^{-1} of Lentil at different days after sowing

Treatment combinations	Number of leaves plant^{-1} at			
	35 DAS	**50 DAS**	**65 DAS**	**At Harvest**
I_0B_0	14.00	24.89 c	34.44 ab	33.44
I_0B_1	14.00	24.73 c	36.78 ab	35.44
I_0B_2	14.78	25.21 c	34.49 ab	37.02
I_0B_3	15.00	25.14 bc	34.67 ab	35.70
I_1B_0	13.56	24.22 bc	41.67 ab	42.33
I_1B_1	13.70	23.22 bc	43.89 ab	44.89
I_1B_2	14.81	25.55 ab	44.44 ab	49.44
I_1B_3	14.78	31.78 a	43.00 ab	40.13
I_2B_o	12.67	20.22 bc	36.55 ab	36.52
I_2B_1	13.33	21.45 bc	32.33 b	36.14
I_2B_2	24.43	42.56 d	48.22 ab	46.96
I_2B_3	25.46	45.19 d	53.22 ab	55.23
SE	NS	2.4713	12.363	NS
CV (%)	15.46	11.82	13.89	12.5

NS = Non significant

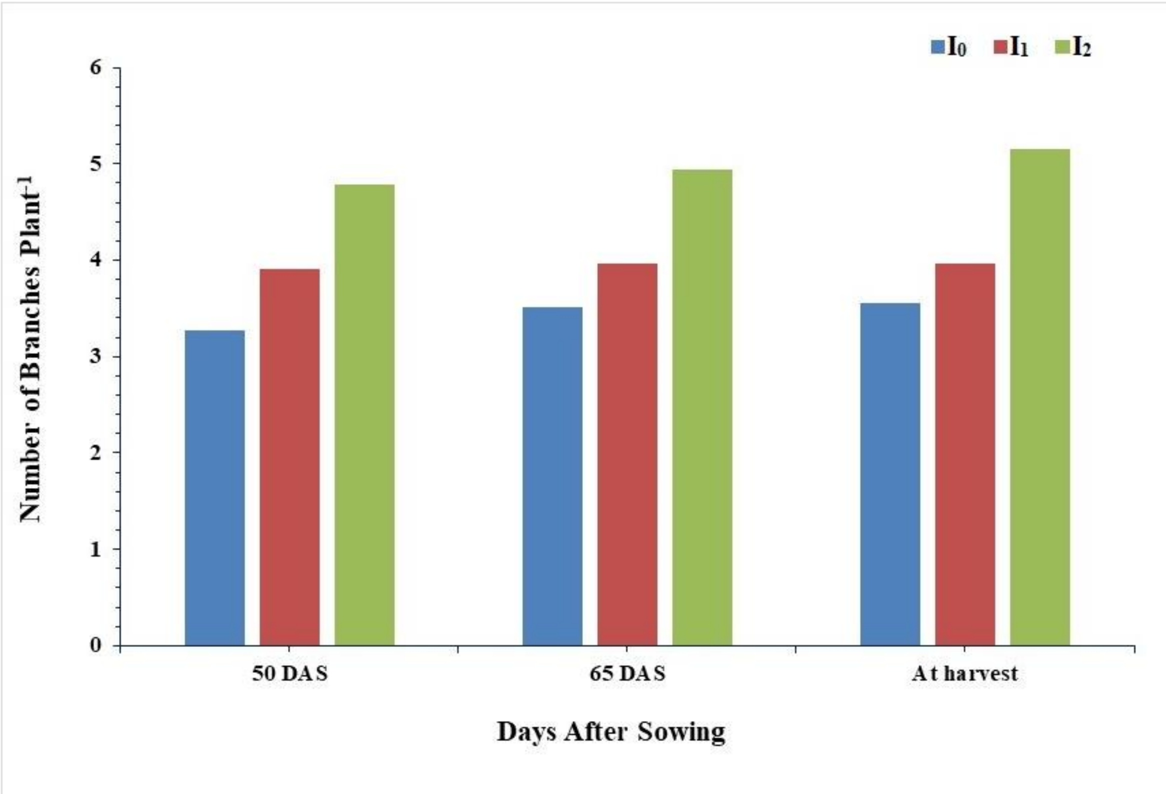
Note: I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

4.1.3 Number of branches plant^{-1}

Effect of irrigation

From the study it was found that irrigation had great influence on the number of branches per plant in lentil (Appendix VII and Figure 5). The highest number of branches per plant (4.79, 4.93 and 5.15 at 50, 65 DAS and at harvest respectively) was recorded from I_2 (25 DAS and 40 days after sowing) and the lowest number of branches per plant (3.26, 3.05 and 3.55 at 50, 65 DAS and at harvest respectively) was recorded from I_0 (control). Rahman (1994) also reported that two irrigations gave the highest number branches per plant and the lowest number of branches/ plant was found in case of without irrigation.

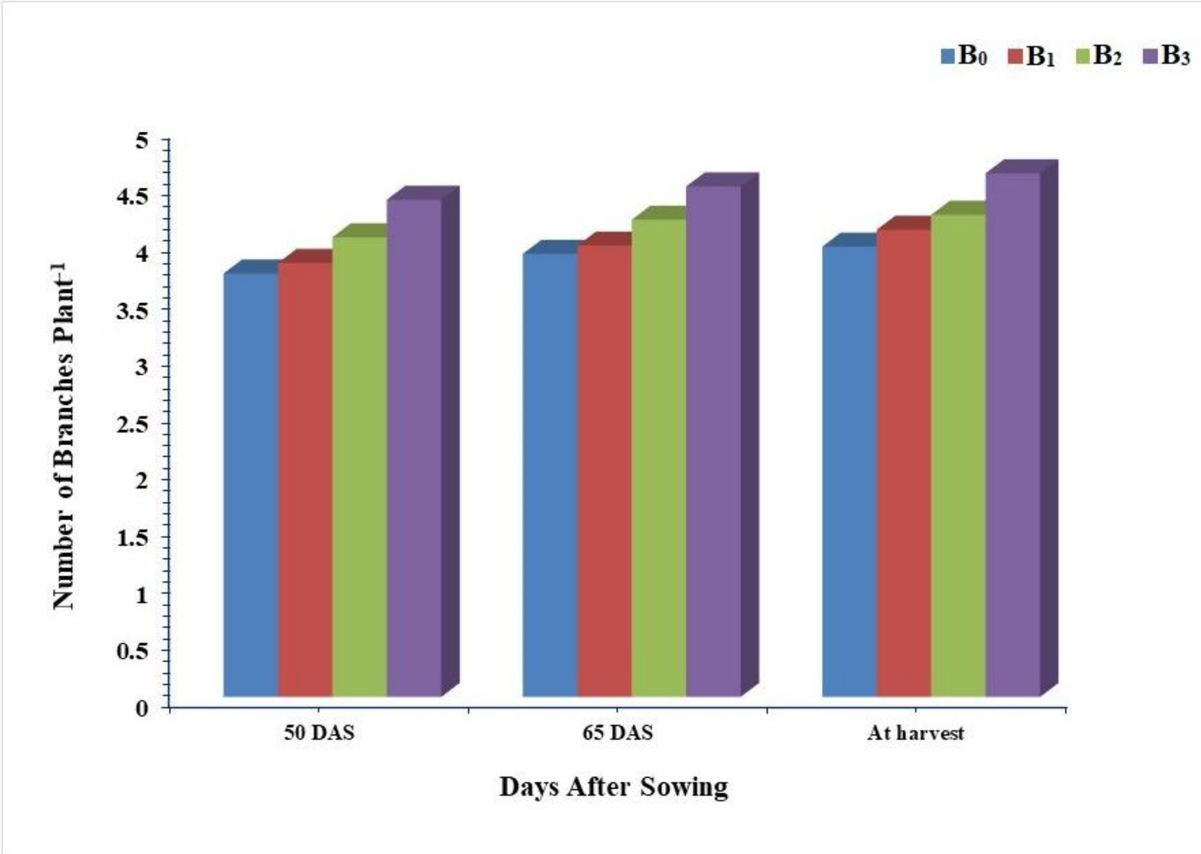


Note: I_0 = No irrigation, I_1= 25 DAS I_2 = 25 DAS & 40 DAS

Fig. 5 Response of irrigation on number of branches plant^{-1} of Lentil at different days after sowing (SE = 0.2719, 0.127, 0.1085 at 50, 65 DAS and at harvest respectively)

Effect of Boron

Number of branches per plant of lentil also significantly increased by different levels of boron treatments at different days after sowing (Figure 6 and Appendix VII). Results exposed that the highest number of branches plant^{-1} (4.37, 4.48, 4.60 at 50, 65 DAS and at harvest) was obtained from B_3 (40% recommended dose as basal + 60% as foliar spray at pre flowering) which was statistically same with B_2 (60% RD as basal + rest 40% as FS at PF) at 65 DAS and at harvest. Likewise, the lowest number of branches plant^{-1} (3.72, 3.89, 3.95 at 50, 65 DAS and at harvest separately) was recorded from B_0 (control) followed by B_1 (80% RD as basal + rest 20% as FS at PF). Similar findings were also found by Schon and Blevins (1987).



