2016

Effect of Potassium and Boron on the Growth, Development and Yield of Lentil

Khan, Sabiha

University of Rajshahi

Ph. D.
Thesis

EFFECT OF POTASSIUM AND BORON ON THE GROWTH, DEVELOPMENT AND YIELD OF LENTIL

EFFECT OF POTASSIUM AND BORON ON THE GROWTH, DEVELOPMENT AND YIELD OF LENTIL

Ph. D. THESIS

BY
SABIHA KHAN
Ph. D. Fellow
Roll No. 10605
Registration No. 3171
Session: 2010-2011

JUNE, 2016

AGRONOMY FIELD LABORATORY
DEPARTMENT OF AGRONOMY
AND AGRICULTURAL EXTENSION
FACULTY OF AGRICULTURE
UNIVERSITY OF RAJSHAHI
RAJSHAHI-6205, BANGLADESH

June
2016

EFFECT OF POTASSIUM AND BORON ON THE GROWTH, DEVELOPMENT AND YIELD OF LENTIL

A thesis Submitted for the Degree of Doctor of Philosophy in Agronomy in the Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi-6205

BY

SABIHA KHAN

Ph. D. Fellow

Roll No. 10605

Registration No. 3171

Session: 2010-2011

JUNE, 2016

AGRONOMY FIELD LABORATORY
DEPARTMENT OF AGRONOMY
AND AGRICULTURAL EXTENSION
FACULTY OF AGRICULTURE
UNIVERSITY OF RAJSHAHI
RAJSHAHI-6205

DECLARATION

I hereby declare that the whole of the work now submitted as a thesis entitled **EFFECT OF POTASSIUM AND BORON ON THE GROWTH, DEVELOPMENT AND YIELD OF LENTIL** *for the degree of Doctor of Philosophy is the results of the investigation as embodied here are original and have not been submitted else where for any other degree.*

Date:

(SABIHA KHAN)
Candidate

Dr. Md. Arifur Rahman
Professor
Department of Agronomy and Agricultural Extension
University of Rajshahi
Rajshahi-6205, Bangladesh.
Mobile: 01711941327
E-mail: arifur_ru@yahoo.com

W. †gvt Awidi ingvb
c‡dmi
G‡Mvbgx GÛ GwMKvjPvivj G·‡Ubkb wefvM
ivRkvnx wekwe`¨vjq
ivRkvnx-6205, evsjv‡`k

CERTIFICATE

This is to certify that the research work entitled **EFFECT OF POTASSIUM AND BORON ON THE GROWTH, DEVELOPMENT AND YIELD OF LENTIL** *submitted for the degree of Doctor of Philosophy in the subject of Agronomy is a bonafide research work carried out by* **Sabiha Khan** *under my supervision in the University of Rajshahi, Rajshahi-6205, Bangladesh. The results of the investigation, which embodied here are original and have not been submitted before in substance for any other degree of this or any other university.*

(Professor Dr. Md. Arifur Rahman)


DEDICATED TO
MY
DEPARTED FATHER

ACKNOWLEDGEMENTS

At first I take the opportunity to express my deepest sense of gratefullness to Almighty Allah who enabled the author to complete her research work and preparation of thesis successfully.

The author wishes to extend her sincere appreciation, heartfelt in deftness and deep sense of gratitude to her honorable supervisor Dr. Md. Arifur Rahman, Professor, Department of Agronomy and Agricultural Extension, University of Rajshahi, for his untiring patients and attention, sincere efforts, constant encouragement, affectionate feelings given to him during accomplishing the work. Whose keen interest on the topic, scholastic and precious suggestions and spiritual direction during the work made it fruitful. The author again is grateful to him for allowing the author to work under his guidance and giving his precious time for consulting on the topic constructive valuable and effective advice wherever the author felt need.

Profound appreciation and gratefulness are intended to the Chairman and all the respected teachers of the Department of Agronomy and Agricultural Extension, University of Rajshahi for their suggestions and encouragement during the whole course of work.

The author expresses her deepest sense of gratitude to her beloved parents Md. Abdul Aziz Khan and Aleya Aziz Khan, friends, and well wishers for moral support and co-operation during the period of study.

The author expresses gratefully indebted to her brother, sister, brother-in-law and sister-in-law whose blessings and encouragement opened the gate of higher studies in her life.

The author her special thanks to her heartfelt lovely sons Sabib and Sakif for their sacrifice during the study period.

The author is grateful to her beloved husband Md. Shamim Hossain for his constant encouragement and continuous support in various ways during the whole period of study.

The author expresses her gratitude to Mr. Abu Daud to co-operate for collecting data and other activities. Thanks are also due to Md. Anwar Arif for him the careful composing of data and typing this thesis.

Finally, the kind help and co-operation of all staff of the Department of Agronomy and Agricultural Extension, University of Rajshahi is gratefully acknowledged.

The author

CONTENTS

Particulars		Page no.
Experiment no. 2: Effect of boron on the growth, development and yield of lentil		

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMES

AEZ	=	Agro-ecological Zone
Agric.	=	Agriculture
Agril.	=	Agricultural
Agron.	=	Agronomy
Dept.	=	Department
ANOVA	=	Analysis of Variance
B	=	Boron
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BPR	=	Branch production rate
Cm	=	Centimeter
CV (%)	=	Coefficient of variation percent
cv.	=	Cultivar
DAS	=	Days after sowing
day^{-1}	=	Per day
df	=	Degrees of freedom
DMRT	=	Duncan Multiple Range Test
et al.	=	And others or and elsewhere
FR	=	Rate of Flowering
W	=	West
Fig	=	Figure
FAO	=	Food and Agriculture Organization
Intl.	=	International
Inst.	=	Institute
J.	=	Journal
K	=	Potassium
Kg.	=	Kilogram
kg ha^{-1}	=	Kilogram per hector
g	=	Gram
g day^{-1}	=	Gram per day
g m^{-2} day^{-1}	=	Gram per meter square per day
ha^{-1}	=	Per hectare

HI	=	Harvest index
i.e.	=	That is
LPR	=	Leaf production rate
m	=	Meter
m^2	=	Square meter
mm	=	Millimeter
MP	=	Muriate of potash
MT	=	Metric Tones
No.	=	Number
NS	=	Non-significant
$plant^{-1}$	=	Per plant
pod^{-1}	=	Per pod
$Plot^{-1}$	=	Per plot
PRC	=	Pulse Research Center
RCBD	=	Randomized Complete Block design
Res.	=	Research
Sci.	=	Science
TDM	=	Total dry matter
Univ.	=	University
tha^{-1}	=	Ton per hectare
viz.	=	Namely
%	=	Percent
0	=	Degree
°C	=	Degree centigrade
&	=	And
@	=	At the rate of
X	=	Cross
/	=	Per

ABSTRACT

The study was carried out at the Agronomy Field Laboratory, University of Rajshahi, Bangladesh during the period of 2010-2011 and 2011-2012 to study the effect of potassium and boron on the growth, development and yield of lentil. The treatment comprised of four varieties of lentil viz. BARI masur-1, BARI masur-4, BARI masur-5, BARI masur-6, Five levels of potassium (0, 15, 25, 35, 45 kg K ha^{-1}) and five levels of boron (0, 0.5, 1, 1.5, 2 kg B ha^{-1}). The experiments were laid out in RCBD design with three replications. Growth characters differed significantly due to variety, potassium and boron at different stages. The BARI masur-6 produced the highest TDM and CGR than other varieties in both the experiments. The highest growth characters were observed when field was fertilized with 35 kg K ha^{-1} and 1.5 kg B ha^{-1}. TDM and CGR increased with the advancement of plant ages. The highest development parameters like LPR, BPR, FR, Days to 50% flowering and Days to maturity were observed in BARI masur-6 where applied different levels of potassium and boron. The lowest values were found in Control. The highest yield contributing characters like plant height, number of branches plant^{-1}, number of effective pods plant^{-1}, number of non-effective pods plant^{-1}, number of seeds pod^{-1}, length of the pod, and 1000 seed weight were produced BARI masur-6 which was statistically similar to BARI masur-5. Among the varieties BARI masur-6 produced the highest grain yield. When the field was fertilized with potassium and boron, the yield components were found maximum. The grain yield was highest when 35 kg K ha^{-1} and 1.5 kg B ha^{-1} were applied to the field. Grain yield was positively correlated with plant height, number of branches plant^{-1}, number of effective pods plant^{-1}, number of seeds pod^{-1}, length of the pod and 1000 seed weight. So it could be concluded that BARI masur-6 is better for maximizing growth, development and yield of lentil when the field was fertilized with 35 kg K ha^{-1} and 1.5 kg B ha^{-1}.

CHAPTER ONE

INTRODUCTION

Lentil is one of the oldest and most popular food legumes in Bangladesh. It provides a valuable and balanced protein source that, coupled with its ability to thrive on relatively marginal lands and under adverse environmental conditions, has ensured its survival as a crop. In Bangladesh, lentil is second most important pulse crop in terms area (154,000 ha) and production (116, 000 t) but rank the highest in consumer preference and total consumption (BBS, 2002). Lentil is cultivated during winter (rabi or post rainy season; Nov-Mar.). It grows well all over the country except the district of Rangamati. The major lentil growing districts are greater Faridpur, Jessore, Kustia, Pabna and Rajshahi. Top ten districts of lentil cultivation in Bangladesh on the average of five year data are arranged in order of extensive acreage of cultivation are- Jinaidah, Magura, Jessore, Narail, Faridpur, kushtia, Natore, Pabna, Chuadanga and Meherpur and average yield is 526 kg acre^{-1} and production is 1.7-2.5 m t ha^{-1} (BARI, 2009).

Lentils are used to prepare an inexpensive and nutritious split (Dal) all over Bangladesh. They are frequently combined with rice providing more complete protein. In addition to this food value of lentil also plays an important role in cropping systems because of its ability to fix nitrogen (101 kg ha/annum) and thereby enrich the soil (Anonymous. 1984). Lentil contains carbohydrates, mainly starches (55-65%), proteins, including essential amino acids (24-28%), and fat (1-4 %). Domestic pulse production satisfies less than half of the country's needs and some 419648 m tons is imported at a cost of about 12307 million US$ (FAO, 2006). Lentil, purchased mostly from Australia, Nepal, Turkey and Canada, accounts for US$ 17.6 million (MOA, 2002). Bangladeshi's consumes about 10.5 g of pulses per capita per day, far below the 45 g per day recommended by FAO/WHO (Islam and Ali, 2002).

Food and Agriculture Organization Corporate Statistical Database (FAO STAT) reported that the world production of lentils for calendar year 2013 was 4,975,621 metric tons, primarily coming from Canada, India and Turkey. Lentil (*Lens culinaris* medik) is the third most important pulse crop of North India (Singh *et al*., 2014). In India it is cultivated in area of 1.47 m ha with the production of 0.9 m tones and productivity of 675 kg ha^{-1} (Singh *et al*., 2013a). Canada is the largest export producer of lentils in the world, and Saskatchewan is the most important producing region in Canada (growing 99% of Canadian lentils).

Lentil is a bushy annual shrub plant that is popular for its lens shaped seeds, which are consumed as food in stew or other forms all over the world. Lentil is a nutritious food legume. In Bangladesh lentil is short duration type crop which matures within 100-110 days, causing an asynchrony in flowering of the local cultivars and those of exotic origin. It is cultivated for its seed and mostly eaten as dhal. Dhal is seed that is decorticated and split. The primary product is the seed which has relatively higher contents of protein, carbohydrate and calories compared to other legumes and it is the most desired crop because of its high average protein content and fast cooking characteristic in many Lentil producing regions (Muehlbauer *et al.,* 1985). Lentils are the main source of protein and other essential nutrients for the majority of the people of

Bangladesh. Lentil usually served as dhal with rice, is considered "poor man's meat" because of its high protein content. It is also rich in Fe, Zn, and micronutrients that are essential for health. The seeds of lentil approximately contain 11.2% water, 25% protein, 10% fat, 55.8% carbohydrates, 3.7% fiber, and 3.3% ash (Purseglove, 1968; Wang *et al*., 2009).

Potassium (K), as a plant nutrient is becoming increasingly important in Bangladesh and a good crop response to K is being reported from many parts of the country. Pulse crops showed yield benefits from potassium application. Improved potassium supply also enhances biological nitrogen fixation and potassium nutrition is associated with grain quality, including protein content of pulse grains (Srinivasarao *et al,* 2003). Soil fertility was improved significantly with farm yard manure used either alone or in combination with NPK over that of initial soil status (Singh *et al.* 2001). The supply of phosphorus and potassium to leguminous crops is necessary especially at the flowering and setting stages (Zahran *et al.* 1998).

An improved variety is the first and foremost requirement for initiation and accelerated production program of any crop. Variety plays an important role in producing high yield of lentil because different varieties responded differently for their genotypic characters, input requirements and growth process under the prevailing environment during the growing season. Bangladesh has developed some varieties of lentil. Plant height, number of branches, number of pods, 100 grains weight, grain yield and other yield contributing characters essentially differ from local variety. These parameters are also affected the K -application on crop. Tiwari and

Nigam (1985) reported that application of 35 kg K_20 ha^{-1} enhanced the chickpea, pea and lentil yield by 21, 24 and 25% respectively.

Balanced fertilization with micronutrients can enhance the lentil production to a considerable extent. Micronutrients play an important role in increasing the yield of pulse and oilseed legumes through their effects on plant itself and on the nitrogen fixing symbiotic process. Gaur *et al.* (2010) reported that intensive cropping without application of micronutrients, limited or no application of organic fertilizers and leaching losses lead to deficiency of one or more micronutrients in the soil. The soils of different parts of Bangladesh are more or less deficient in B. Boron is very important in cell division, regulate carbohydrates metabolism, involved in protein synthesis and play role in pod and seed formation (FRG 2012; Dell and Huang, 1997; Tanaka and Fujiwar, 2008).

Boron deficiency in Bangladesh is also reported on some soils and crops (Jahiruddin and Islam, 2014). It requirement may vary among plant species. Usually dicots have higher boron requirement than monocots. Reproductive growth is more sensitive than vegetative growth (Dear and Lipsett, 1987). Gupta (1979) states that because of non-ionic nature, boron is once released from soils it can be leached out from soils fairly rapidly. Deficiency of both Zn and B usually occurs in high pH and light textured soils. Besides Zn and B, deficiencies of other micronutrients may also arise in this country's soil due to exhaustion of nutrients for continuous cropping.

Boron is very important in cell division and in pod and seed formation (Vitosh *et al.* 1997). Reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth (Noppakoonwong *et al.* 1997). Boron influence the absorption of N, P, K and its deficiency changed the equilibrium of optimum of those three macronutrients. The N and B concentrations of grain for lentil were markedly influenced by B treatment indicating that the B had a positive role on protein synthesis (Iqtidar and Rahman, 1984) found that essential amino acid increased with increasing B supply. It is an essential micronutrient needed by plants but its higher amounts could be toxic and harmful to crops. It plays an important role in cell differentiation and development, translocation of photosynthetic and growth regulators from sources to sink. Judicious combination of K and B may bring considerable yield increase owing to their complementary effects.

Objective of the study

Lentil is the number one preferred pulse in Bangladesh; however, domestic production is less than half of the country's demand. Generally, the growth and development characteristics and yield components of lentil are genetically controlled. But its maximum expression depends upon suitable environmental condition viz. climate, soil and the applied inputs. Fertilizer and variety plays an important role in increasing the yield of lentil. Considering all the factors, our aim in this thesis is to achieve the following objectives:

- To find out the optimum level of potassium for lentil varieties for maximizing yield.
- To find out the optimum dose of boron for better growth and yield to maintain superior quality of lentil.
- To observed the performance of superior promising lentil variety.
- To see the interaction effect between potassium and variety on the growth development and yield of lentil.
- To see the interaction effect between boron and variety on the growth development and yield of lentil.

CHAPTER TWO

REVIEW OF LITERATURE

Lentil (*Lens culinaris*) is one of the most important pulse crops in Bangladesh but very few experimental evidences are available regarding the response of variety, potassium and boron fertilizer on this crop. Some of the works pertinent to the present study have been reviewed below:

Mondal *et al.* (2014) conducted an experiment to investigate the growth, dry mass production and its partitioning into plant parts of three lentil varieties viz. BINA masur-1, BINA masur-2 and BINA masur-3. The leaf area and total dry mass plant^{-1} were superior in BINA masur-3 over its growth period followed by BINA masur-2 with same statistical rank. In contrast, BINA masur-1 performed inferiority in leaf area and total dry mass plant^{-1}. Dry mass partitioning into seed (HI) was significantly greater in BINA masur-2 and BINA masur-3 with being the highest in BINA masur-2 but total economic yield and its related traits were greater in BINA masur-3 than in BINA masur-2. Results indicated that percent contribution of dry mass partitioning into different plant parts had no significant influence on seed yield but leaf and stem dry mass production had influence on seed yield in lentil. BINAmasur-3 produced the highest in leaf and stem dry mass and also showed the highest seed yield followed by BINA masur-2. In contrast, BINA masur-1 showed the lowest seed yield for contributed lower leaf dry mass.

Karan *et al.* (2014) conducted an experiment at Indian Institute of Pulses Research, Kanpur to study the response of lentil cultivars on yield and nutrient balance in the soil in relation to various levels of zinc and boron. Results revealed that lentil cultivar PL 639 produced significantly highest grain, straw and biological yield of lentil than the other cultivars of lentil. Grain, straw and biological yield of lentil was significantly increased with the application of 1 kg B ha^{-1} than control. Highest available nutrient viz., N, P, K, S, Zn and B in the soil showed increasing trend with lentil cultivar in sequence in DPL 62< K 75 < PL 406 < PL 639 after two consecutive crop season. The contents of available N, K, Zn and B in the soil showed increasing trend while available P and S showed decreasing trend with the increasing levels of zinc. Highest available N, P, K, S, Zn and B in the soil was restored more in 1 kg B ha^{-1} applied plot, however, minimum available N, P, K, S, Zn and B in the soil was obtained in control.

Quddus *et al.* (2014) carried out an experiment in Calcareous Low Ganges River Floodplain Soil (AEZ 12) at Regional Pulses Research (RPRS), Madaripur during the rabi season of 2010-12.The objectives were to evaluate the effect of zinc (Zn) and boron (B) on the yield and yield contributing characters of lentil (*Lens culinaris* Medic) and to estimate the optimum dose of Zn and B for yield maximization. There were 16 treatment combinations comprising four levels each of zinc (0, 1.0, 2.0 and 3.0 kg ha^{-1}) and boron (0, 0.5, 1.0 and 1.5 kg ha^{-1}) along with a blanket dose of N_{20} P_{10} K_{30} S_{10} kg ha^{-1} were used. The observed that the combination of $Zn_{3.0}$ $B_{1.5}$ produced significantly higher seed yield (1156 kg ha^{-1}). The lowest seed yield (844 kg ha^{-1}) was found in control (Zn_0 B_0) combination. The combined application of zinc and boron were superior to their single application. Therefore, the combination of $Zn_{3.10}$ $B_{1.5}$ may be considered as suitable dose for lentil cultivation in Bangladesh. But from regression analysis, the optimum treatment combination was $Zn_{2.85}$ $B_{1.44}$ for Madaripur, Bangladesh.

Datta *et al.* (2013) conducted an experiment to study the effect of variety and level of phosphorus fertilizer on the yield and yield components of lentil at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during October 2009 to March 2010. Three lentil varieties viz. BINA masur 2, BINA masur 3 and BARI masur 4 and four levels of phosphorus viz. 0 kg P ha^{-1} (P_0), 15 kg P ha^{-1} (P_{15}), 30 kg P ha^{-1} (P_{30}) and 45 kg P ha^{-1} (P_{45}) were used in this experiment. Varieties showed significant influence on the all characters except plant height. The highest seed yield (1165 kg ha^{-1}) was observed in BARI masur 4, and the lowest seed yield (1028 kg ha^{-1}) was found in BINA masur 3.

Singh *et al.* (2013) conducted an experiment during rabi seasons of 2008-2009 and 2009-10 to study the effect of potassium and cobalt application on growth, yield and nutrient uptake in lentil. The results revealed that the plant height, branches $plant^{-1}$, dry matter accumulation, pods per plant, test weight, grain and straw yield of lentil and protein content increased significantly up to 90 kg K_2O ha^{-1}.However, yields attributes and yield at 60 and 90 kg K_2O ha^{-1} were statistically on par. The protein content in lentil grain improved appreciably when crop was fertilized with 90 kg K_2O and 8 kg Co ha^{-1} over respective controls. The uptake of K and Co in lentil grain and straw increased significantly with increasing levels of K and Co. Potassium application tended to increase the uptake of N, P and S by the crop significantly over control.

Khatun ***et al.*** **(2010)** carried out an experiment to determine the effect of seeds collected from different parts on growth yield and yield attributes of lentil. Lentil seed of three varieties (2,3,4) were collect from different parts i.e. collection of pods from upper parts of lentil / plants, collection of pods from middle parts of lentil/ plant collection of pods from lower parts of lentil/ plant prior to harvesting. All the seeds were stores in earthen pot until conducting to laboratory study. The highest plant height, pods/ plant, seeds/pod, 1000 seed weight and seed yield were observed in BARI masur-4 and lowest in BARI masur-2. Seeds collected from middle parts of lentil recorded the highest pods/ plant seeds/pod and seed yield. BARI masur-3 seeds were collected from middle parts and BARI masur-4 from lower parts recorded higher seed yield.

Kurdali *et al.* **(2010)** conducted a dual natural abundance analysis of nitrogen (N) and carbon (C) isotopes in lentil plants subjected to different soil moisture levels and rates of potassium (K) fertilizer were determined to assess crop performance variability in terms of growth and N_2-fixation (Ndfa). Consequently, the Ndfa % ranged from 45 and 65% of total plant N uptake. Water stress reduced A C values. However, K fertilization enhanced whole plant A C along with dry matter yield and N_2-fixation. The water stressed plants amended with K fertilizer seemed to be the best treatment because of its highest pod yield, high N balance, and N_2-fixation with low consumption of irrigation water. This illustrates the ecological and economical importance of K fertilizer in alleviating water stress occurring during the post-flowering period of lentil.

Abedin (2010) conducted an experiment at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi during the winter from October 2009 to February 2010 to study the effect of potassium on the growth and yield of lentil. The experiment was laid out by RCBD design and comprised of four varieties of lentil viz. BARI masur^{-1} (V_1), BARI masur-4 (V_2). BARI masur-5 (V_3) and BARI masur-6 (V_4) and five potassium levels viz. 0 kg K ha^{-1} (K_0), 15 kg K ha^{-1} (K_1), 25 kg K ha^{-1} (K_2), 35 kg K ha^{-1} (K_3) and 45 kg K ha^{-1} (K_4). The results revaluated that among the studied lentil varieties, BARI masur-6 produced the highest grain yield and hence its cultivation would be benefited for farmers. Among the potassium level, 35kg K ha^{-1} performed best for almost all the growth and yield characters. 35 kg K ha^{-1} produced the highest grain yield. As most crop characters of lentil are genetically controlled to increase the grain yield unit^{-1} area through selecting suitable variety and most judicious use of space, the interaction of BARI masur-6 and 35 kg K ha^{-1} would be the most suitable combination for increasing lentil production.

Kumar *et al.* (2009) Conducted during at Bichpuri (Agra) to study the effect of B and P levels on the yield and nutrients uptake in lentil. The grain and straw yield of lentil increased significantly up to 4 kg B and 90 kg P_2O_5 ha^{-1}. The highest grain and straw yield (13.58 and 15.0 q ha^{-1}) at 4 kg B ha^{-1} was 12.6 and 20.0% higher in comparison to the yield at control. Similarly 90 kg P_2O_5 ha^{-1} produced highest grain and straw yield (15.47 and 18.18 g ha^{-1}), which was 46.8 and 45.0% higher compared to control. Application of B and P increased significantly the uptake of N, P and B in grain and straw over control. Protein content and yield of lentil grain also increased significantly with B and P application.

Chakraborty (2009) conducted an experiment during winter seasons of 2004-05 and 2005-06 at the RRSS, Sekahmpur, BCKV, to study the effect of B and Mo to the growth, and yield of lentil grown on inherently poor lateritic soil. The lentil (cv. B77) was raised with application of B and Mo either separately or in mixture through foliage or to soil along with NPK fertilizers. The leaf area index, above ground dry matter and crop growth rate increased with the application of B and Mo. Soil application of B coupled with foliar application of Mo enhanced the yield attributing characters and yield of the lentil crop. The study indicated that growing of lentil in lateritic soils depleted the nutrients particularly micronutrients which resulted in loss of yield and could be recovered, if the relevant micronutrients are supplemented through appropriate application methods and dosage.

Zahan *et al. (2009)* was conducted a split experiment at the Agronomy Field Laboratory, University of Rajshahi to study the effects of potassium levels on the growth, yield and yield contributing characters of lentil. The experiment comprised of three varieties viz. BARImasur-4, BARImasur-5 and BARImasur-6 and five potassium levels viz. 0, 15, 25, 35 and 45 Kg K ha^{-1}. The results revealed that among the three varieties, BARImasur-6 produced the highest seed yield (2.24 t ha^{-1}) and BARImasur-4 produced the lowest seed yield (1.79 t ha^{-1}). Grain and Stover yield of all varieties were increased with the increase of potassium application up to 35 kg ha^{-1}. The highest grain yield (2.16 t ha^{-1}) was found at 35 kg K ha^{-1} and the lowest grain yield (1.61 t ha^{-1}) was exhibited from control potassium level and the highest Stover yield (3.89 t ha^{-1}) was also found in 35 kg K ha^{-1} and the lowest (3.32 t ha^{-1}) was found in control potassium level. In case of interaction, the highest seed yield (2.58 t ha^{-1}) was produced by BARImasur-6 with 35 kg K ha^{-1}. Therefore, fertilization of all the varieties with 35 kg K ha^{-1} appeared as the best rate of potassium in respect of grain and stover yield. It can be suggested that farmers may be used BARImasur-6 with 35 kg K ha^{-1} for better grain and stover production of lentil.

Mohammadjanloo *et al.* (2009) carried out an experiment to study the effects of nitrogen and potassium fertilizers on yield and yield components of lentil under rain-fed-conditions; an experiment was carried out in Agriculture Research Center of Ardabil, Iran in 2008. A factorial experiment based on a complete randomized block design with three replications was used. Nitrogen treatments included three levels (0, 25 and 50 kg ha^{-1}), potassium treatments included three levels (0, 30 and 60 kg ha^{-1}) and there were two cultivars (a local and a new cultivar named ILL180). Traits including plant height, number of branches $plant^{-1}$, number of filled pod/plant, pod number, seed number $plant^{-1}$, 100-seed weight and grain yield per unit area were measured. Analysis of variance showed that cultivars were not statistically significant regarding grain yield. Application of 50 kg N ha^{-1} fertilizer significantly increased the number of secondary branches $plant^{-1}$, number of filled pod $plant^{-1}$, total number of pod, seed number $plant^{-1}$ and seed yield. Maximum seed yield was achieved when 50 kg N ha^{-1} fertilizer was applied. Potassium fertilizer had no significant effect on the above-mentioned traits.