Note: B_0 =control; B_1 = 80% as recommended dose + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

Fig. 6. Response of boron application on number of branches plant^{-1} of Lentil at days after sowing (SE = 0.2385, 0.2527, 0.161 at 50, 65 DAS and at harvest respectively)

Interaction effect of irrigation and boron on branches plant^{-1}

Interaction effect of different levels of irrigation and boron application on number of branches plant^{-1} also showed significant variation at different days after of sowing (Appendix VII and Table 4). Result represented that the highest number of branches plant^{-1} (5.34, 5.45 and 5.74 at 50, 65 DAS and at harvest) was recorded from I_2B_3 combination. Correspondingly, the lowest number of branches plant^{-1} (3.12, 3.45 and 3.55 at 50, 65 DAS and at harvest,) was collected from I_0B_0 treatment combination which was statistically similar with I_0B_1 and I_0B_2 followed by I_0B_3, I_1B_0 and I_1B_1.

Table 4. Interaction effect of irrigation and boron on the number of branches plant^{-1} of lentil at different days after sowing

Treatment combinations	Number of branches plant^{-1} at		
	50 DAS	**65 DAS**	**At Harvest**
I_0B_0	3.11 c	3.45 d	3.55e
I_0B_1	3.16 c	3.47 cd	3.55 e
I_0B_2	3.33 c	3.54 cd	3.55 e
I_0B_3	3.45 bc	3.55 cd	3.56 e
I_1B_0	3.68 bc	3.69 cd	3.70 de
I_1B_1	3.72 bc	3.74 cd	3.79 de
I_1B_2	3.89 a-c	3.98 b-d	3.87 c-e
I_1B_3	4.32 a-c	4.45 a-d	4.51 b-d
I_2B_o	4.37 a-c	4.54 a-d	4.62 bc
I_2B_1	4.56 a-c	4.69 a-c	4.97 ab
I_2B_2	4.89 ab	5.06 ab	5.29 ab
I_2B_3	5.33 a	5.45 a	5.73 a
SE	0.4131	0.4378	0.2789
CV (%)	17.94	18.33	11.43

NS = Non significant

Note: I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

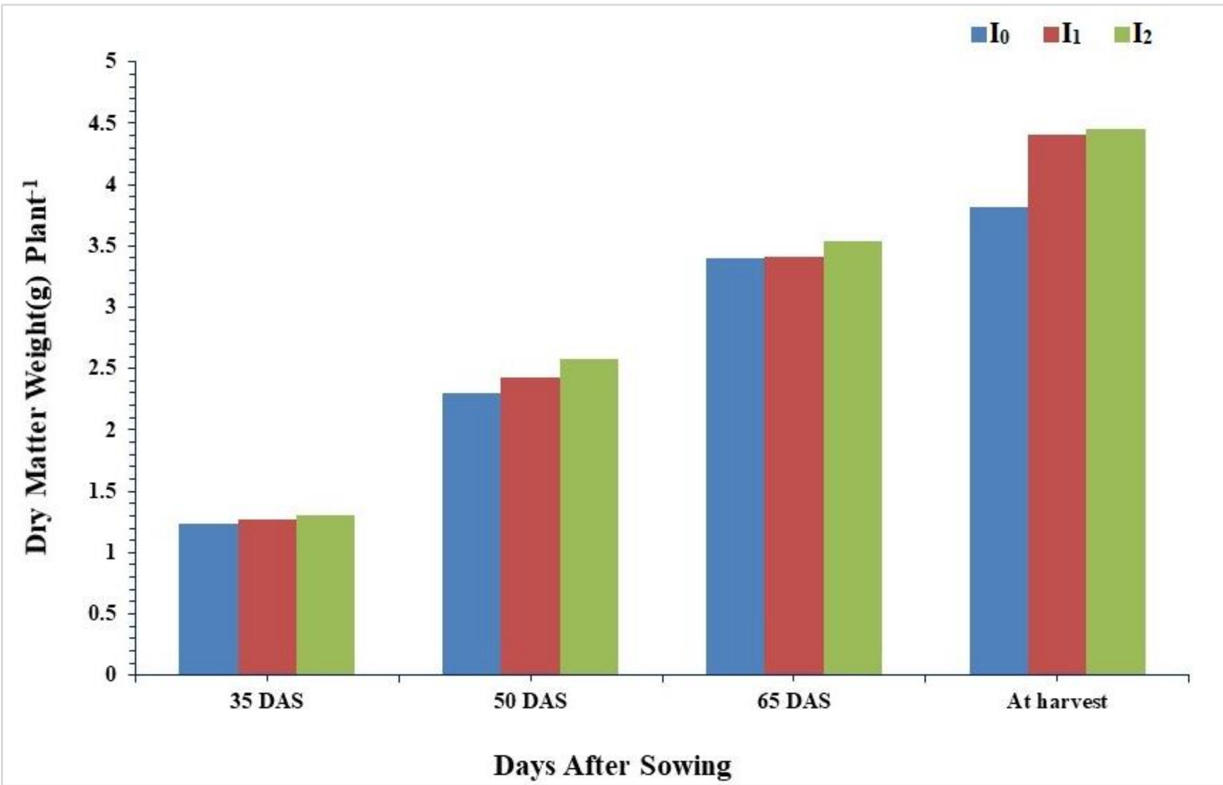
B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

4.1.4 Dry matter weight plant^{-1}

Effect of irrigation

The material that was dried to a constant weight is total dry matter. The production of total dry matter (TDM) shows the potential of a crop. The requirement for high yield is a high total output of dry matter. In case of irrigation, major variability was observed in total dry matter weight (Appendix VIII and Fig. 7). The figure indicated that plant dry matter increased with advancement of growth stage irrespective of irrigation levels. It can be concluded from the figure that two irrigations (I_1 and I_2) produced the maximum amount of plant dry matter (1.30, 2.58, 3.54 and 4.44 g at 35, 50, 60 DAS and at harvest) and control (I_0) showed the minimum (1.23, 2.30, 3.39 and 3.82 g at 35, 50, 60 DAS and at harvest) for sampling dates of 25 DAS and 40 days after sowing. The two irrigations

(25 DAS and 40 DAS) produced highest number of branches which might have contributed in the accumulation of highest dry matter at those in this stages. It might be due to maximum plant length and stem thickness in this treatment. Similar result was founded by Latif (2006) and Kibria (2013) found more dry matter weight per plant in mustard with two irrigations than with one irrigation.