Mohammad (2008) conducted a study that yield and seed yield components of twenty lentil genotypes were compared in a split plot RCBD based design with 3 replications at the Zanjan University Research

Farmland in 2004. The main plots were lentil planted under drought stress and non-stress (irrigation) condition and subplots were twenty of genotype lentil. There were significant differences between traits in lentil genotypes. The seed yield plant^{-1} was sensitive to drought stress but 100-seed weight was more tolerance and stable trait in drought condition. As correlation analysis of traits in various stress condition, the harvest index, seed yield plant^{-1}, pods plant^{-1} and biological yield were correlated with grain yield. In addition harvest index, seed yield plant^{-1}, pods plant^{-1} and biological yield were the most important traits that have a relationship with grain yield.

Togay *et al.* (2008) reported that experiment was conducted in Van, Turkey and the trial laid out by factorial randomized complete block design with three replications; sazak-91 lentil variety was applied at three different potassium levels (0, 35 and 65 kg ha^{-1}) and four different molybdenum levels (0, 2, 4, and 6 g kg^{-1} seed) in 2005-2006 and 2006-2007. In the study, the effect of K and Mo levels on the plant height, no. of branches, no. of pod plant^{-1}, no. of seed plant^{-1}, 100-seed weight, grain yield, harvest index, biological yield, number of nodules plant^{-1}, root dry weight, shoot dry weight protein ratio and potassium content in seed were investigated. Whereas the highest grain yield were obtained from 35 kg ha^{-1} K with 1086 kg ha^{-1} and from 6 g kg^{-1} seed Mo with 1231 kg ha^{-1} in the first year, the values were 40 kg ha^{-1} K with 1049 kg ha^{-1} and from 6 g kg^{-1} seed Mo with 1049 kg ha^{-1} in the second year.

Hossain *et al.* (2007), reported that response of rainfed lentil (CV. BARI masur-4) to planting method and fertilizer placement was evaluated during Rabi (winter) 2004-2005 and 2005-2006 at the Research Farm of

Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. Sowing methods and fertilizer placement significantly influenced soil water depletion from the root profile, total dry matter (TDM) and water-expense efficiency (WEE). Method of sowing and fertilizer placement especially the K_20 fertilizer had significant effect on population, plant height, pods plant^{-1}, 1000-grain weight and yield. In both the years, significantly higher grain yields, TDM and WEE were obtained by drilling of seeds and placing fertilizer in the moist sub-surface below the seed or in-between furrows compared with broadcasting seeds and fertilizer.

McKenzie *et al.* (2007) trailed an experiment in Netherlands that lentils are often grown in difficult edaphically conditions on stored soil water, this usually results in low yields. While responses to fertilizers are variable, Lentils can usually fix enough N for their own requirements. There are many reports that K at 40-60 kg ha^{-1} can help provide increased yields. Also application of K at around 30-35 kg ha^{-1} may be beneficial in sandy or eroded soils.

Vinay *et al.* (2006) conducted a trial with small-seeded and bold-seeded genotypes of lentil during winter seasons of 2002-03 and 2003-04 to understand and compare the contribution of various characters to yield. Seed yield was positively associated with pod length, plant. Delayed maturity in small-seeded lentil contributed more towards yield. Plant height showed more of direct contribution towards yield than indirect contribution. A significant shift in the association between yields with pods plant^{-1}, flowering and maturity was observed.

Sepat ***et al.*** **(2006)** conducted a field experiment during Rabi 2001-2002, in Pantnagar, Uttar Pradesh, India, to evaluate the effect of planting date on the performance of 6 bold-seeded lentil cultivars. Planting on 5 November recorded the highest values for the different yield attributes, which decreased with delay in planting. Among cultivars, DPL 58, DPL 62 and Pant L5 recorded the highest values for grain and straw yields and yield-related attributes.

Hobson ***et al.*** **(2006)** was reported that for lentil production to expand further in Australia, to evaluate the range of K tolerance in lentil germplasm, 310 lines were screened in soil with a high concentration of K and tolerance was assessed at the seedling stage. A wide range in response to high concentrations of soil K was observed in the germplasm tested. A subsequent experiment comparing lentils with different levels of K tolerance found that tolerant accessions (ILL213A and ILL2024) produced greater above and below ground biomass than intolerant accessions. The tolerant accessions had no significant yield loss under a high K treatment (extractable K = 18.20 mg kg^{-1}) compared to the control treatment (extractable K = 1.55 mg kg^{-1}). The large improvement in K tolerance, suggests there is potential to improve the tolerance level of adapted varieties and expand lentil production areas to regions with higher concentrations of soil K.

Uddin ***et al.*** **(2006)** reported in their recent work that lentil ranks first position in respect of consumer's performance and second in terms of area and production in Bangladesh. The productivity of the crop suffers from numerous biotic factors. Stem phyllium blight causes 88%, collar rot 444% Rust 34.4% yield loss. A collaborative breeding approach between

ICARDA and Pulses Research Centre (PRC) of Bangladesh Agricultural Research Institute (BARI) was launched to incorporate resistance to these major diseases and to enchase earliness and yield potential in lentil. After 10-11 years of research including hybridization, advancement of generation, nursery management, yield trials both at research station and farmers field, two new varieties of lentil have been released and registered by the Nation Seed Board of Bangladesh. These varieties provide approximately 15-20% yield advantage are resistant to stemphyllium blight, rust and BGM and contain 24.5 have 28% seed protein.

Yadav *et al.* (2005) evaluated fifty diverse genotypes of lentil for characters association and path coefficient analysis under two environments (E_1 and E_2) in Haryana, India created by the use of single and dose of N, P and K. Seed yield per plant and harvest index in both environments with pods per plant in E_1 and primary branches per plant in E_2.

Yamur *et al.* (2005) conducted a field experiment during October 2002 to July 2003 winter growing seasons in Van, Turkey. Mineral fertilizer (20 kg N ha^{-1} + 35 kg K_20 ha^{-1}) and sex levels of sewage biosolid (T_l=10-T_6=60 t ha^{-1}) were applied to lentil variety Sazak-91 (*Lens culinaris Medic.)* to supply organic matter and micronutrients. The experimental design was a randomized complete block with four replications. Some important plant characters such as plant height, first pod height, number of pod $plant^{-1}$, number of seed $plant^{-1}$, seed weight $plant^{-1}$ (g), 1000-seed weight and one of the yield characters number of plant per m were investigated in this experiment. Application of sewage biosolid to lentil increased plant seed yield significantly. Compared with the treatment of mineral NK fertilizers and sewage biosolid treatments of 10, 20, 30, 40, 50 and 60 t ha^{-1} with the control plots increased the seed weight per plant 34,7%, 14.4%, 36.6%, 42.7%, 53.6%, 1.4%, 56.6% respectively. Treatment (extractable K = 18.20 mg kg^{-1}) compared to the control treatment (extractable K = 1.55 mg kg^{-1}). The large improvement in K tolerance, suggests there is potential to improve the tolerance level of adapted varieties and expand lentil production areas to regions with higher concentrations of soil K.

Sinha and Sinha (2004) conducted trials in Patna, Bihar, India to investigate the efficacy of neem cake at 250 kg ha^{-1} and muriate of potash at 60 kg ha^{-1} at final bed preparation, Blitox 50 at 0.3% as soil drench and other fungicides against the wilt disease complex in lentil. Neem cake at 250 kg ha^{-1} and muriate of potash at 60 kg ha^{-1}, respectively, gave the lowest disease incidence and the highest lentil yield (9.l and 7.9 q ha^{-1}).

Ali *et al.* (2004) reported the effect of *Rhizobium* inoculation on lentil was evaluated at adaptive research farm Koror, Pakistan, studied on sandy loam soil during winter 2000-2001 and 2001-2002. Masoor-93 variety was used as a medium. The treatment were controls, inoculation alone, 57kg K_20 ha^{-1} + 22 kg N ha^{-1}, 57 kg K_20 ha^{-1} + 22 kg N ha^{-1} + inoculation, 28 kg K_20 ha^{-1} + 11 kg N ha^{-1} + inoculation and 28 kg K_20 ha^{-1} + 11 kg N ha^{-1}. The treatment comprising of 57 kg K_20 ha^{-1} + 22 kg N ha^{-1} + inoculation produced significantly the highest grain yield ha^{-1}, number of nodules $plant^{-1}$ and net return as compared to other treatments. All other treatments also differ significantly from one another during both the year.

Singh (2004) evaluate that correlation studies revealed positive association of harvest index with grain yield but no association with plant dry matter. Grain yield and plant dry matter showed positive correlation with pod number, plant height, and number of primary and secondary branches, 100-grain weight but negative correlation with no. of non-effective pods. Generally, the genotypic correlations were in agreement with phenotypic correlations, though the magnitude of the values was higher in the former case. Also found that the number of non-effective pods showed negative direct effect on grain yield and plant dry matter. Use of phenotypic or genotypic correlations in path analysis resulted in similar conclusions.

Srivastava *et al.* (2004) carried out a study to improve the production of lentil in Nepal. Boron (B) deficiency was revealed as the primary cause of the problem and the first limiting nutrient, because an exotic genotype, which exhibited the symptoms, yielded only 103 kg seed ha^{-1}, but produced 1367 kg seed ha^{-1} with the application of 0.5 kg boric acid ha^{-1}, a 13-fold yield increase. There was also a significant but lower response in yield (20%) to applied Zn. Exotic germplasm from various countries showed differences in B-deficiency symptoms. Accessions from Syria, representative of the Mediterranean region where lentil originated, all exhibited B-deficiency symptoms. Accessions without B-deficiency symptoms were mainly from Bangladesh (37% accessions free of B deficiency). In a subsequent trial to estimate yield losses, landraces from Nepal, which exhibited no deficiency symptoms, were B efficient and gave a mean seed yield of 1173 kg ha^{-1}. In contrast, 10 exotic lines exhibited severe symptoms and gave no seed yield.

Sing *et al.* (2004) found in mean yield of lentil due to application of boron. Seed and stover yield ranged from 896-1040 kg ha^{-1} and 1997-2349 kg ha^{-1}, respectively. The highest seed yield 1040 kg ha^{-1} was recorded with B level 1.5 kg ha^{-1} which was statistically identical with B level 1.0 kg ha^{-1} but significantly higher than that of others. The yield increased 13.8% with boron level 1.5 kg ha^{-1} over control. The stover yield of lentil showed similar trend as it was stated in seed yield. Balanced application of N, P, K, S, Zn and B significantly increased the yield of lentil over control.

Solanki *et al.* (2004) investigated among the commonly consumed food legumes in the Indian subcontinent. Twenty-one lentil genotypes were evaluated for such nutrition related parameters as moisture, protein, crude fiber, fat, ash (total mineral matter), carbohydrates, total energy and metabolically energy. These genotypes were also analyzed for 100-seed weight and seed yield $plant^{-1}$. Protein content ranged between 22.1 and 27.4% with significant differences among genotypes. Considerable variations were observed among the genotypes for calcium, phosphorus, iron and tannin contents. Large variations existed in yield and 100-seed weight of these genotypes. Seed yield $plant^{-1}$ was not significantly correlated with any of the principal seed constituents analyzed in the present study. The genotypes, LH 97 and LH 37 were found to be better and hence could be explored for further development and selection of desirable characteristics.

Shing and Pathak (2003) found that grain and straw as biological yield of lentil were increased with increasing rates of potassium i. e 35 kg ha^{-1}. They also reported that yields were statistically at per at 35 kg and 45 kg K_20 ha^{-1}

Vijay-laxmi (2003) carried out a field experiment in Kanpur Uttar Pradesh, India from 1997-98 to 2001-02 to determine the dry matter distribution and seed yield in lentil cultivars PL406, PL639, K75, L4076, DPL15, secure 74-3, DPL52, DPL58, DPL62 and L4147. Under soil moisture stress, the yielding ability depends on the seed filling period. Under non-stress conditions, seed yield was mainly depended on the rate of dry matter partitioning per day of seed filling period and dry matter accumulation. Harvest index was highest in cultivar sehore 74-3.

BARI (2003) conducted an experiment in pulses and oilseed Research center, is Ishuradi, Pabna, tested some varietals performance in Rajshahi and found that BARI masur-6 produced highest yield (2025 kg ha^{-1}) followed by BARI masur-5 (1900 kg ha^{-1}) and lowest yield produced by BARI masur-1 (1360 kg ha^{-1}). And other characters are also greatly performance by BARI masur-6.

BARI (2001) released the lentil variety BARI masur-6 was the best variety followed at BARI masur-5, BARI masur-4, BARI masur-1. This variety exceeded the yield of other variety by 12-15% and it was considerably resistant to rust and stemphylium blight, tolerant to foot rot and moderately resistance to aphid.

Boktiar *et al.* (2001) conducted a field experiment during 1999- 2000 in Rajshahi (High Barind Tract) and Jaipurhat (Tista Meander Flood plain), in Bangladesh to determine the site specific nutrient requirement of sugarcane and inter crops, onion and lentil (cv. BARI 4), under sugarcane based cropping system. Maximum sugarcane yield was recorded in High Barind Tract with the application of 190 N +44 P +65 K +20 S +3.5 Zn kg ha^{-1} to sugarcane. In Tista Meander Flood plain soils, application of 120 N +40 P +75 K +20 S +2 Zn +15 Mg kg ha^{-1} and 15 N +5 P +6 K +3 S kg ha^{-1} to sugarcane and lentil, respectively produce high yield.

Song *et al.* (2001) reported that the application of fertilizer N, P, K alone or fertilizer N, P, K combined with organic matter increased the pod length, grains pod^{-1} and plant height compared with control treatment thus enhancing biomass and grain yield of lentil.

BARI (2000) observed that among the varieties BARI mausr-1 (Uthfala), BARI masur-4, BARI masur-5 and BARI masur-6 produced significantly higher plant height, pod length, number of $grains^{-1}$, total tillers $plant^{-1}$, grain yield (2.1 ton ha^{-1}) than BARI masur-5 and significantly followed by BARI masur-4 and BARI masur-1.