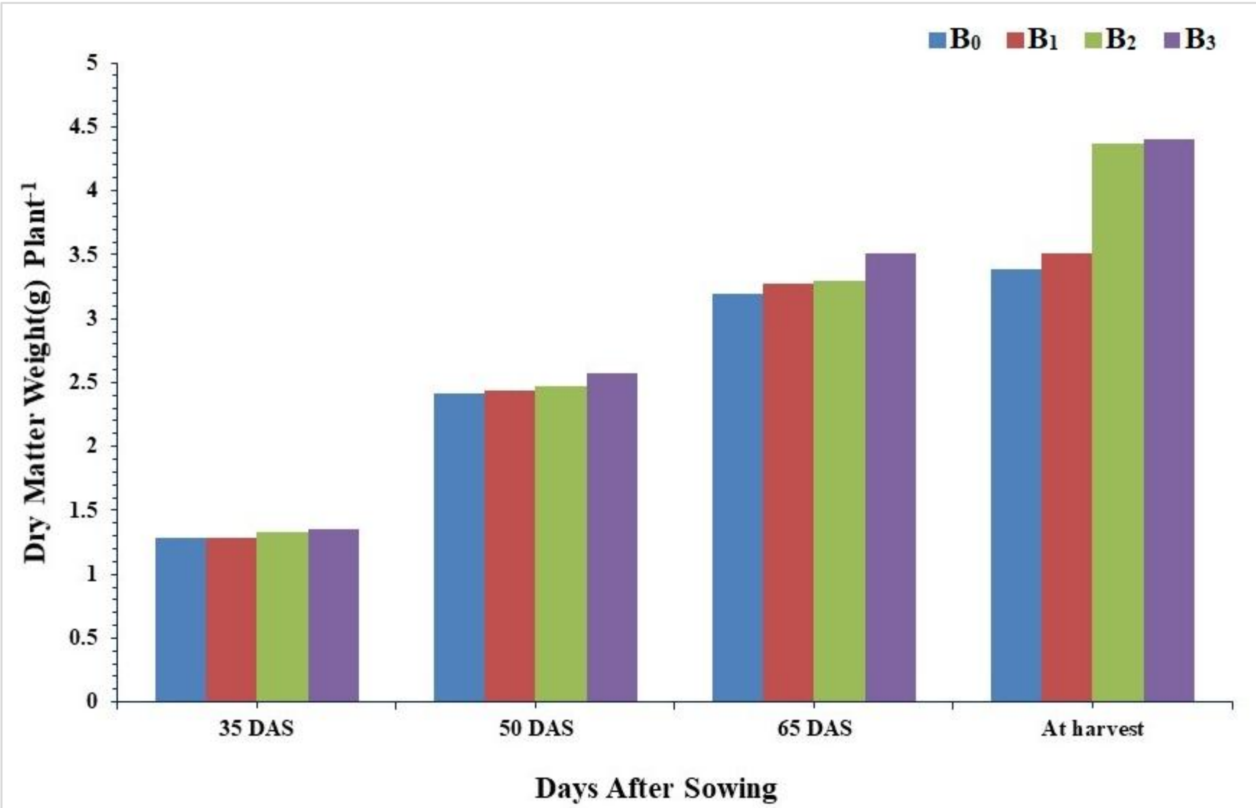
Note: I_0 = No irrigation, I_1= 25 DAS I_2 = 25 & 40 DAS

Fig. 7. Response of irrigation application on dry weight (g) plant^{-1} of Lentil at different days after sowing (SE= 0.0508, 0.056, 0.4946, 0.4956 at 35, 50, 65 DAS and at harvest respectively)

Effect of Boron

In all the durations observed, substantial variability in plant dry matter was found due to boron (Appendix VIII and Fig. 8). The figure showed that plant dry matter weight showed an increasing trend with advances of time for all boron levels. The rate of increase was found slow up to 35 DAS after that dry weight increased up to harvest irrespective of boron levels. The figure showed that B_3 (40% recommended dose as basal + Rest 60% as FS at PF) had produced the highest dry matter weight (1.34, 2.57, 3.51and

4.40 g at 35, 50, 65 DAS and at harvest) and Control (B_0) showed that the lowest (1.28, 2.41, 3.19 and 3.39 g at 35, 50, 65 DAS and at harvest) respectively.



Note: B_0 =control; B_1 = 80% as recommended dose + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal +rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

Fig. 8. Response of boron application on dry weight (g) plant^{-1} of Lentil at different days after sowing (SE = at 1.030, 1.039, 1.038, 1.469 35, 50, 65 DAS and at harvest respectively)

Interaction effect of irrigation and boron on dry matter weight (g) plant^{-1}

It was revealed from (Appendix VIII and Table 5) that the combined effect of two levels of irrigation at (25 and 40 days after sowing) with Boron at (40% recommended dose as basal + rest 60% as foliar spray at pre flowering) gave the significant highest weight of dry matter per plant at all growth stages. The results revealed that the vast plant dry matter (4.83 g) was found from I_2B_3 (Irrigations at 25 and 40 DAS and Boron at 40% recommended dose as basal + rest 60% as foliar spray at pre flowering) at harvest which was statistically identical with I_2B_2, I_2B_1, I_1B_2, I_1B_3 and I_1B_2 (at 50, 65 DAS and at harvest). The lowest plant dry matter weight (1.30, 2.26, 2.72 and 3.51 g at 35, 50, 65

DAS and at harvest) was found from I_0B_0 (control) group which was statistically identical with I_0B_1, I_0B_2, I_0B_3 and I_1B_1. The maximum dry matter weight (4.74 g) was observed from I_2B_1 statistically similar with I_2B_2, I_2B_3, I_1B_2 and I_1B_3 respectively.

Table 5. Interaction effect of different levels of irrigation and boron on dry weight (g plant^{-1}) of lentil at different days after sowing

Treatment combinations	**Dry weight (g) plant^{-1} at**			
	35 DAS	**50 DAS**	**65 DAS**	**At Harvest**
I_0B_0	1.30	2.26	2.72 ab	3.51
I_0B_1	1.30	2.25	3.13 b	3.54
I_0B_2	1.29	2.25	3.16 b	2.97
I_0B_3	1.28	2.26	3.18 b	3.25
I_1B_0	1.22	2.27	3.26 ab	3.78
I_1B_1	1.29	2.25	3.33 ab	4.84
I_1B_2	1.37	2.31	3.34 ab	3.62
I_1B_3	1.39	2.32	3.38 ab	3.63
I_2B_o	1.31	2.32	4.45 ab	3.27
I_2B_1	1.28	2.36	4.36 ab	4.74
I_2B_2	1.30	2.38	3.73 ab	4.75
I_2B_3	1.31	2.41	4.21 ab	4.83
SE	NS	NS	0.6709	NS
CV (%)	13.63	17.76	15.45	16.31

NS = Non significant

Note: I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

4.1.5 Interaction effect of irrigation and boron on days to flowering and days to maturity

Days to flowering of lentil showed substantial variability due to different levels irrigation and boron treatment (Appendix IX). The highest days to flowering (56 days) was recorded from I_0B_2 treatment, while the lowest days to flowering (52 days) was recorded from I_1B_1 (Table 6). Statistically significant differences were found for days to pod maturity of lentil due to different levels of irrigation and boron treatment. The maximum days to pod maturity (94 days) was recorded from I_2B_3, which was statistically similar to

I_2B_2, I_2B_1, I_1B_1, I_2B_1, I_2B_3. The minimum days to pod maturity (88 days) was recorded from I_0B_0, which was statistically similar to I_0B_1, I_0B_2 and I_0B_3, respectively (Table 6).

Table 6. Interaction effect of irrigation and boron on days to flowering and days to maturity of lentil at different days after sowing

Treatment combinations	**Days to flowering and Days to maturity**	
	Days to flowering	**Days to maturity**
I_0B_0	55.78 ab	88.99 d
I_0B_1	55.12 a-c	89.37 d
I_0B_2	56.18 a	89.89 cd
I_0B_3	55.77 ab	89.85 cd
I_1B_0	53.51 a-c	91.22 b-d
I_1B_1	52.52 c	92.43 a-c
I_1B_2	52.91 bc	94.00 a
I_1B_3	53.24 a-c	93.87 a
I_2B_o	54.04 a-c	94.10 a
I_2B_1	53.35 a-c	93.91 a
I_2B_2	53.40 a-c	93.77 ab
I_2B_3	54.13 a-c	94.32 a
SE	0.538	0.7112
CV (%)	1.72	1.34

NS = Non significant

Note: I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

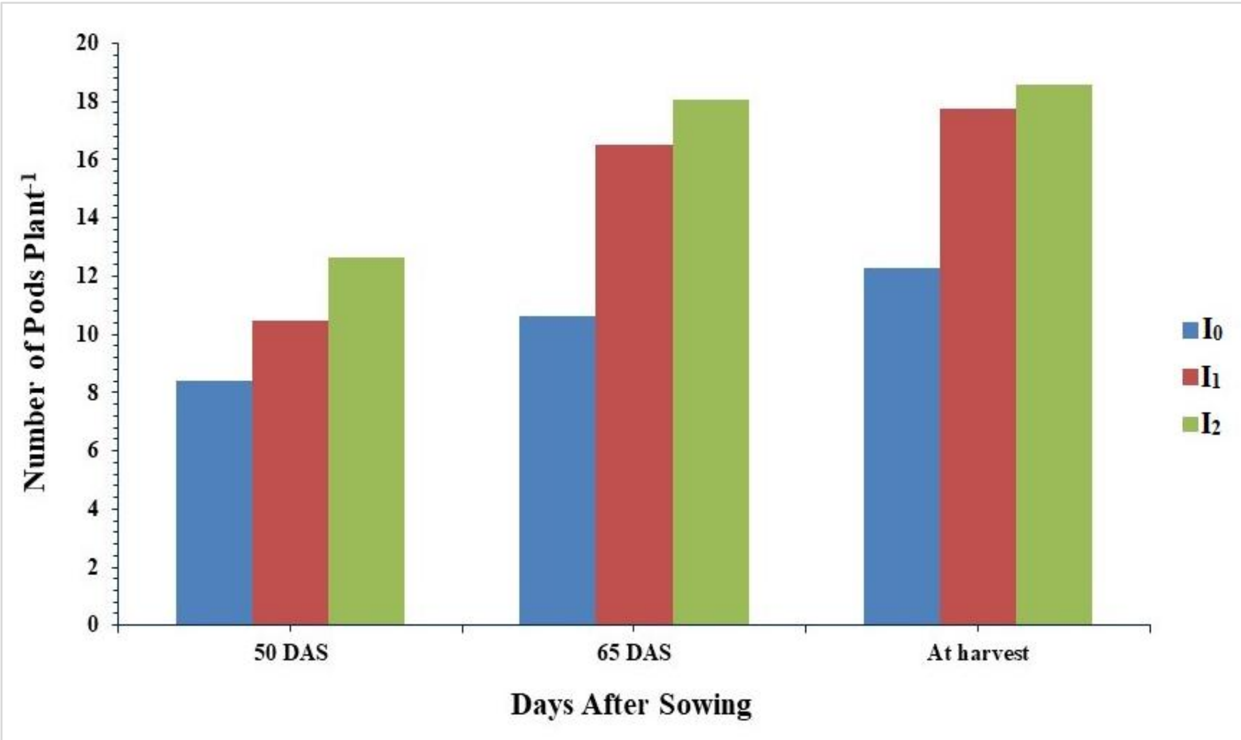
B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

4.2 Yield contributing parameters

4.2.1 Number of pods plant^{-1}

Effect of irrigation

A significant variation was found in total number of pods per plant due to different irrigation levels (Figure 9 and Appendix X). Among the irrigation levels, at harvest the highest number of pods per plant (18.59) was found in irrigation at vegetative and reproductive stage (I_2) followed by the treatment of I_1 (17.78). On the other hand, the lowest number of pods per plant (12.28) was also produced when it was observed in no irrigation treatment.

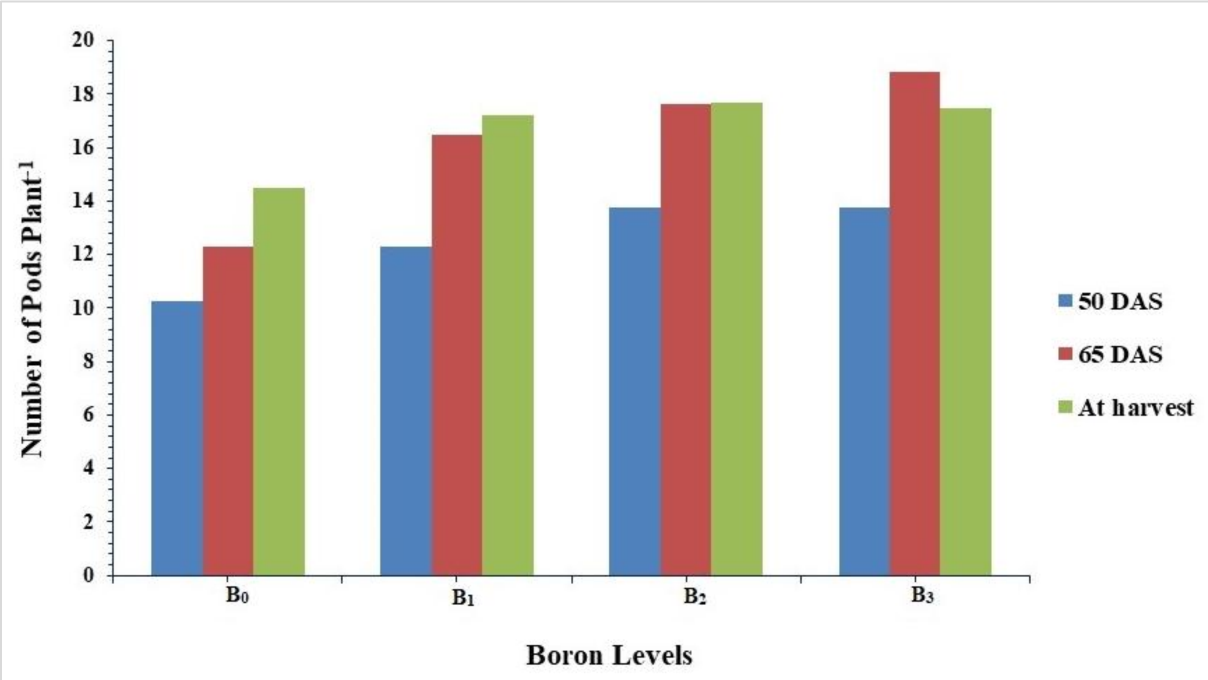


Note: I_0 = No irrigation, I_1= 25 DAS I_2 = 25 & 40 DAS

Fig. 9. Response of irrigation application on number of pods plant^{-1}of Lentil at different days after sowing (SE= 0.837, 1.529, 0.2562 at 50, 65 DAS and at harvest respectively)

Effect of Boron

Number of pods per plant of lentil varied significantly due to different levels of boron application (Figure 10 and Appendix X). Result viewed that the highest number of pods par plant (18.49) was obtained from B_3 (40% recommended dose as basal + rest 60% as foliar spray at pre flowering) at 65 days after sowing (DAS). Likewise, the lowest number of pods per plant (13.47) was recorded from B_0 (control) at harvest treatment.



Note: B_0 =control; B_1 = 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

Fig. 10. Response of boron application on number of pods plant^{-1} of Lentil at different days after sowing (SE = 0.599, 1.5679, 1.220 at 50, 65 DAS and at harvest respectively)

Interaction effect of irrigation and boron on number of pods plant^{-1}

Number of pods plant^{-1} of lentil varied significantly due to different levels of irrigation and boron treatment (Table 7 and Appendix X). Result displayed that the highest number of pod per plant (17.78) was recorded from I_2B_3 at harvest which was statistically similar with others. The lowest number of pods per plant (11.56) at harvest was obtained from I_2B_0 treatment.

Table 7. Interaction effect of irrigation and boron on number of pods plant^{-1} of lentil at different days after sowing

Treatment combinations	Number of Pods plant^{-1}		
	50 DAS	**65 DAS**	**At Harvest**
I_0B_0	2.78 bc	13.45 a-c	13.72 a
I_0B_1	2.89 bc	12.78 a-c	13.74 ab
I_0B_2	6.55 a	11.67 a-c	14.52 ab
I_0B_3	5.44 a-c	10.55 bc	12.14 b
I_1B_0	5.33 a-c	15.22 a-c	13.15 ab
I_1B_1	5.78 ab	15.89 a-c	14.67 ab
I_1B_2	2.56 c	14.22 a-c	15.74 ab
I_1B_3	4.11 a-c	20.67 a	16.55 ab
I_2B_o	4.61 a-c	10.23 c	11.56 ab
I_2B_1	4.22 a-c	11.78 a-c	15.26 ab
I_2B_2	5.11 a-c	16.98 a-c	17.77 ab
I_2B_3	5.33 a-c	19.22 ab	17.78 a
SE	1.039	2.715	2.113
CV (%)	12.97	13.46	14.05

NS = Non significant

Note: I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

4.2.2 Pod length (cm)

Effect of irrigation

Significant variation was observed on pod length of lentil due to different levels of irrigation treatments (Table 8 and Appendix XI). Results indicated that the highest pod length (1.31cm) was obtained from two irrigation I_2 (at 25 days after sowing and 40 DAS) which was statistically similar with I_1 (25 DAS). Similarly, the lowest pod length (1.26 cm) was recorded from I_0 (control).

Effect of boron

Substantial difference was also observed on seed length of lentil due to different levels of boron treatments (Table 9 and Appendix XI). Results indicated that the highest pod length (1.33cm) was obtained from B_1 (80% as recommended dose as basal + rest 20% as foliar spray at pre flowering) was statistically similar with B_2 (60% RD as basal + rest 40% as FS at PF), and B_3 (40% RD as basal + rest 60% as FS at PF). Similarly, the lowest pod length (1.20 cm) was recorded from B_0 (0 $kgha^{-1}$).

Interaction effect of irrigation and boron on number of pod length (cm)

Pod length was significantly improved by the interaction effect of different levels of irrigation and boron application (Table 10 and Appendix XI). Results signified that the highest pod length (1.42 cm) was recorded from I_2B_3 combination (Irrigations at 25 and 40 DAS and Boron at 40% recommended dose as basal + rest 60% as foliar spray at pre flowering) which was statistically similar with I_2B_2, I_2B_1. Likewise, the lowest pod length (1.23cm) was recorded from I_0B_0 combination which was statistically similar with I_0B_1, I_0B_2, I_0B_3, I_1B_0, I_1B_2 and I_2B_0 respectively.