H**ussain *et al.* (2000)** investigated to see the yield and quality response of three varieties of lentil to potassium application were carried out at the University of Agriculture, Faisalabad, Pakistan. Varieties used were local, Masoor-85 and Masoor-93. The potassium levels were 0, 25, 50 and 75 kg K_20 ha^{-1}. Masoor-93 yielded higher than to other varieties when treated with 50-75-50 kg N, P_20_5 and K_20 ha^{-1} and the increase in grain yield was attributed to increase in the number of seed pod^{-1}, total seed weight $plant^{-1}$ and weight $grains^{-1}$.

Singh (2000) determined the effects of K fertilizer rates and application methods on rice-lentil cropping system. They observed that the highest yield, yield attributes and N, K uptakes was recorded at 40 kg K ha^{-1} while the lowest values for yield, yield attributes and N, P uptake was recorded in control treatments.

Sarker *et al.* (1999) derived 'Barimasur-4' for its stable and high yield combined with resistance to rust *(Uromyces fabae)* and Stemphylium botryosum *(Pleospora herbarum)*. In yield trials conducted at 4 lentil-growing regions of Bangladesh over 3 years, Barimasur-4 produced a mean seed yield of 2300 kg ha^{-1}, compared with 1800 kg ha^{-1} for Barimasur-2 and an increase of 53% over the standard cultivar 'Uthfala'.

Sarker *et al.* (1999) derived 'Barimasur-2' for its high yield, wide adaptability and high level of resistance to lentil rust. In preliminary, advanced and regional yield trials conducted at 4 representative locations in Bangladesh during 1987-992, Barimasur-2 produced average grain yields of 1800 kg ha^{-1}, compared with 1500 kg ha^{-1} for the best standard cultivar 'Uthfala'.

Singh *et al.* (1998) carried out a one year field experiment during Rabi season 1992-1993 at Dundahera, Haryana, India. Lentil *(Lens culinary)* was given 0, 20, or 40 kg K ha^{-1} and or 40 kg S ha^{-1}. Growth and yield components did not differ between K and S rates. Yields increased with S and K application, but did not differ between K rates.

Sekhon *et al.* (1998) carried out a field trial from 1993-1994 to 1995-1996 in Ludhiana, Punjab, India, Lentil *(Lens culinaris* cv. LL 147) was given 0, 25 or 45 kg K ha^{-1} as elemental K, K_20. Yields and yield components generally increased with increasing K rate and were generally highest with single super phosphate and lowest with elemental K. K increased the crude protein content of seeds.

Zahran *et al.* (1998) laid out a field experiment at Ismailia Agricultural Research Station in Egypt during 1994-1995 and 1995-1996 growing seasons to evaluate the effect of foliar application of the supernatant of soaked calcium super phosphate (SP) and potassium sulfate (KS). Foliar spray with the solutions of SP at the rate of 5 kg fed^{-1} (lfedden= 0.42 ha) or the mixture of 10 kg SP+5 kg K fed^{-1} induced significant increases in yield and yield components of both crops during the two growing seasons. The straw yield and seed potassium content of lentil showed significant increases due to foliar application of KS -5 kg fed^{-1} and 5 kg SP+10 kg K S fed^{-1}.

Ghosal *et al.* (1994) worked with lentil (Lens culinaris Medik.) using 0-45 kg K_20 ha^{-1} as muriate of potas. They reported that grain yield and net return increased with up to 35 kg K_20 ha^{-1}.

Kumar *et al.* (1993) conducted an experiment on loam soil in Faisalabad, Pakistan, found that un-inoculated and inoculated with Rhizobium and given 0 or 20 kg N and 13, 35, 55 and 75 kg K_20 ha^{-1} percentage germination 15 days after sowing was increased by inoculation from 71.4 to 78.3 %. N application @ 20 kg N ha^{-1} significantly increases plant dry matter and K_20 up to 35 kg ha^{-1} also significantly increased plant dry matter, plant dry weight. Inoculation increased seed weight plant^{-1}, 100 seed weight, seed yield and seed protein content.

Yadav *et al.* (1993) conducted in a large number of field experiments on cultivator fields in alluvial tracts, Uttar Pradesh (U.P), positive response to Potassium (K) up to 30 to 35 kg K_20 ha^{-1} in pulse like-lentil, gram, black gram and pigeon pea under rain fed conditions were observed. The yield response was 4 to 8 kg grain kg^{-1} K_20.

Khan (1993) observed that the lentil varieties influenced plant height, length of pod, number of grains pod^{-1}, number of branches plant^{-1}, number of effective grains pod^{-1}, grain and straw yield.

Sinha *et al.* (1991) conduced a field experiment and the response of five *Kharif* (monsoon) crops viz. onion, groundnut, maize sweet potato and yam bean as well as five rabi (winter) crops viz. mustard, onion lentil maize and sunflower to boron application was studied on boron deficient calcareous soils under field condition. Boron was applied as borax @ 1.5 and 2.5 kg B ha^{-1}. All the crops responded to boron, the magnitude of yield response differed from to crop. The optimum level of B for *Kharif* as well as rabi crops was 1.5 kg B ha^{-1}. The order of yield response of boron in the *Kharif* crops was onion > maize> sweet potato> sunflower> maize>lentil. Application of boron progressively increased the B concentration and uptake by crops.

Sing and Sing (1983) reported that the application of boron increased the grain yield of lentil but the increase in yield was significant only up to 2 kg B ha^{-1} in both the years. But increases in straw yield were significant up to 4 kg B ha^{-1}. The increases in grain yield due to 1, 2 and 4 kg B ha^{-1} over control were 5.1 and 5.8, 8.7 and 9.3 and 12.0 and 13.3 percent, respectively. The corresponding increases in straw yield were 11.1 and 11.8, 14.9 and 14.4 and 20.7 and 19.2 percent. The marked response in grain and straw yield due to B addition may be attributed to the deficiency of available B in the soil. The non-significant increase in yield of grain due to higher level of B may be attributed to the increased accumulation of B in the root medium with its addition to soil beyond tolerance limit to the lentil crop.

CHAPTER THREE

MATERIALS AND METHODS

The study was conducted at the Agronomy Field Laboratory, Department of Agronomy and Agricultural extension, Rajshahi University during the period from October 2010 to February 2011 and October 2011 to February 2012 to study "the effect of potassium and boron on the growth, development and yield of lentil". The details of methods followed and materials used in the study are described below.

3.1. Description of experimental site

3.1.1. Location

The experimental farm is located at the western side of Agronomy and Agricultural Extension department. Geographically the experimental field was located at 24°17' N latitude and 88°28' E longitudes at an elevation of 20 m above the sea level belonging to the Agro-ecological Zone-11 (AEZ-11).

3.1.2. Soil

The experimental plot of the department of Agronomy and Agricultural Extension of Rajshahi University, Rajshahi is of poorly drained soil with moderately slow permeability. The top soil is silty loam and slightly alkaline in reaction. The chemical characteristics of experimental soil have been presented in Appendix I-II-III.

3.1.3. Climate

Lentil is a rabi season crop that can be grown in a short growing season. The crop was grown in the winter season when the day length (sunshine period) was reduced and there was unexpected rainfall at the beginning of the experiment and also at the time of harvesting .The monthly average temperature, humidity, rainfall and plenty of sunshine hours prevailed at the experimental area during the period of study (October to February). The monthly average, maximum and minimum air temperature, relative humidity and sunshine hours of the experimental area during the experimental period are given in Appendix IV-V.

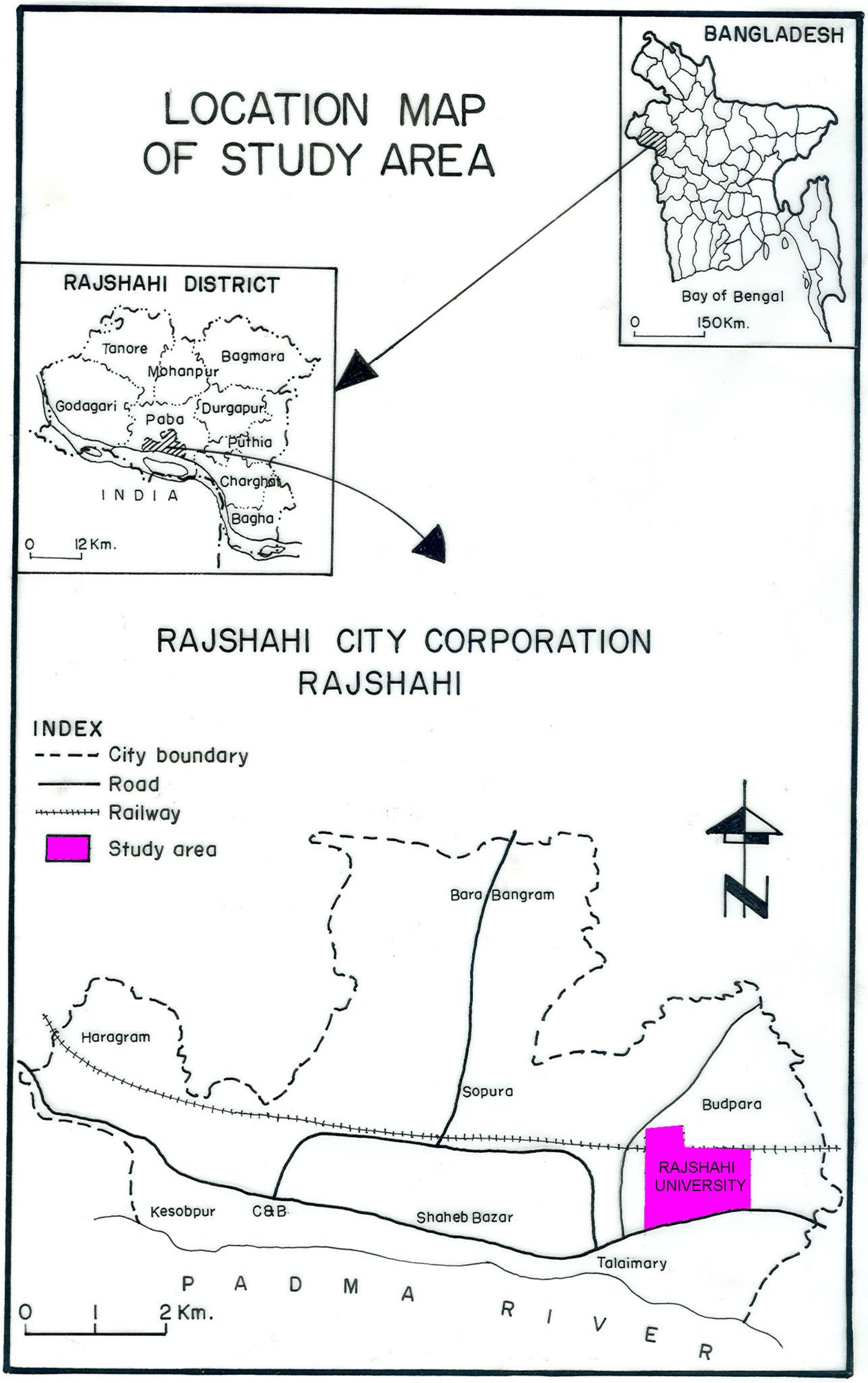

Plate 1. Location of Study area

3.2 Plant materials: Description of different varieties

The crop undertaken in this study was lentil *(Lens culinaris)* used as planting material having dwarf high yielding characteristics. Four lentil varieties named BARI masur-1, BARI masur-4, BARI masur-5 and BAR! masur-6 were used for this study. Seeds were collected from Pulses and Oilseed Research Center, Ishurdi, Pabna. Germination test of seed was done in the laboratory before sowing and germination percentage. Through national and international efforts, four improved lentil varieties released by Pulse Research Center, BARI in Bangladesh are given in the Table 1.

Table 1. Description of different varieties

Variety	Year of release	Source of Origin	Maturity day	Seed size (g 100 seed^{-1})	Yield ton ha^{-1}	Remarks
BARI masur-1 (Uthfala)	1991	Local selection-PRC	110	1.6	1.3-1.5	susceptible to rust and Stemphylium blight
BARI masur-4	1996	BARI-ICARDA	116	1.7	1.8-2.0	resistance to rust and Stemphylium blight
BARI masur-5	2006	BARI-ICARDA	110	1.8	2.0-2.1	combined resistant to rust and stemphylium blight, tolerant to foot rot and moderately resistance to aphid
BARI masur-6	2006	BARI-ICARDA	110	1.8	2.1-2.3	combined resistant to rust and stemphylium blight, tolerant to foot rot and moderately resistance to aphid

BARI masur-1 (Uthfala)

Uthfala is an early maturing, small seeded, semi dwarf type with determinate growth pattern and good pudding intensity variety. It was selected from a landrace, Pabna and released in 1991 with national association number BLL 79694. It has an average yield 1.3-1.5 t ha^{-1} and it less susceptible to rust and Stemphylium blight than the local cultivars. Stem pigmentation is absent at the seedling stage and is light green at late-vegetative stage. Leaves are dark green with light Pubescence. Leaf size is medium with a dark green, short piteol and rachis that from no tendrils. Its flower is white. Seed color is ash and testa is dotted. The seed are small seed surface with red cotyledon. The average 100-seed weight is 1.6 g. Its recovery percentage (splitted/dehulled quantity from whole seed) is 74%. The variety requires 16 minute cooking, which is like by the consumers. Its seed contain 27.8% protein. The variety is suitable for sole cultivation in all lentils growing area in Bangladesh.