4.2.3 Number of seeds pod^{-1}

Effect of irrigation

In terms of number of seeds per pod of lentil, significant variation was observed due to different levels of irrigation treatments (Table 8 and Appendix XI). Results revealed that the highest number of seeds per pod (1.94) was obtained from I_2 (25 days after sowing and 40 DAS) which was statistically similar with I_1 (25 DAS). Similarly, the lowest number of seeds per pod (1.61) was acquired from I_0 (without irrigation). Similar result was founded by Roy *et al*. (2016) with the present study.

Effect of boron

Substantial influence was also found by different levels of boron application for number of seeds per pod of lentil (Table 9 and Appendix XI). Result revealed that the vast number of seeds per pod (2.00) was recorded from B_3 (40% recommended dose as basal + rest 60% as foliar spray at pre flowering) which was statistically identical to B_1 (1.96). Similarly, the lowest number of seeds per pod (1.74) was collected from B_2 (60% RD as basal + rest 40% as FS at PF) respectively. The achieved result from the present study was similar with the findings of Pandey and Gupta (2013).

Interaction effect of irrigation and boron on number of seeds pod^{-1}

Number of seeds pod^{-1} was significantly influenced by interaction effect of different levels of irrigation and boron application (Table 10 and Appendix XI). Results signified that the highest number of seed pod^{-1} (2.00) was recorded from I_2B_3 combination (Irrigations at 25 and 40 DAS and Boron at 40% recommended dose as basal + rest 60% as foliar spray at pre flowering) which was statistically similar with I_2B_1, I_2B_2, I_2B_1 and I_1B_1 treatment combination. Likewise, the lowest number of seeds per pod (1.40) was recorded from I_0B_0 (control) combination which was statistically similar With I_0B_2, I_0B_2, I_1B_0 I_0B_3, I_1B_0 and I_2B_0.

4.2.4 Weight of 1000-seeds (g)

Effect of irrigation

From the (Appendix XI and Table 8), it can be seen that the irrigation levels had significant effect on 1000-seed weight. The result showed that the highest 1000-seed weight (24.26 g) was recorded from two irrigation (I_2) at 25 and 40 DAS which was significantly similar with I_1 (25 DAS) respectively. Likewise, the lowest 1000-seed weight (19.61 g) was obtained from I_0 (control) respectively. Hossain *et al*. (2013) found a significant increase 1000-seed weight with two irrigations one at pit-flowering stage and another at fruiting stage.

Effect of boron

Significant influence was also found by different levels of boron treatments for 1000-seed weight of lentil (Table 9 and Appendix XI). Result revealed that the highest 1000-seed weight (22.87 g) was recorded from B_2 (60% recommended dose as basal + rest 40% as foliar spray at pre flowering) which was statistically similar to B_1 (22.53 g) and B_3 (22.53

g). Similarly, the lowest 1000-seed weight (21.11 g) was collected from B_0 (control). Similar outcomes was also observed by Maqbool *et al*. (2018), Vimalan *et al*. (2017).

Interaction effect of irrigation and boron on 1000-seed weight (g)

Weight of 1000-seed was significantly influenced by interaction effect of different levels of irrigation and boron application (Table 10 and Appendix XI). Results signified that the highest 1000-seed weight (25.53 g) was recorded from I_2B_2 combination (Irrigations at 25 and 40 DAS and Boron at 60% recommended dose as basal + rest 40% as foliar spray at pre flowering) which was statistically identical with I_1B_1 and statistically similar with I_2B_3. Accordingly, the lowest 1000-seed weight (17.69 g) was recorded from I_0B_0 (control) combination which was statistically similar with I_0B_1 followed by I_0B_2, I_0B_3 and I_1B_0 respectively.

Table 8. Response of irrigation application on yield contributing parameters of lentil at harvest

Treatments	**Yield contributing parameters**		
	Pod length (cm)	**Number of seeds pod^{-1}**	**1000-seed weight (g)**
I_0	1.26	1.61	19.61 b
I_1	1.30	1.94	22.84 a
I_2	1.31	1.86	24.26 a
SE	NS	NS	0.7246
CV (%)	8.52	12.14	11.29

Note: NS = Non significant, I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

Table 9. Response of boron application on yield contributing parameters of lentil at harvest

Treatments	Yield contributing parameters		
	Pod length (cm)	Number of seeds pod^{-1}	1000-seed weight (g)
B_0	1.20	1.92 a	21.11b
B_1	1.33	1.96 ab	22.43 ab
B_2	1.29	1.74 b	22.87 a
B_3	1.25	2.00 a	22.53ab
SE	NS	0.065	0.508
CV (%)	8.84	10.33	6.86

Note: B_0 =Control; B_1 = 80% recommended dose as basal + Rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + Rest 40% as FS at PF; B_3 = 40% RD as basal + Rest 60% as FS at PF

Table 10. Interaction effect of irrigation and boron on yield contributing parameters of lentil at harvest

Treatment combinations	Yield contributing parameters		
	Pod length (cm)	Number of seeds pod^{-1}	1000-seed weight (g)
I_0B_0	1.23 ab	1.40	17.69 e
I_0B_1	1.28 ab	1.40	19.99 de
I_0B_2	1.31 ab	1.67	21.05 cd
I_0B_3	1.22 ab	1.57	20.98 cd
I_1B_0	1.30 ab	1.70	23.01 a-d
I_1B_1	1.22 ab	1.89	23.35 a-c
I_1B_2	1.21 b	1.89	22.37 b-d
I_1B_3	1.30 ab	2.00	23.29 a-c
I_2B_o	1.36 ab	1.69	22.64 b-d
I_2B_1	1.4 a	1.89	23.95 a-c
I_2B_2	1.41 a	1.66	25.53 a
I_2B_3	1.42 a	2.00	24.42 ab
SE	0.066	NS	0.8137
CV (%)	8.84	10.33	6.3

NS = Non significant

Note: I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

4.3 Yield Parameters

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

Effect of irrigation

Irrigation level exerted a significant result on lentil seed yield (Appendix XII and Table 11). The maximum seed yield (570.56 kg ha^{-1}) of lentil was obtained from the treatment I_2 (Irrigation at 25 DAS and 40days after sowing) followed by the treatment I_1 (Irrigation at 25 days after sowing). The lowest seed yield (363.1 kg ha^{-1}) was recorded from I_0 (control). From the result it was observed that seed yield increased gradually with the irrigation level. Shortage of irrigation water greatly reduced the yield. Similar result was founded by Zhang *et al*. (2000).

Effect of boron

Significant variation was also found by different levels of boron treatment (Appendix XII and Table 12). The highest amount of seed yield (583.51 kg ha^{-1}) was recorded from B_3 (40% recommended dose as basal + rest 60% as foliar spray at pre flowering) followed by B_2 (60% RD as basal + rest 40% as FS at PF) and B_1 (80% RD as basal + rest 20% as FS at PF). Likewise, the lowest amount of seed yield (448.70 kg ha^{-1}) was obtained from B_0 (0 kg/ha) respectively. Vimalan *et al*. (2017) reported the same result of green gram seed.

Interaction effect of irrigation and boron on seed yield (kg ha^{-1})

The interaction of irrigation level and boron had a significant influence on seed yield (Appendix XII and Table 13). The highest seed yield (638.23 kg ha^{-1}) was recorded in the interaction I_2B_3 (Irrigation at 25 and 40 days after sowing and Boron at 40% recommended dose as basal + rest 60% as foliar spray at pre flowering) which was statistically similar with I_2B_2, I_2B_1, I_2B_0, I_1B_3, I_1B_2, I_1B_1, I_1B_0, I_0B_3 combinations. Likewise, the lowest amount of seed yield (240.67 kg ha^{-1}) was recorded from in the combination of I_0B_0 (control).

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

Effect of irrigation

Application of different levels of irrigation had a significant variation on stover yield of lentil (Appendix XII and Table 11). Result showed that the highest amount of stover yield (573.98 kg ha^{-1}) was obtained from I_2 (Irrigation at 25 days after sowing and 40 DAS). The lowest amount of stover yield (405.14 kg ha^{-1}) was recorded from I_0 (noirrigation). Same result was found by Paramjit and Roy (2001).