BARI masur-4

BARI masur-4 was released in Bangladesh in 1996 for its stable and high yield and its resistance to rust and Stemphylium blight (Sarker *et al,* 1999). It is only variety grown in Bangladesh that has combined resistance against these two major diseases. It was developed from the cross ILL 5888 X ILL 5782 made at ICARDA in Syria especially for Bangladesh. The female parent BARI masur-4 was an improved lentil variety developed through pure line selection from a landrace in Bangladesh. BARI masur-4 produced an averages mean seed yield 1.8-2.0 t ha^{-1} compared to 1.6 t ha^{-1} for BARI masur-2. BARI masur-4 is an erect cultivar of medium stature (40-42cm) with long fruiting branches. The stem have anthocyanin pigmentation, the leaves are light green with narrow leaflets and rudimentary tendril. The flower is bluish-purple and the pods, leaves, stemsturn a light straw color at maturity. Most leaflets are shed at 100% pod maturity. The seed coat is reddish-grey, dotted and cotyledon is light orange. It has a 100-seed weight of about 1.7 g. The variety matures in 116 days, hamper the existing cropping pattern. Seed of the cultivar have 89% kernel content, but produce 78% head dhal. It takes about 17 minute to cook and shows solid dispersion of 54%. It contains 28.5% protein and 48% carbohydrate. The most importance agronomic advantage of this cultivar is that having an erect growth habit, more plants can be accommodated per unit area. It is potential cultivar for intercropping with sugarcane and mixed cropping with mustard. Due to the wide adaptability the cultivar is popular all over lentil growing areas of Bangladesh except Rajbari and Faridpur areas.

BARI masur-5

BARI masur-5 is developed by BARI and released in 2006. Its stable and high yield with combined resistant to rust and stemphylium blight, tolerant to foot rot and moderately resistance to aphid. BARI masur-5 was developed from the cross between ILL 69 (Jordanian origin) X ILL 1316 (Iraq origin) during 1995 at ICARDA. Tel Hadya, Syria under glass house conditions with 18 hour light intensity and temperature between 18-21°C to develop ILL 7616. The ICARDA breeding line (ILL 7616) was then crossed with ILL 2501 (Indian origin) using as female parent to develop X95S-136. Single plant selection from this breeding line was done from F_3 in Bangladesh. BARI masur-5 a released variety of lentil in Bangladesh developed from this line X95S-136. It is semi erect and medium stature with plant height 38-42cm. Plant is light green color, seeds are large than local variety and color is reddish brown. The leaves are dark green, with broad leaf lets without tendrils. The flowers are self-pollinated, with cross-pollination vectored by thrips or other small insects but not by wind or honeybees. Flowers are white, the pods and leaves turn to straw color light violet. Reproductive nodes generally bear single flowers, sometimes two or three and, rarely, four flowered racemes on short peduncles. It takes about 12 minute to cook. This variety takes maturity at 110 days and 105-115 days to complete life cycle. Yield varies between 2.0-2.1 t ha^{-1}. It has 12-15% yield advantage over BARI masur-4. It is potential cultivar for intercropping with sugarcane, mixed cropping with mustard, wheat and linseed and relay cropping with transplanted rice. The variety is suitable for cultivation in all lentils growing area in Bangladesh like Rajshahi, Kustia, Magura, Nator, Rajbari, Pabna, Comilla, Noakhali and Barisal districts. National Seed Board of Bangladesh give registration of the variety and this variety has now highly been accepted by farmers in the country.

BARI masur-6

BARI masur-6 is developed by BARI and released in 2006. Its stable and high yield with combined resistant to rust and stemphylium blight, tolerant to foot rot and moderately resistance to aphid. This released variety of lentil in Bangladesh developed from the line X95S-165(5). The line X95S-165(5) was developed by crossing between ILL 7667 X Idlib-1 in 1995 at ICARDA, Tel Hadya, Syria under glass house conditions with 18 hour light intensity and temperature between 18-21°C. ILL 7667 are breeding lines developed at ICARDA by crossing ILL98 X (ILL 5746 X ILL 5700). ILL 5746 is a breeding lines developed by crossing ILL 39 X ILL 954 was developed from a cross between ILL 20 X ILWL-1. Single plant selection was done from F_3 of X95S-165(5) in Bangladesh to developed BARI masur-6. This variety is semi erect and medium structure cultivar with plant height 35-40 cm. Plant is light green color, seeds are large than local variety and color is reddish brown. The leaves are dark green, with broad leaf lets without tendrils. The flowers are self-pollinated, with cross-pollination vectored by trips or other small insects but not by wind or honeybees. Flowers are white and the pods and leaves turn to straw color light violet. Reproductive nodes generally bear single flowers, sometimes two or three and, rarely, four flowered racemes on short peduncles. The variety takes maturity at 110 days and 105-115 days to complete its life cycle. Yield varies between 2.1-2.3 t ha^{-1}. BARI masur-6 is potential cultivar for intercropping with sugarcane, mixed cropping with mustard, wheat and linseed, relay cropping with transplanted rice and as pure culture. It can be grown in all types of soil but sandy loam and silty loam is the best. Due to the wide adaptability the cultivar is popular all over lentil growing areas of Bangladesh. It is growing as a mixed crop in Rajbari, Magura, Jossore, Kustia, Nator and Pabna, as an intercrop in Rajshahi, Kustia, Magura and Meherpur, as a relay cropping Comilla, Noakhali and Barisal districts. National Seed Board of Bangladesh give registration of the variety and this variety has now highly been accepted by farmers in our country.

3.3 Experimental treatments

I have two experiments. In the first year, I applied potassium and in the second year, I applied boron in the field.

The treatments included in the experiment were as follows-

Experiment No 1: Effect of potassium on the growth, development and yield of lentil.

Factor A: Four Varieties

1) BARI masur-1 (V_1)
2) BARI masur-4 (V_2)
3) BARI masur-5 (V_3)
4) BARI masur-6 (V_4)

Factor B: Potassium (5 levels)

1) 0 kg K ha^{-1}/control (K_0)
2) 15 kg K ha^{-1} (K_1)
3) 25 kg Kha^{-1} (K_2)
4) 35 kg Kha^{-1} (K_3)
5) 45 kg K ha^{-1} (K_4)

Experiment No. 2: Effect of boron on the growth, development and yield of lentil.

Factor A: Four Varieties

1) BARI masur-1 (V_1)
2) BARI masur-4 (V_2)
3) BARI masur-5 (V_3)
4) BARI masur-6 (V_4)

Factor B: Boron (5 levels)

1) 0 kg B ha^{-1}/control (B_0)
2) 0.5 kg B ha^{-1} (B_1)
3) 1 kg B ha^{-1} (B_2)
4) 1.5 kg B ha^{-1} (B_3)
5) 2 kg B ha^{-1} (B_4)

3.4 Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with three replications. At first, the entire field was divided into three blocks. Each block was divided into 20 unit plots. Thus the total number of unit plots in the entire experimental area was 4×5×3 =60. The unit plot size was 2.5 m x 2 m. The plot to plot distance was 0.3 m and block to block distance was 1.0 m. The treatments were randomly distributed to the plots within a block.

3.5 Land preparation of experimental area

In the first year the land of the experimental plot was opened on 20^{th} October 2010, with a power tiller and it was made ready for sowing on 28^{th} October 2010 by subsequently 3 to 4 ploughing and cross ploughing with a country plough followed by laddering and in the second year, the land of the experimental plot opened on 15^{th} October 2011, with a power tiller and it was made ready for sowing on 25^{th} October 2011 by subsequently 3 to 4 ploughing and cross ploughing with a country plough followed by laddering was done to achieve a good tilth. Weeds, stubbles and crop residues were removed from the land. The bunds around the individual plots were made firm enough to control water movement between the plots. The corners of the land were spaded and the larger clods were hammered to break into small pieces. The unit plots were finally prepared on the day of seed sowing and the basal dose of fertilizer was incorporated thoroughly.

3.6 Fertilizer application

In the first year the each and every plot was fertilized with 45 kg ha^{-1} urea, 85 kg ha^{-1} triple super phosphate (TSP) at the time of final land preparation. Potassium fertilizer was applied as per experimental specification at the time of final land preparation. In the second year the each and every plot was fertilized with 45 kg ha^{-1} urea, 85 kg ha^{-1} triple super phosphate (TSP) at the time of final land preparation. Boron fertilizer was applied as per experimental specification at the time of final land preparation. All the applied fertilizers were thoroughly mixed to the soil of experimental plots.

3.7 Collection of the seeds

Seeds of different lentil variety were collected from Pulses and Oilseed Research Center, Ishurdi, Pabna.

3.8 Seed treatment

Before sowing collected seeds were treated with Vitavax-200 @ 0.25% to prevent seeds from the attack of soil born diseases and pathogens.

3.9 Time of seed sowing

In the first year seeds were sown on 28th October 2010 and in the second year 25th October 2011 in 25 cm a part rows opened by specially made an iron hand tine. After sowing, the seeds were covered with soil and slightly pressed by hands. Proper care was taken to protect the seedlings from birds.

3.10 Method of seed sowing

Seeds were applied in the each plot by line sowing method. Seed rate was applied as per treatment was 40 kg ha^{-1}. Depth of the seed sowing in each plot was 3-4 cm. and the larger clods were hammered to break into small pieces. The unit plots were finally prepared on the day of seed sowing and the basal dose of fertilizer was incorporated thoroughly.

3.11 Germination of seed

Germination of seeds (plant emergence) started from 4th day of sowing. On the 9th day the percentage of germination was more than 80% and on the 10th day, plant emergence was nearly complete.

3.12 Intercultural operations

3.12.1 Weeding and thinning

The lentil crop was infested with some local weeds such as Bathua *(Chenopodium album),* Mutha *(Cyperus rotundus),* Durba *(Cynodon dactylon)* etc. In the first year weeding was done with the help of hand hoe (nirani) on 17th November 2010 (20 DAS) and 2nd December 2010 (35 DAS) and in the second year 15th November 2011 (20 DAS) and 30th November 2011 (35 DAS) to control weeds in the experimental field. Thinning was done to obtain optimum plant population if necessary.

3.12.2 Irrigation

Irrigation was applied in the experimental field in one time on 22th November 2010 and in the second year 19th November 2011.

3.13 General Observation

The experimental plots were frequently observed to notice any change in plant character and attack of pests and disease on the crop at the time of crop growing stages.

3.14 Insect and pest

Foot rot disease was observed in some plots of experimental area in seedling stages of crops. This disease was observed in the field at 2% rate. *Rhizoctonia solani* and *Fusarium oxysporum* were the causal organisms of this disease. To keep the field prevent from foot rot disease spraying Cupravit @ 2-3 kg ha^{-1}.

3.15 Determination of maturity

When 80% of the pods turned brown in color, the crop was assessed to attain maturity.

3.16 Harvesting

All the varieties become matured more or less at the same time in different plants and in the first year harvesting was done on 20^{th} February 2011 and in the second year 18^{th} February 2012 harvesting was done by hand picking. All of the harvested pods were kept separately in properly tagged gunny bags. Five plants were randomly selected prior to maturity from each plot for data recording. When all the plants looked nearly dead, they were harvested plot wise by uprooting and were bundled separately, tagged and brought to the threshing floor.

3.17 Post harvest operations

3.17.1 Threshing

The crop bundles were sun dried for four consecutive days by spreading them on threshing floor. Seeds were separated from the pods per plant by beating them with the bamboo sticks.

3.17.2 Drying, cleaning and weighting

The collected seeds were dried in the sun for reducing the moisture in the seeds to about 14% level. The dried seeds and straw were cleaned and weighted plot wise.

A. Preparation of experimental plot

B. Seedling stage

C. 15 days after sowing

D. 30 days after sowing

E. 45 days after sowing

F. Flower initiation stage

G. Maturity stage

H. Before harvest

Plate 2: Picture of the experimental field at different growth period of lentil

3.18 Procedure of sampling and collection of data

Randomized procedure was followed to collect the data of growth, development and yield and yield attributing characters. The description of sampling procedure was given below:

3.18.1 Growth and development characters

From each plot five rows of crop were used for collecting data on growth and development characters and other rest was kept for collecting data about yield and yield contributing characters. During the study, the following growth and development characters were recorded.

Growth characters

1. Total dry matter (TDM) at 15, 30, 45, 60, 75, 90 and 105 DAS
2. Crop growth rate (CGR) at 15-30, 30-45, 45-60, 60-75, 75-90 and 90-105 DAS

Development characters

1. Leaf production rate (LPR) at 15-30, 30-45, 45-60, 60-75, 75-90 and 90-105 DAS
2. Branch production Rate (BPR) at 15-30, 30-45, 45-60, 60-75, 75-90 and 90-105 DAS
3. Rate of flowering (FR) at 60-75, 75-90 DAS
4. Days to 50% flowering at duration
5. Days to maturity at duration

A. Growth characters

Total dry matter (TDM): Total dry matter production was determined by adding the weight of stem, leaf, root, pod (when appeared) and then converted into g $plant^{-1}$.

Crop growth rate: Ratio of dry matter production per unit of time per unit of ground area was calculated with the following formula:

$$\text{Crop growth rate (CGR)} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are the total dry weights of formal harvest and later harvest respectively. And is the time interval between later and formal harvest.

B. Development characters

Leaf production rate

Leaf production rate can be estimated by counting the number of leaves on tagged plants at periodical intervals. It is expressed as number of leaves per day.

$$\text{Leaf production rate (LPR)} = \frac{L_{n_2} - L_{n_1}}{t_2 - t_1}$$

Where L_{n_1} and L_{n_2} are number of leaves at times t_1 and t_2 respectively.

Branch production rate

Branch production rate can be estimated by counting the number of branch on tagged plants at periodical intervals. It is expressed as number of branch per day.

Branch production rate (BPR) = $\frac{B_{n_2} - B_{n_1}}{t_2 - t_1}$

Where B_{n_1} and B_{n_2} are number of branch at times t_1 and t_2 respectively.

Rate of Flowering

This parameter indicates whether most of the tillers or branches flower in quick succession or not. In other words, it indicates synchronous flowering. It is expressed as number of flowers that appear per day.

Rate of flowering (FR) = $\frac{F_{r_2} - F_{r_1}}{t_2 - t_1}$

Where F_{r_1} and F_{r_2} are number of flowers that appear per plant at times t_1 and t_2 respectively.

Days to 50 percent flowering

It is the number of days in which 50 percent of the plants flower.

Days to Maturity

It is the number of days in which plants attain maturity.

3.18.2 Yield and yield contributing characters

At maturity, five plants per plot were carefully uprooted randomly at each time for collecting data on yield attributes. After sampling, the crop from each plot was harvested at full maturity to record the data on grain and straw yield. During the study the following yield parameters were recorded.

1. Plant height (cm)

2. Number of branches plant^{-1}

3. Number of effective pods plant^{-1}

4. Number of non-effective pods plant^{-1}

5. Number of seeds pod^{-1}

6. Length of the pod (mm)

7. 1000-seed weight (g)

8. Grain yield (t ha^{-1})

9. Stover yield (t ha^{-1})

10. Biological yield (t ha^{-1})

11. Harvest index (%)

3.18.2.1 Procedure of data collection at harvest

Plant height (cm): The plant was taken from five randomly selected plants of each plot. The height of the plant was measured from the ground level to the top of the leaf.

Number of effective pods per plant: The pods that had at least one seed were considered as number of effective pod.

Number of non-effective pods per plant: The pods that had no seed were regarded as number of non-effective pod.

Number of branches per plant: Branches plant^{-1} that had at least one leaf visible was counted. It included both effective and non-effective branch.

Number of seeds per pod: Presence of any food material in the pod was considered as grain and total of grains present on each pod was counted.

Length of the pod (mm): Length of the pod was measured from neck node to apex of the pod.

1000-seed weight (g): One thousand grains were counted from grains of sample plants of each treatment plot, dried properly and weight by using an electric balance. Counting of the plants was done by hand.

Grain yield (t ha^{-1}): Grain yields were determined by harvesting crops grown one square meter area at the center of each plot. The harvested samples were then threshed, dried, weighted and the values were expressed in t ha^{-1}.

Stover yield (t ha^{-1}): After separation of grains from plants, the straw obtain from one square meter area of each unit plot were sun dried and weight to record the final Straw yield plot^{-1} and the value were finally converted to t ha^{-1}.

Biological yield (t ha^{-1}): Grain yield and straw yield together regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield

Harvest index (%): It denotes the ratio of grain yield (economic yield) and biological yield was calculated with the following formula (Gardner *et al.* 1985):

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

3.19 Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package programme MSTAT and the mean differences among the treatments were adjusted by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Simple correlation was done to determine the relationships between grain yield and its components with the help of SPSS computer programme.

CHAPTER FOUR

RESULTS

Experiment no. 1: Effect of potassium on the growth, development and yield of lentil

4.1 Growth parameters

4.1.1 Total dry meter (TDM)

Total dry matter (TDM) was significantly affected by the variety of lentil at the period of 45, 60, 75, 90 and 105 DAS except 15 and 30 DAS. Table 2 showed that TDM was slow at early stage, but it increasing with the increasing of days and it reached to maximum level at 105 DAS. BARI masur-6 (2.005) gave the highest value of TDM at 105 DAS which was statistically similar to V_2 (BARI masur-4) and V_3 (BARI masur-5). Here, the lowest value of TDM was observed in V_1 (BARI masur-1) (Figure 1 and Table 2).

Potassium level had significant effect on TDM at 30, 45,60,75,90 and 105 DAS except 15 DAS. At 15 DAS, TDM of lentil are more or less similar at different level of potassium. But at 30 DAS, the highest TDM was produced by K_3 (35 kg K ha^{-1}) and K_4 (45 kg K ha^{-1}) which was statistically identical with K_1 (15 kg K ha^{-1}) and K_2 (25 kg K ha^{-1}). At 45 and 60 DAS, three split of potassium gave the highest result and control treatment gave the lowest. At 75 DAS, three split of potassium gave the highest TDM which was statistically similar with four split of potassium. At 90 DAS, K_3 (35 kg K ha^{-1}) gave the highest result and K_0 (0 kg K ha^{-1}) gave the lowest result respectively. From the Table 3 the highest value of TDM was obtained from three split (K_3=35 kg K ha^{-1}) of potassium at 105 DAS. The lowest value was observed in control treatment (K_0= 0 kg K ha^{-1}) at all sampling dates (Figure 2 and Table 3).

TDM was significantly affected by the interaction of variety and potassium level at 30, 60 and 75 DAS, while interaction effect of variety and potassium did not significant in case of 15, 45, 90 and 105 DAS. At 30 DAS, the highest TDM was observed in BARI Masur-1 with 35 kg K ha^{-1} which is statistically similar to BARI Masur-4, BARI Masur-5 and BARI Masur-6 with 35 kg K ha^{-1}. On the other hand, lowest result was found in case of BARI Masur-1 with no potassium application (control). At 45 DAS, no significant was found in interaction between variety and potassium level. At 60 DAS, BARI Msur-5 and BARI Masur-6 gave highest result with 35 kg K ha^{-1} combination respectively and the lowest result was observed in BARI Masur-4 with no potassium application ($V_2 \times K_0$). At 75 DAS, the highest TDM was observed at $V_4 \times K_3$ Treatment combination and the lowest result was observed in control treatment with BARI Masur-1($V_1 \times K_0$). The other result at 90 and 105 DAS was not significant but the highest TDM value was marked at 105 DAS in all interaction and the lowest one was found on control treatment (Table 4).

Table 2. Effect of variety on TDM (g $plant^{-1}$) at different days after sowing

Variety	TDM (g $plant^{-1}$) at different DAS						
	15	30	45	60	75	90 S	105
V_1	0.015	0.041	0.135b	0.294c	0.630b	1.524c	1.615b
V_2	0.017	0.041	0.144ab	0.296c	0.650ab	1.652b	1.823ab
V_3	0.017	0.042	0.154a	0.362b	0.739ab	1.732a	1.904ab
V_4	0.016	0.044	0.152a	0.403a	0.811a	1.769a	2.005a
LS	NS	NS	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

NS = Non significant, LS = Level of significance, DAS = Days after sowing, TDM= Total dry matter

Table 3. Effect of potassium on TDM (g $plant^{-1}$) at different days after sowing

Treatment	TDM (g $plant^{-1}$) at different DAS						
	15	30	45	60	75	90	105
K_0	0.016	0.034b	0.122c	0.293d	0.606b	1.594c	1.701d
K_1	0.016	0.043ab	0.145b	0.331c	0.638b	1.580c	1.795c
K_2	0.017	0.041ab	0.138b	0.357b	0.702b	1.636b	1.829b
K_3	0.016	0.049a	0.184a	0.380a	0.855a	1.855a	2.020a
K_4	0.016	0.045a	0.142b	0.333c	0.737ab	1.681b	1.837b
LS	NS	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

NS = Non significant, LS = Level of significance, DAS = Days after sowing, TDM= Total dry matter

Table 4. Interaction effect of variety and potassium on TDM (g $plant^{-1}$) at different days after sowing

Interaction of variety and potassium level	TDM (g $plant^{-1}$) at different DAS						
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
V_1K_0	0.014	0.030c	0.098	0.281gh	0.505e	1.379	1.531
V_1K_1	0.016	0.042(a-c)	0.121	0.274h	0.564de	1.533	1.583
V_1K_2	0.016	0.041(a-c)	0.136	0.292g	0.564de	1.394	1.613
V_1K_3	0.016	0.049a	0.174	0.315ef	0.840(a-c)	1.778	1.727
V_1K_4	0.015	0.044(a-c)	0.146	0.309f	0.677(b-e)	1.538	1.619
V_2K_0	0.016	0.031bc	0.120	0.234i	0.585de	1.659	1.696
V_2K_1	0.015	0.039(a-c)	0.145	0.319ef	0.566de	1.491	1.724
V_2K_2	0.020	0.035(a-c)	0.135	0.326e	0.651(b-e)	1.586	1.804
V_2K_3	0.016	0.049a	0.186	0.313ef	0.818(a-c)	1.799	2.008
V_2K_4	0.016	0.050a	0.135	0.287gh	0.628(c-e)	1.727	1.883
V_3K_0	0.017	0.036(a-c)	0.131	0.316ef	0.662(b-e)	1.682	1.763
V_3K_1	0.017	0.042(a-c)	0.157	0.352d	0.648(b-e)	1.608	1.889
V_3K_2	0.017	0.041(a-c)	0.152	0.383c	0.760(a-d)	1.765	1.854
V_3K_3	0.017	0.048a	0.187	0.442a	0.848(a-c)	1.913	2.149
V_3K_4	0.016	0.044(a-c)	0.142	0.318ef	0.775(a-d)	1.691	1.866
V_4K_0	0.016	0.037(a-c)	0.141	0.340d	0.669(b-e)	1.658	1.816
V_4K_1	0.016	0.047ab	0.156	0.378c	0.773(a-d)	1.688	1.984
V_4K_2	0.016	0.046ab	0.131	0.427b	0.833(a-c)	1.797	2.047
V_4K_3	0.017	0.050a	0.189	0.451a	0.913a	1.931	2.196
V_4K_4	0.017	0.042(a-c)	0.145	0.419b	0.868ab	1.769	1.982
LS	NS	0.05	NS	0.01	0.01	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

NS = Non significant, LS = Level of Significance, DAS = Days after sowing,

TDM= Total dry matter

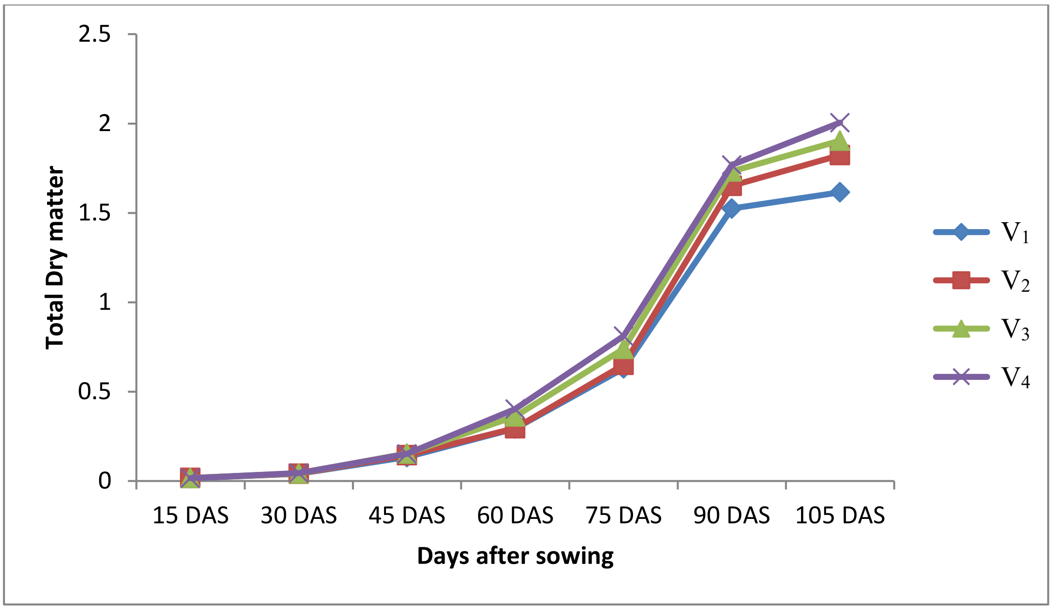

Figure 1. Effect of variety on TDM (g plant^{-1}) at different days after sowing

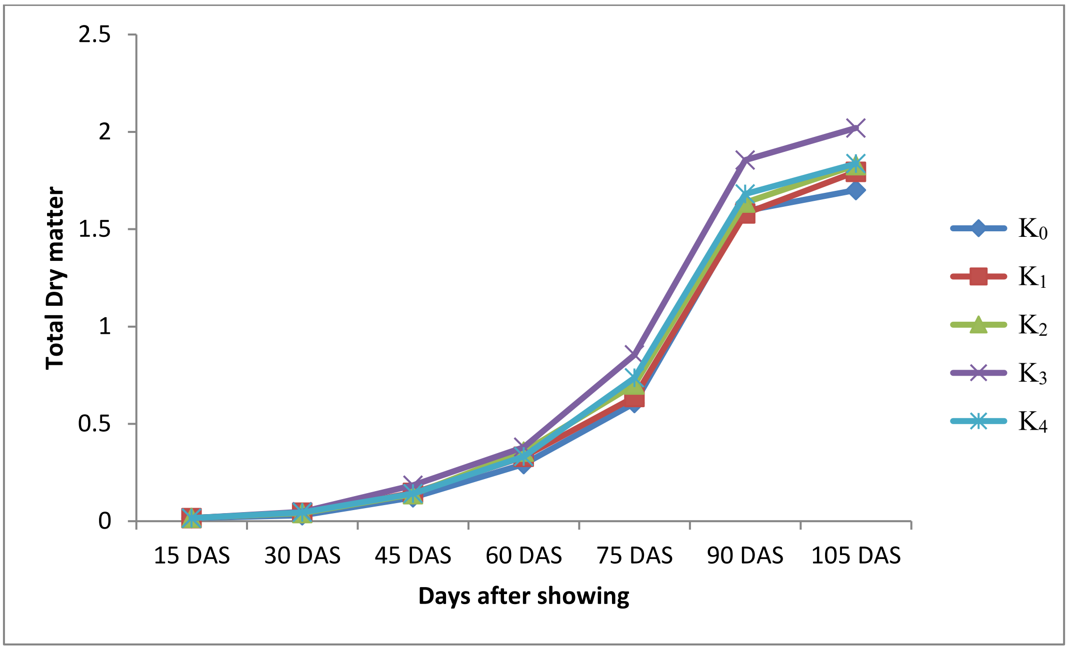

Figure 2. Effect of potassium on TDM (g plant^{-1}) at different days after sowing

4.1.2 Crop growth rate (CGR)

There was significant effect of variety on CGR within the period of 30-45, 45-60 and 60-75 DAS. On the other hand, CGR was not influenced by the varieties significantly at 15-30, 75-90 and 90-105 DAS. CGR was slow at early stage and reached to maximum level at 75-90 DAS and then declined. Within the period of 15-30 DAS, the result showed that varieties had no significant effect on CGR and all the results are more or less similar. Within the period of 30-45 DAS, V_3 (BARI Masur-5) and V_4 (BARI Masur-6) gave the higher CGR and BARI Masur-1 gave lower. Within the period of 45-60 DAS and 60-75 DAS, all the varieties showed statistically identical crop growth rate (CGR). The height CGR was obtained in BARI Masur-4 at 75-90 DAS. Within the period of 90-105 DAS, crop growth rate (CGR) of all varieties decreases (Figure 3 and Table 5).