Effect of boron

Substantial variation was also found by different levels of boron on stover yield of lentil (Appendix XII and Table12). From the result it was obtained that the greatest amount of stover yield (598.81 kg ha^{-1}) was recorded from B_3 (40% recommended dose as basal + rest 60% as foliar spray at pre flowering) respectively. Likewise, the lowest amount of stover yield (496.31 kg ha^{-1}) was collected from B_0 (0 kg ha^{-1}) respectively. Similar result was recorded by Malewar *et al*. (2001).

Interaction effect of irrigation and boron on stover yield (kg ha^{-1})

The combination effect of irrigation and boron had a significant effect on stover yield of lentil (Appendix XII and Table 13). The largest amount of stover yield (751.20 kg ha^{-1}) was recorded from in the combination I_2B_3 (Irrigation at 25 and 40 DAS and Boron at 40% recommended dose as basal + rest 60% as foliar spray at pre flowering). The maximum amount of stover yield (556.57 kg ha^{-1}) was obtained in the combination I_1B_1 (Irrigation at 25 days after sowing and Boron at 80% RD as basal + rest 20% as FS at PF) followed by I_2B_0, I_0B_3 and I0B_1 treatment. The lowest amount of stover yield (252.27 kg ha^{-1}) was recorded from the combination I_0B_0 (control) respectively.

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

Effect of irrigation

Significant observation was observed due to the different levels of irrigation on biological yield (Appendix XII and Table 11). The largest biological yield (1167.2 kg ha^{-1}) was recorded from I_1 (25 days after sowing) which was statistically similar to I_2 (25 days after sowing and 40 DAS). The lowest biological yield (768.3 kg ha^{-1}) was obtained from I_0 (no irrigation) respectively. Roy *et al*. (2016) was mentioned similar result of chickpea.

Effect of boron

Biological yield was found significant in respect of boron (Appendix XII and Table 12). The result revealed that the highest biological yield (1182.4 kg ha^{-1}) was recorded from B_3 (40% recommended dose as basal + rest 60% as FS at PF) which was significantly different with B_2 (60% RD as basal + rest 40% as FS at PF). Likewise, the lowest biological yield (945.0 kg ha^{-1}) was obtained from B_0 (control).

Interaction effect of irrigation and boron on biological yield (kg ha^{-1})

The interaction effect of irrigation and boron had significant variation on biological yield (Appendix XII and Table 13). From the table it was showed that the highest biological yield (1389.4 kg ha^{-1}) was recorded in the combination of I_2B_3 (Irrigation at 25 and 40 DAS and Boron at 40% recommended dose as basal + rest 60% as FS at PF) which was statistically incompatible with other treatments. From the table the lowest biological yield (492.9 kg ha^{-1}) was collected from the combination I_0B_0 (control) respectively.

4.3.4 Harvest index

Effect of irrigation

Harvest index is an important measurement of yield performance. The harvest index was found significant due to different levels of irrigation (Table 11). The highest harvest index (49.85%) was recorded from I_2 (Irrigation at 25 DAS and 40DAS), which was statistically similar with I_1 (25 DAS) respectively.

Effect of boron

There were no significant variations in case of harvest index due to different boron management except control treatment (Table 12). Among the treatments, B_3 (40% recommended dose as basal + rest 60% as foliar spray at pre flowering) gave the highest harvest index (53.34%) which was followed by other treatments except B_0 (control). The lowest harvest index (46.40%) was recorded from B_0 (control) which was significantly incompatible with other treatments respectively.

Interaction effect of irrigation and boron on harvest index (%)

The combined application of irrigation and boron had a significant variation on harvest index (Appendix XII and Table 13). The interaction of result showed that the highest harvest index was calculated from I_2B_3 (Irrigation at 25 and 40 DAS and Boron at 40% RD as basal + rest 60% as FS at PF) which was statistically different with other treatments. Likewise, the lowest harvest index (43.24%) was recorded from the combination of I_0B_0 (control).

Table11. Response of irrigation application on yield and harvest index of lentil at harvest

Treatments	**Seed yield ($kg\ ha^{-1}$)**	**Stover yield ($kg\ ha^{-1}$)**	**Biological yield ($kg\ ha^{-1}$)**	**Harvest index (%)**
I_0	363.1 b	405.14 b	768.3 b	47.26
I_1	545.0a	552.22 a	1167.2 a	46.69
I_2	570.56 a	573.98 ab	1144.5 a	49.85
SE	2.0573	5.4673	5.7822	NS
CV (%)	14.46	35.48	19.51	16.02

Note: NS = Non significant, I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

Table12. Response of boron application on yield and harvest index of lentil at harvest

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
B_0	448.70 b	496.31 a	945.0 b	47.48
B_1	466.98 ab	486.90 a	953.9 b	48.95
B_2	472.44 ab	553.02 a	1025.5 ab	49.06
B_3	583.51 a	598.89 a	1182.4 a	49.34
SE	4.0633	5.0607	7.2662	NS
CV (%)	24.73	28.44	21.23	16.2

NS = Non significant

Note: B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

Table 13. Interaction effect of irrigation and boron on yield and harvest index of parameters of lentil at harvest

Treatment combinations	Yield and harvest index parameters			
	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
I_0B_0	240.67 c	252.27 c	492.9 d	47.36 ab
I_0B_1	368.77 bc	477.57 a-c	846.3 b-d	43.57 ab
I_0B_2	371.03 bc	412.57 bc	783.6 cd	47.34 ab
I_0B_3	472.20 ab	478.17 a-c	950.4 bc	49.68 ab
I_1B_0	457.23 ab	711.03 ab	1168.3 a-c	39.13 b
I_1B_1	574.30 a	556.57 a-c	1130.9 a-c	50.78 b
I_1B_2	508.37 ab	653.97 ab	1162.3 a-c	43.73 b
I_1B_3	634.10 a	567.30 ab	1207.4 ab	52.51 b
I_2B_o	632.20 a	525.63 a-c	1173.8 a-c	53.85 b
I_2B_1	457.87 ab	426.57 bc	884.4 b-d	51.77 b
I_2B_2	537.93 ab	592.53 ab	1130.5 a-c	47.58 b
I_2B_3	638.23 a	751.20 a	1389.4 a	45.93 a
SE	7.0378	8.7653	12.585	4.6611
CV (%)	24.73	28.44	21.23	16.2

NS = Non significant

Note: I_0 = No irrigation; I_1= 25 DAS; I_2 = 25 DAS and 40 DAS

B_0 =Control; B_1= 80% recommended dose as basal + rest 20% as foliar spray at pre flowering; B_2 = 60% RD as basal + rest 40% as FS at PF; B_3 = 40% RD as basal + rest 60% as FS at PF

CHAPTER V
SUMMARY AND CONCLUSION

A field experiment was conducted to study the effect of irrigation and boron on growth, yield and quality of lentil during the rabi season (November-February) 20018-20019 at the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka. The experiment was laid out in a split-plot design in two factors with three replications comprising 36 plots. Irrigation used as a factor A and boron used as factor B. There are three levels of irrigation *viz*., I_0 = control (no irrigation), I_1 = Irrigation at 25 days after sowing (DAS), I_2 = Irrigation at 25 and 40 DAS and four levels of boron *viz*., B_0 = (Control), B_1 = (80% recommended dose as basal + Rest 20% as foliar spray at pre flowering), B_2 = (60% RD as basal + Rest 40% as FS at PF), B_3 = (40% RD as basal + Rest 60% as FS at PF)].The study was aimed at finding out the most effective combination of treatment of lentil under different levels of irrigation and boron.

Lentil seeds were sown on 3th November, 2018 and harvested at 9th to 13th February, 2019. Data on growth, yield contributing characters and yield were recorded and analyzed statistically following SE test at 1% and 5% level of significance. Data were recorded on crop growth parameters like plant length, leaves plant^{-1}, branches plant^{-1}, and above ground dry matter plant^{-1} at different growth stages. Other yield and yield contributing character like pods plant^{-1}, seeds pod^{-1}, pod length, 1000-seeds weight, seed yield, stover yield, biological yield (kg ha^{-1}) and harvest index were recorded after harvest.