Potassium level showed significant effect on CGR at 15-30, 30-45, 45-60 and 60-75 DAS. On the other hand, in 75-90 DAS and 90-105 DAS, the effect of potassium level on CGR showed non-significant. Within 15-30 DAS, 35 kg K ha^{-1} showed the highest value (0.216) and lowest result was obtained from one split and control application of potassium, which gave statistically identical results. Within 30-45 DAS, 45-60 DAS and 60-75 DAS, three splits of potassium (35 kg K ha^{-1}) showed the highest results. In case of 30-45 DAS, one, two and four splits of potassium give the similar results. Within 45-60 DAS, the lowest crop growth rate was found in control treatment (K_0). Within 60-75 DAS, control and one split of potassium gave the similar results and two splits of potassium is statistically similar with the result of four splits of potassium. The highest crop growth rate was found in three splits of potassium at 75-90 DAS.

Table 6 showed that. The crop growth rate was decreased after 75-90 DAS (Figure 4 and Table 6).

CGR was influenced significantly due to the interaction between variety and potassium level at 15-30 DAS, 45-60 DAS and 60-75 DAS while there was no significant effect of interaction combination at 30-45, 75-90 and 90-105 DAS. Within 15-30 DAS, the highest CGR was obtained from treatment combination of BARI Masur-4 with the application of 45 kg K ha^{-1} ($V_2 \times K_4$) which was statistically similar to BARI Masur-4 with the application of 35 kg k ha^{-1} ($V_2 \times K_3$), while the lowest result was obtained from the interaction of varieties with control treatment $V_1 \times K_0$, $V_2 \times K_0$, $V_3 \times K_0$ and $V_4 \times K_0$. Within 30-45 DAS, interaction between variety and potassium level on CGR not significantly varied. Within 45-60 DAS, the highest CGR was obtained from BARI Masur-6 with two splits of potassium application which is identical with four splits of potassium application ($V_4 \times K_4$). Here, the lowest result was found in BARI Masur-4 with control treatment combination ($V_2 \times K_0$). Within 60-75 DAS, the highest result was obtained from the interaction of BARI Masur-1 with 35 kg K ha^{-1} ($V_1 \times K_3$) and the lowest result was found in the same variety with control treatment combination ($V_1 \times K_0$). 75-90 DAS and 90-105 DAS not significantly varied between the variety and potassium interaction effect on CGR. But table-7 showed that higher CGR was found at 75-90 DAS and $V_2 \times K_4$ gave the highest CGR which was identical with $V_2 \times K_4$ at 15-30 DAS. After 75-90 DAS, the crop growth rate was decreased (Table 7).

Table 5. Effect of variety on CGR (g m^{-2} day^{-1}) at different DAS

Variety	CGR (g m^{-2} day^{-1}) at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1	0.173	0.626c	1.061b	2.240b	5.963	1.934
V_2	0.164	0.687b	1.011b	2.357b	6.686	2.221
V_3	0.169	0.744a	1.391ab	2.510ab	6.620	2.483
V_4	0.187	0.719a	1.672a	2.721a	6.383	2.609
LS	NS	0.01	0.01	0.01	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

NS = Non significant, LS = Level of significance, DAS = Days after sowing, CGR= Crop growth rate

Table 6. Effect of potassium on CGR (g $m^{-2}day^{-1}$) at different days after sowing

Treatment	CGR (g m^{-2} day^{-1}) at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
K_0	0.119e	0.592b	1.136d	2.085b	6.593	2.048
K_1	0.175c	0.683ab	1.239c	2.047b	6.281	2.431
K_2	0.159d	0.650ab	1.311b	2.301ab	6.226	2.624
K_3	0.216a	0.899a	1.457a	3.164a	6.670	2.767
K_4	0.195b	0.647ab	1.277bc	2.688ab	6.294	2.376
LS	0.01	0.01	0.01	0.01	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4= 45 Kg K ha^{-1}

NS = Non significant, LS = Level of significance, DAS = Days after sowing, CGR=Crop growth rate

Table 7. Interaction effect of variety and potassium on CGR (g m^{-2} day^{-1}) at different days after sowing

Interaction of variety and potassium level	CGR (g m^{-2} day^{-1}) at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1K_0	0.107i	0.458	1.216(b-f)	1.497n	5.824	2.347
V_1K_1	0.171fg	0.530	1.015(d-f)	1.938kl	6.459	1.665
V_1K_2	0.172fg	0.629	1.040(c-f)	1.815l	5.536	2.789
V_1K_3	0.216(b-d)	0.838	0.942ef	3.500a	6.254	0.993
V_1K_4	0.198e	0.678	1.090(c-f)	2.448fg	5.741	1.874
V_2K_0	0.099i	0.589	0.763f	2.341gh	7.157	1.583
V_2K_1	0.160g	0.706	1.159(b-f)	1.645m	6.167	2.885
V_2K_2	0.102i	0.668	1.270(a-f)	2.164j	6.241	2.784
V_2K_3	0.224ab	0.908	0.848ef	3.370b	6.537	2.727
V_2K_4	0.234a	0.565	1.015(d-f)	2.267(h-j)	7.327	2.374
V_3K_0	0.130h	0.630	1.235(b-f)	2.310hi	6.399	1.872
V_3K_1	0.164g	0.769	1.303(a-f)	1.973k	6.396	3.201
V_3K_2	0.166fg	0.737	1.540(a-e)	2.516ef	6.699	1.926
V_3K_3	0.204de	0.926	1.704(a-d)	2.705d	7.103	2.903
V_3K_4	0.180f	0.655	1.176(b-f)	3.049c	6.102	2.502
V_4K_0	0.141h	0.691	1.328(a-f)	2.194ij	6.592	2.388
V_4K_1	0.207(c-d)	0.728	1.479(a-f)	2.632de	6.104	3.307
V_4K_2	0.196e	0.566	1.977a	2.708d	6.427	2.995
V_4K_3	0.220(a-c)	0.925	1.749(a-c)	3.082c	6.786	3.099
V_4K_4	0.169fg	0.688	1.827ab	2.988c	6.006	2.754
LS	0.01	NS	0.01	0.01	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

NS = Non significant, LS= Level of Significance, DAS = Days after sowing, CGR=Crop growth rate

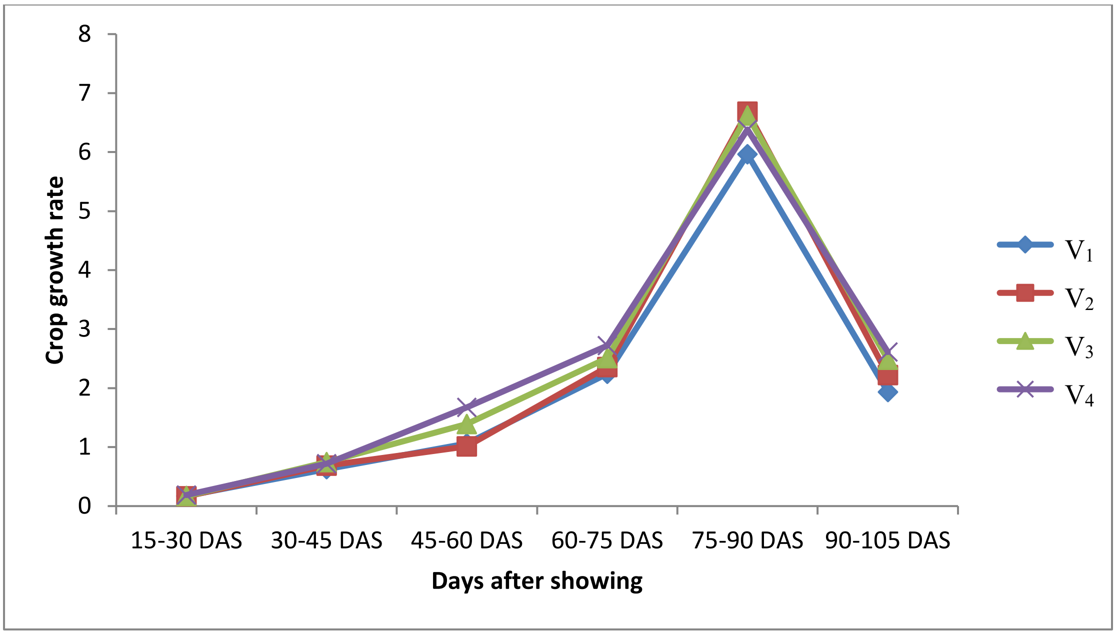

Figure 3. Effect of variety on CGR (g m^{-2} day^{-1}) at different DAS

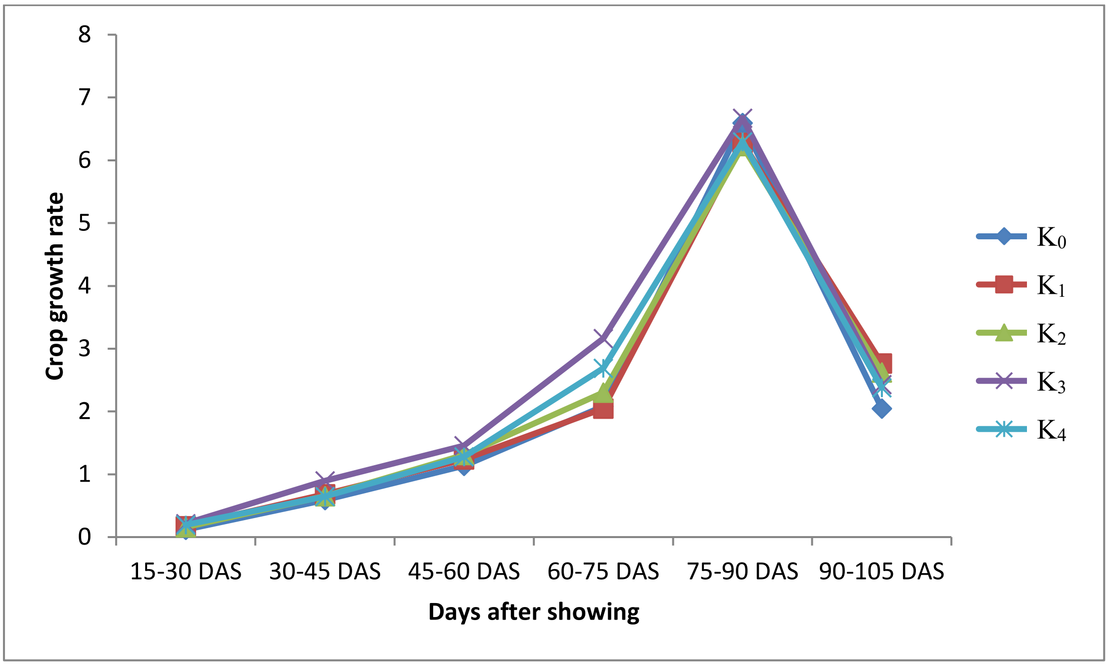

Figure 4. Effect of potassium on CGR (g $m^{-2}day^{-1}$) at different days after sowing

4.2 Development parameters

4.2.1 Leaf production rate (LPR)

LPR varied significantly due to variety of lentil 15-30 and 30-45 DAS. At 45-60, 60-75, 75-90 and 90-105 DAS variety had no significant effect on LPR. Within 15-30 DAS, BARI Masur-5 and BARI Masur-6 showed higher LPR value and BARI Masur-1 showed lower LPR value. Within 30-45 DAS, BARI Masur-6 showed higher and BARI masur-5 showed lower LPR value. Among the different days after sowing, 30-45 DAS showed higher LPR value which was statistically significant and 90-105 DAS showed the lower LPR value, which was not significant. In case of individual variety, BARI Masur-6 showed the higher LPR value at 30-45 DAS whereas BARI Masur-1 showed lower LPR value at 90-105 DAS (Table 8).