From the result it was observed that application of two irrigation at 25 days after sowing and 40 DAS had no significant difference among them. The best result of plant length (24.72 cm), leaves plant^{-1} (42.21), branches plant^{-1} (5.15), pods plant^{-1} (15.59), plant dry weight plant^{-1} (4.14 g), pod length (1.31 cm), seeds pod^{-1} (1.94), 1000-seed weight (24.26 g), seed yield (570.56 kg ha^{-1}), stover yield (622.23 kg ha^{-1}), biological yield (1167.2 kg ha^{-1}) produced by two irrigations at 25 DAS (I_1) and 40 DAS (I_2) stages at harvest time. Lowest result (22.09 cm, 35.65, 3.55,15.28, 3.82, 1.26 cm, 1.61, 19.61g, 14 kg ha^{-1}

363.114 kg ha^{-1}, 405.14 kg ha^{-1}, 768.3 kg ha^{-1} respectively) were also found with no irrigation (I_0) on plant length, number of branches, number of leaves, number of pods, plant dry weight, 1000-seed weight, seed yield, stover yield and biological yield, respectively whereas irrigation at 25 DAS and 40 DAS stages significantly at harvest index (46.19%).

However, the tallest plant (23.97 cm) was recorded from B_3 (40% RD as basal + rest 60% as FS at PF), while the shortest plant (23.14 cm) was recorded from B_0 (0 kg ha^{-1}) at harvest. The highest number of leaves $plant^{-1}$ (53.63), branches $plant^{-1}$ (4.60), plant dry weight (4.40 g), pods $plant^{-1}$ (25.49), pod length (1.33 cm), seeds pod^{-1} (2.00), seed yield (583.51kg ha^{-1}), stover yield (598.81 kg ha^{-1}), biological yield (1182.4 kg ha^{-1}) and harvest index (53.34%) were recorded from B_3 respectively. The smallest plant length , leaves $plant^{-1}$, branches $plant^{-1}$, plant dry weight, pods $plant^{-1}$, pod length, seeds pod^{-1}, seed yield, stover yield, biological yield and harvrst index (23.14 cm, 44.43, 3.95, 3.39 g, 14.49, 1.20 cm, 1.74, 21.11g, 448.70 kg ha^{-1}, 496.31 $kgha^{-1}$, 945.0 kg ha^{-1} and 46.40 %) were recorded from B_0 (0 kg ha^{-1}) respectively.

Combined effect of irrigation and boron also significantly affect the growth, as well as yield contributing characters and yield of lentil. The interaction result had significantly different from others treatment. From the result it was concluded that the tallest plant (27.59 cm) was obtained from the combination I_2B_3 (Irrigation at 25 & 40 DAS) and Boron at (40% RD as basal + rest 60% as FS at PF) at harvest, while the smallest plant (23.30 cm) was recorded from I_0B_0 (no irrigation and 0 kg ha^{-1}Boron) treatment. The highest plant dry weight (4.83 g) was recorded from I_2B_3, while the lowest dry weight (3.51 g) was obtained from I_0B_0 combination. The highest number of leaves per plant and number of branches (55.23 and 5.73) was collected from the combination I_2B_3 and the lowest (45.44 and 3.55) was collected from I_0B_0 treatment at harvest time. From the result the highest number of pods (17.78) was recorded from $I_2B_{3,}$ and the lowest (13.72) was recorded from control treatment (I_0B_0). The highest number of seeds per pod (2.00) was recorded from I_2B_3 combination and lowest (1.40) was collected from control (I_0B_0).

The highest pod length (1.35 cm) was recorded from the interaction I_2B_2 (Irrigation at 25 & 40 DAS) and Boron at (60% RD as basal + rest 40% as FS at PF) and the lowest pod length (1.23 cm) was recorded from I_0B_0. The maximum 1000-seed weight (25.5 g) was recorded from I_2B_2, while the lowest 1000-seed weight (17.69 g) was recorded from I_0B_0. The maximum seed yield, stover yield and biological yield (658.23 kg ha$^{-1,}$ 751.26 kg ha^{-1}, 1389.4 kg ha^{-1}) was recorded from I_2B_3 and the lowest (240.67 kg ha^{-1}, 252.27 kg ha^{-1}, 492.9 kg ha^{-1}) was recorded from control (I_0B_0). From the result the highest harvest index (61.44%) was recorded from I_2B_3 and the lowest harvest index (47.36%) was recorded from I_0B_0 treatment respectively.

It can be concluded from the discussion that the combined effect of irrigation and boron levels had influenced the production, growth and yield of lentil characteristics. Among the irrigation levels two irrigation I_2 (Irrigation at 25 DAS and 40 DAS) followed by one irrigation (I_1) at 25 days after sowing and among the boron levels B_3 (40% recommended dose as basal + rest 60% as foliar spray at pre flowering) and the interaction I_2B_3 (two irrigations at 25 DAS and 40 DAS and Boron at 40% RD as basal + rest 60% B as FS at PF) were found to be most promising. Their interaction also best combined effect for its growing and yield of lentil.
During the study period on December 2018 two rainfall (12.8 mm) at 10 and 25 December irrigation occurred so that every plant received sufficient moisture received for proper growth and development for that reason I_0B_3 treatment also showed the similar yield.

Recommendation

Such study should be conducted at different lentil growing areas of Bangladesh for the justification and evaluation at different agro-ecological zones of the variability towards improvement of the crop. In case of Rabi season. irrigation shed must be applied for conducting irrigation based experiment.

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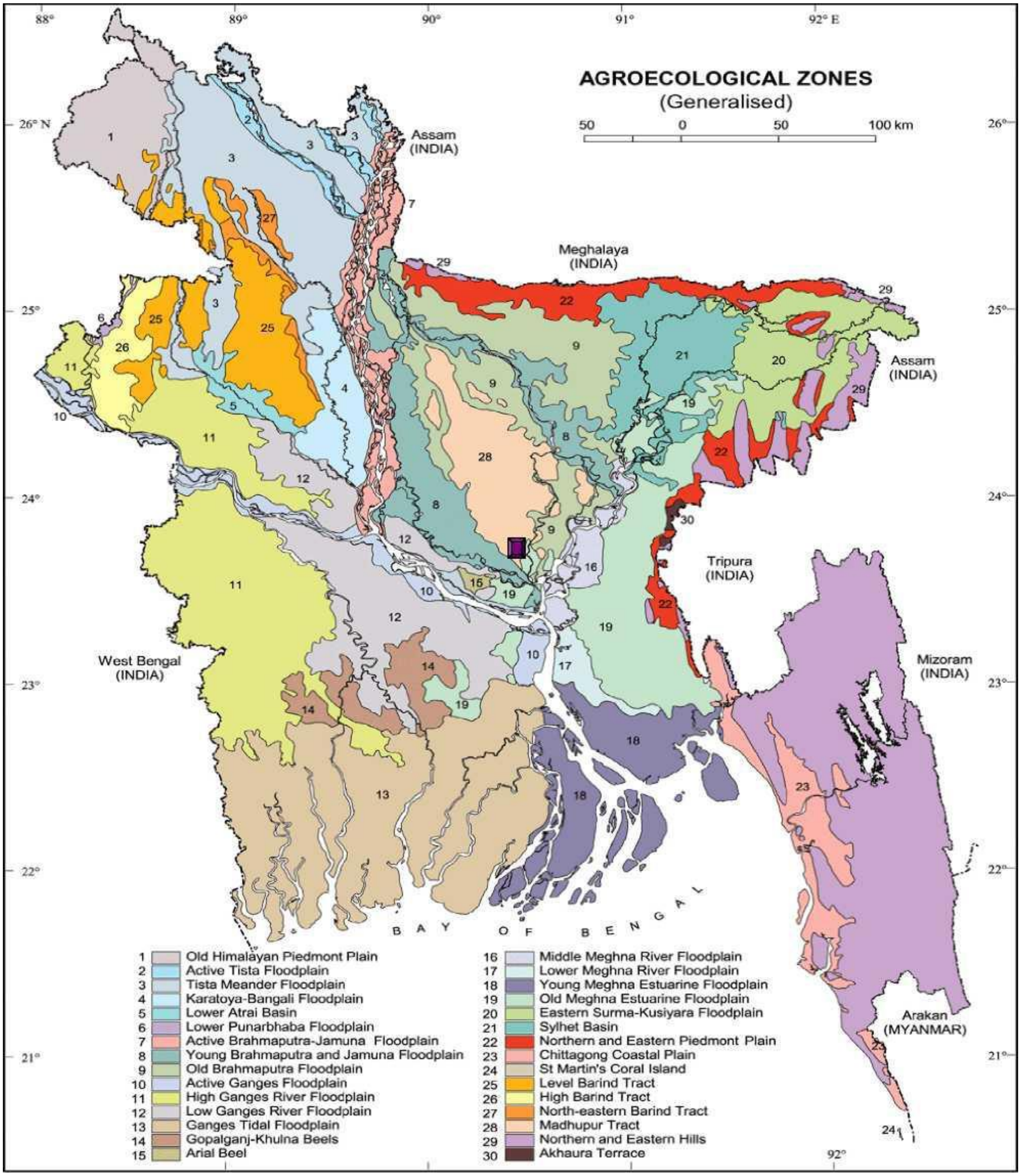
APPENDICES

Appendix l: Experimental site showing in the map under the present study



Appendix II. Monthly records of Temperature, Rainfall, and Relative humidity of the Experiment site during the period from November 2018 to February 2019

Year	Month	Air temperature(^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Minimum	Maximum	Mean			
2018	November	19.2	29.6	24.4	53	34.4	11
2018	December	14.1	26.4	20.25	50	12.8	11
2019	January	12.7	25.4	19.05	46	7.7	11
2019	February	15.5	28.1	21.8	37	28.9	11

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

Appendix III. The mechanical and chemical characteristics of soil of the experimental as observed prior to experimentation

Particle size constitution:

Sand : 40 %
Silt : 40 %
Clay : 20 %
Texture : Loamy

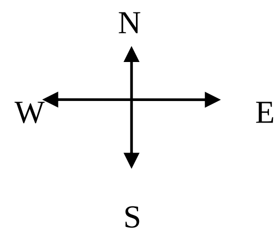
Chemical composition:

Constituents	0-15 cm depth
pH	5.45-5.61
Total N (%)	0.07
Available P (μ g/g)	18.49
Exchangeable K (μ g/g)	0.07
Available S (μ g/g)	20.82
Available Fe (μ g/g)	229
Available Zn (μ g/g)	4.48
Available Mg (μ g/g)	0.825
Available Na (μ g/g)	0.32
Available B (μ g/g)	0.94
Organic matter (%)	0.83

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

Appendix IV: Layout of the experiment

LEGEND



Layout:

Split-plot design

Plot size: 2.5 m × 1.5 m

Between plot: 0.25m

Between block: 0.5 m

Treatments

Factor A: Irrigation

I_0 = no irrigation

I_1 = one irrigation at 25 days after sowing (DAS)

I_2 = two irrigation at 25 DAS and 40 DAS

Factor B: Boron

B_0 = Control

B_1 = 80% recommended dose as basal basal+ rest 20% as foliar spray at pre flowering

B_2 = 60% RD as basal+ Rest 40% as FS at PF

B_3 = 40% RD as basal+ rest 60% as FS at PF

Appendix V: Response of irrigation and boron application on Plant length (cm) of lentil

Source of variance	Degrees of freedom	Mean square of plant length (cm)			
		35DAS	50DAS	65DAS	At Harvest
Replication	2	15.228	10.960	17.3198	24.790
Factor A	2	35.24**	27.732**	42.990**	26.655**
Error	4	13.829	9.8612	3.180	3.036
Factor B	3	26.028**	6.861**	3.699*	0.980^{NS}
AB	6	6.526**	6.458**	10.293**	3.629*
Error	18	4.292	7.446	7.853	8.165

*Significant at level of 5% ** Significant at level of 1%
^{NS}= Non significant, Factor A= Irrigation, Factor B= Boron

Appendix VI: Response of irrigation and boron application on number of Leaves plant^{-1} of lentil

Source of variance	Degrees of freedom	Mean square number of leaves plant^{-1}			
		35DAS	50DAS	65DAS	At Harvest
Replication	2	7.457	4.036	902.9	680.385
Factor A	2	0.205^{NS}	46.288**	496.965**	232.523**
Error	4	1.812	20.795	759.838	74.211
Factor B	3	6.867**	36.061**	321.713**	221.4**
AB	6	0.759^{NS}	10.919**	455.682**	287.398**
Error	18	2.855	18.321	458.546	484.902

*Significant at level of 5% ** Significant at level of 1%
^{NS}= Non significant, Factor A= Irrigation, Factor B= Boron

Appendix VII: Response of irrigation and boron application on number of branches plant^{-1} of lentil

Source of variance	Degrees of freedom	Mean square number of branches/plant		
		50DAS	65DAS	At Harvest
Replication	2	0.844	0.864	0.058
Factor A	2	7.028*	6.423^{NS}	8.250*
Error	4	0.887	0.193	0.141
Factor B	3	0.749^{NS}	0.640^{NS}	0.684^{NS}
AB	6	0.060^{NS}	0.117^{NS}	0.199^{NS}
Error	18	0.511	0.574	0.233

*Significant at level of 5% ** Significant at level of 1%
^{NS}= Non significant, Factor A= Irrigation, Factor B= Boron

Appendix VIII: Response of irrigation and boron application on dry weight ($g\ plant^{-1}$) of lentil

Source of variance	Degrees of freedom	Mean square of dry weight (g)			
		35DAS	50DAS	65DAS	At Harvest
Replication	2	0.022	0.0173	2.445	0.324
Factor A	2	0.0041^{NS}	0.0184^{NS}	11.160*	8.777*
Error	4	0.0309	0.0375	2.936	2.947
Factor B	3	0.0022^{NS}	3.2101*	3.631*	3.484*
AB	6	0.0051^{NS}	3.0064*	3.915*	3.258*
Error	18	0.0085	0.0142	1.350	1.986

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

^{NS}= Non significant, Factor A= Irrigation, Factor B= Boron

Appendix IX: Response of irrigation and boron application on days to flowering and days to maturity of lentil

Source of variance	Degrees of freedom	Mean square of days to flowering and days to maturity	
		Days to flowering	Days to maturity
Replication	2	0.9492	5.5121
Factor A	2	23.0122**	66.4599**
Error	4	6.565	2.9891
Factor B	3	1.1289^{NS}	3.1649*
AB	6	0.2566^{NS}	1.424^{NS}
Error	18	0.8683	1.5174

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

^{NS}= Non significant, Factor A= Irrigation, Factor B= Boron

Appendix X: Response of irrigation and boron application on number of Pods $plant^{-1}$ of lentil

Source of variance	Degrees of freedom	Mean square number of Pods $plant^{-1}$		
		50DAS	65DAS	At Harvest
Replication	2	1.769	18.559	4.253
Factor A	2	0.199^{NS}	54.397**	2.029^{NS}
Error	4	8.405	27.430	0.787
Factor B	3	0.672^{NS}	31.714**	1.293^{NS}
AB	6	8.306**	30.762**	17.419**
Error	18	3.239	22.123	13.397

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

^{NS}= Non significant, Factor A= Irrigation, Factor B= Boron

Appendix XI: Response of irrigation and boron application on number of yield contributing parameters of lentil

Source of variance	Degrees of freedom	Mean square of yield contributing parameters		
		Pod length (cm)	Number of seeds pod^{-1}	1000-seed weight (g)
Replication	2	0.0002	0.021	21.057
Factor A	2	0.009^{NS}	0.021^{NS}	68.166**
Error	4	0.012	0.053	6.300
Factor B	3	0.0082^{NS}	0.118^{NS}	5.374**
AB	6	0.014^{NS}	0.017^{NS}	2.605*
Error	18	0.013	0.038	2.327

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

^{NS}= Non significant, Factor A= Irrigation, Factor B= Boron

Appendix XII: Response of irrigation and boron application on seed yield, stover yield biological yield and harvest index of lentil

Source of variance	Degrees of freedom	Mean square of seed yield, stover yield, biological yield and harvest index			
		Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Replication	2	753.64	265.21	1201.65	96.147
Factor A	2	1534.56**	1559.11**	6023.87**	197.073*
Error	4	50.79	358.69	401.2	63.769
Factor B	3	337.638**	246.33**	1086.6**	83.363**
AB	6	182.72**	407.06**	691.42**	71.198**
Error	18	148.59	230.49	475.18	65.177

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

^{NS}= Non significant, Factor A= Irrigation, Factor B= Boron

LIST OF PLATES

Plate 1. Field view at seed sowing

Plate 2. Field view of treatment combination (I_1B_1) at 40 DAS.

Plate 3. Field view of treatment combination (I_0B_0) at 40 DAS.

Plate 4. Field view at flower stage of treatment combination (I_0B_0) at 40 DAS.

Plate 5. Field view at flower stage of treatment combination (I_2B_3) at 40 DAS.

Plate 6. Field view at pod formation of treatment combination (I_2B_3) at 40 DAS.

Plate 7. Field view at pod formation of treatment combination (I_0B_0) at 40 DAS.

Plate 8: Field view at application of irrigation.

Plate 9. Field view at spraying of boron pre flowering.

Plate 10. Field view at maturity of the pods in the experiment field.

Plate 11. Field view at harvest time.

Plate 12. During process of drying.

Plate 13. During collection of seeds.

Plate 14. During measuring the seeds**.**

Plate 15. Overview of the experiment field.