LPR was significantly influenced due to potassium levels at 15-30, 75-90 and 90-105 DAS. On the other hand, there was no significant effect of potassium level on LPR at 30-45, 45-60 and 60-75 DAS. Within 15-30 DAS, the highest LPR was observed in 35 kg K ha^{-1} which is statistically similar with 25 kg and 45 kg K ha^{-1}. The lowest LPR was obtained in control treatment. At 75-90 DAS, the highest LPR was found in three splits of potassium which is equal to four splits of potassium. Here, the lowest value also found in control treatment (0 kg K ha^{-1}). Within 90-105 DAS, the LPR was decreased. Here, the highest LPR was found in two and three splits of potassium application and the lower value was observed in control treatment (Table 9)

LPR was only significant within 15-30 DAS due to interaction effect of variety and potassium. In other sampling dates, LPR was not significant due to the interaction of variety and potassium. Within 15-30 DAS, the highest LPR was observed in BARI Masur-6 with 35 kg K ha^{-1} ($V_4 \times K_3$) treatment combination which was identical with $V_4 \times K_2$ and $V_4 \times K_4$ treatment combination. On the other hand, the lowest result was observed in BARI Masur-1 with 0 kg K ha^{-1} ($V_1 \times K_0$) treatment combination. (Table 10)

Table 8. Effect of variety on LPR at different days after showing

Variety	LPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1	0.057 c	0.241b	0.177	0.035	0.138	0.027
V_2	0.108b	0.238b	0.172	0.058	0.127	0.030
V_3	0.144a	0.220c	0.179	0.050	0.140	0.028
V_4	0.154a	0.268a	0.171	0.042	0.155	0.048
LS	0.01	0.01	NS	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6, NS = Non significant,

LS= Level of Significance, DAS = Days after sowing, LPR=Leaf Production Rate

Table 9. Effect of potassium on LPR at different days after showing

Treatment	LPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
K_0	0.079c	0.241	0.147	0.049	0.086d	0.009c
K_1	0.113b	0.234	0.194	0.042	0.133c	0.026b
K_2	0.124ab	0.237	0.175	0.048	0.145b	0.050a
K_3	0.136a	0.259	0.183	0.040	0.170a	0.051a
K_4	0.126ab	0.237	0.174	0.052	0.167a	0.032b
LS	0.01	NS	NS	NS	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

NS = Non significant, LS= Level of Significance, DAS = Days after sowing, LPR= Leaf Production Rate

Table 10. Interaction effect of variety and potassium on LPR at different days after showing

Interaction of variety and potassium level	LPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1K_0	0.035l	0.227	0.127	0.056	0.087	0.007
V_1K_1	0.049k	0.249	0.200	0.033	0.149	0.025
V_1K_2	0.062jk	0.240	0.178	0.031	0.147	0.036
V_1K_3	0.089i	0.247	0.195	0.015	0.164	0.036
V_1K_4	0.051k	0.242	0.184	0.038	0.142	0.031
V_2K_0	0.071j	0.231	0.138	0.064	0.089	0.007
V_2K_1	0.125fg	0.213	0.180	0.069	0.120	0.018
V_2K_2	0.116gh	0.233	0.186	0.055	0.142	0.027
V_2K_3	0.118gh	0.271	0.182	0.036	0.147	0.069
V_2K_4	0.111gh	0.242	0.173	0.064	0.136	0.031
V_3K_0	0.107h	0.227	0.153	0.055	0.087	0.007
V_3K_1	0.145de	0.216	0.204	0.033	0.120	0.022
V_3K_2	0.149de	0.207	0.189	0.049	0.142	0.029
V_3K_3	0.156cd	0.238	0.171	0.060	0.175	0.053
V_3K_4	0.167bc	0.211	0.176	0.053	0.176	0.029
V_4K_0	0.105h	0.262	0.171	0.020	0.082	0.016
V_4K_1	0.136ef	0.258	0.191	0.034	0.142	0.038
V_4K_2	0.171ab	0.269	0.147	0.058	0.147	0.107
V_4K_3	0.182a	0.280	0.185	0.049	0.193	0.044
V_4K_4	0.176ab	0.269	0.162	0.051	0.213	0.035
LS	0.01	NS	NS	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6, K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}, NS = Non significant, LS= Level of Significance, DAS = Days after sowing

LPR= Leaf Production Rate

4.2.2 Branch production rate (BPR)

Branch production rate (BPR) varied significantly due to variety of lentil at 15-30, 30-45 and 45-60 DAS. While effect of variety did not differed significantly at 60-75, 75-90 and 90-105 DAS. Branch production rate was higher in BARI Masue-6 and lower in BARI Masur-1 within 15-30 DAS (Table 11). Table 11 also showed that within 30-45 DAS and 45-60 DAS, BARI Masur-6 producing high branches and BARI Masur-1 showed low branch production rate. No significant effect was found in the other sampling dates. At 45-60 DAS, the highest BPR was observed and then declined. BARI Masur-6 gave the highest value of BPR which was significantly varied with other varieties.

Potassium level had significant effect on branch production Rate at 15-30, 30-45 and 45-60 DAS, while at 60-75, 75-90 and 90-105 DAS, there was no significant effect. At 15-30 DAS, 35 kg K ha^{-1} gave the highest branch production rate whereas lowest branch production rate should be obtained from control (K_0) treatment. Within 30-45 DAS and 45-60 DAS the highest branch production rate was observed in 35 kg K ha^{-1} application, while 0 kg K ha^{-1} gave lower value at 45-60 DAS. The branch production rate reached its maximum stage at 45-60 DAS and then the value was decline (Table 12).

BPR varied significantly due to interaction effect of variety and potassium level at 30-45 and 45-60 DAS and this interaction did not varied significantly at 15-30, 60-75, 75-90 and 90-105 DAS. Within 30-45 DAS, BPR showed the highest value at BARI Masur-5 with 35 kg K ha^{-1} ($V_3 \times K_3$) interaction and lower result should be found in $V_2 \times K_4$ interaction. Within 45-60 DAS, highest value observed in BARI Masur-6 with 35 kg and 45 kg K ha^{-1} which was statistically similar with the interaction of $V_1 \times K_3$, $V_1 \times K_3$, $V_2 \times K_4$, $V_3 \times K_3$, $V_4 \times K_1$ and $V_4 \times K_2$ respectively. Table 13 showed that in the interaction of variety and potassium level, branch production rate increase gradually for all interaction and reached at maximum level within 45-60 DAS. Then the rate was decreased. There was no significant effect was observed due to the interaction of variety and potassium at 60-75, 75-90 and 90-105 DAS (Table 13).

Table 11. Effect of variety on BPR at different days after showing

Variety	BPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1	0.368c	1.129c	2.095c	0.738	1.726	1.009
V_2	0.530b	1.170c	2.303b	0.770	1.818	0.996
V_3	0.553b	1.428b	2.269b	0.746	1.758	1.019
V_4	0.700a	1.534a	2.528a	0.697	1.954	0.925
LS	0.01	0.01	0.01	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6, NS = Non significant, LS= Level of Significance, DAS = Days after sowing, BPR= Branch Production Rate

Table 12. Effect of potassium on BPR at different days after showing

Treatment	BPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
K_0	0.388d	1.162b	1.984d	0.646	1.796	0.819
K_1	0.463cd	1.211b	2.383b	0.782	1.830	0.977
K_2	0.529bc	1.274b	2.307c	0.781	1.764	1.054
K_3	0.728a	1.627a	2.545a	0.760	1.772	1.115
K_4	0.579b	1.302b	2.274c	0.720	1.908	0.972
LS	0.01	0.01	0.01	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

NS= Non significant, LS= Level of Significance, DAS = Days after sowing, BPR= Branch Production Rate

Table 13. Interaction effect of variety and potassium on BPR at different days after showing

Interaction of variety and potassium level	BPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1K_0	0.285	1.062kl	1.567h	0.724	1.540	0.982
V_1K_1	0.311	1.013l	2.400cd	0.943	1.698	0.902
V_1K_2	0.396	1.067kl	2.182e	0.724	1.747	1.053
V_1K_3	0.478	1.340de	2.511ab	0.631	1.849	1.064
V_1K_4	0.369	1.164hi	1.813g	0.667	1.798	1.044
V_2K_0	0.405	1.085jk	2.146ef	0.636	1.656	0.880
V_2K_1	0.440	1.262fg	2.076 f	0.911	1.967	0.907
V_2K_2	0.551	1.147ij	2.160ef	0.916	1.845	0.962
V_2K_3	0.644	1.520c	2.578ab	0.609	1.806	1.191
V_2K_4	0.609	0.836m	2.547ab	0.778	1.816	1.040
V_3K_0	0.413	1.218gh	1.840g	0.729	1.958	0.593
V_3K_1	0.507	1.271fg	2.475bc	0.684	1.644	1.066
V_3K_2	0.531	1.393d	2.329d	0.734	1.689	1.104
V_3K_3	0.711	1.866a	2.542ab	0.831	1.467	1.409
V_3K_4	0.605	1.391d	2.160ef	0.750	2.031	0.922
V_4K_0	0.449	1.285fg	2.382cd	0.493	2.029	0.820
V_4K_1	0.596	1.298fg	2.514ab	0.591	2.011	1.033
V_4K_2	0.640	1.489c	2.556ab	0.751	1.776	1.098
V_4K_3	1.080	1.782b	2.609a	0.967	1.966	0.796
V_4K_4	0.734	1.818ab	2.587a	0.685	1.987	0.880
LS	NS	0.01	0.01	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

NS = Non significant, LS= Level of Significance, DAS = Days after sowing

BPR= Branch Production Rate

4.2.3 Rate of flowering (FR)

FR was significantly influenced due to variety of lentil both at 60-75 and 75-90 DAS. For flowering rate, within 60-75 DAS, BARI Masue-6 showed higher flower production rate, which was identical with BARI Masur-5. Within 75-90 DAS, V_4 (BARI Masur-6) continue it's superiority than other varieties (Table 14).

Potassium had significant effect on FR at 60-75 and 75-90 DAS. Within 60-75 DAS, three splits of potassium gave the higher flowering rate which was similar with two splits of potassium. At 75-90 DAS, 35 kg K ha^{-1} gave the highest result which was statistically identical with K_4 (35 kg K ha^{-1}) treatment (Table 15).

Table 16 showed that there was no significant effect between the interaction of variety and potassium on FR at different DAS. In case of flowering rate, the highest value was observed in $V_4 \times K_4$ treatment at 75-90 DAS and the lowest value was observed in $V_1 \times K_0$ treatment combination at 60-75 DAS.

4.2.4 Days to 50% flowering and days to maturity

Days to 50% flowering and days to maturity was significantly influenced due to variety. For 50% flowering time and days to maturity, BARI Masur-1 took shorter time and BARI Masur-6 took comparatively longer time than the other varieties (Table 14).

Potassium had significant effect on days to 50% flowering 15 kg k ha^{-1} gave earlier 50% flower emergence while 35 kg K ha^{-1} application showed delayed. No significant effect was found on days to maturity (Table 15).

Table 16 showed that there was no significant effect of interaction between variety and potassium on days to 50 % flowering and days to maturity.

Table14. Effect of variety on FR at different days after showing, days to 50% flowering and days to maturity.

Variety	FR at different DAS		Days to 50% flowering	Days to maturity
	60-75	75-90		
V_1	1.037ab	1.093b	61.267c	113.333c
V_2	0.981b	1.437ab	64.533b	114.333bc
V_3	1.161a	1.392ab	64.267b	115.267b
V_4	1.184a	1.498a	66.867a	117.333a
LS	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6, LS= Level of Significance, DAS = Days after sowing, FR= Rate of flowering

Table 15. Effect of potassium on FR at different days after showing, days to 50% flowering and days to maturity.

Treatment	FR at different DAS		Days to 50% flowering	Days to maturity
	60-75	75-90		
K_0	0.536c	0.748c	63.083c	114.917
K_1	1.165b	1.462b	63.000c	114.917
K_2	1.236ab	1.483b	65.000b	115.167
K_3	1.397a	1.559a	65.083a	115.250
K_4	1.121b	1.523a	65.000b	115.083
LS	0.01	0.01	0.01	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

LS= Level of Significance, DAS = Days after sowing, FR= Rate of flowering

Table16. Interaction effect of variety and potassium on FR at different days after showing, days to 50% flowering and days to maturity.

Interaction of variety and potassium level	FR at different DAS		Days to 50% flowering	Days to maturity
	60-75	75-90		
V_1K_0	0.409	0.735	60.667	113.000
V_1K_1	1.062	1.267	60.333	113.000
V_1K_2	1.182	1.149	61.667	113.333
V_1K_3	1.349	1.153	61.667	113.667
V_1K_4	1.182	1.160	62.000	113.667
V_2K_0	0.469	0.703	63.333	114.333
V_2K_1	1.071	1.480	63.333	114.333
V_2K_2	0.934	1.836	65.333	114.333
V_2K_3	1.422	1.647	65.333	114.333
V_2K_4	1.011	1.520	65.333	114.333
V_3K_0	0.580	0.758	62.667	115.000
V_3K_1	1.300	1.471	62.667	115.000
V_3K_2	1.369	1.496	65.333	115.667
V_3K_3	1.329	1.640	65.333	115.667
V_3K_4	1.229	1.598	65.333	115.000
V_4K_0	0.687	0.798	65.667	117.333
V_4K_1	1.227	1.629	65.667	117.333
V_4K_2	1.458	1.451	67.667	117.333
V_4K_3	1.487	1.653	67.667	117.333
V_4K_4	1.062	1.960	67.667	117.333
LS	NS	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6
K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}
NS = Non significant, LS= Level of Significance, DAS = Days after sowing
FR= Rate of flowering

4.3 Yield and yield contributing characters

4.3.1 Plant height

Variety had no significant effect of lentil. From Table 17, it was observed that the taller plant (30.773cm) was resulted from BARI Masur-6 and the lower plant height (29.355cm) was found in BARI Masur-5.

Plant height varied significantly due to potassium application on lentil. Table 18 showed that, the taller plant (31.437cm) was found in K_3 treatment (35 kg k ha^{-1}) and the lower result (28.192cm) obtained in control treatment (0 kg K ha^{-1}).

Plant height did not differ significantly due to interaction effect of variety and potassium level (Table 19).

4.3.2 Number of branches $plant^{-1}$

Variety had significant effect on number of branches $plant^{-1}$. The highest number of branches $plant^{-1}$ (13.267) was observed in V_4 (BARI Masur-6). The lowest number of branches $plant^{-1}$ (8.367) was recorded in V_1 (BARI Masur-1) (Table 17).

Potassium level had significant effect on number of branches $plant^{-1}$ in the trials. The highest number of branches $plant^{-1}$ was observed in three splits of potassium K_3 (13.242) which were identical with two splits of potassium K_2 (12.250). From table 18, it was observed that the lowest result was obtained from control (K_0) treatment (Table 18).

The interaction effect of variety and potassium had no significant effect on number of branches $plant^{-1}$. BARI Masur-6 with 35 kg k ha^{-1} ($V_4 \times K_3$) treatment combination gave the higher number of branches $plant^{-1}$

(14.467). The lower number of branches plant^{-1} was found in BARI Masur-1 with control treatment combination ($V_1 \times K_0$) (Table 19).

4.3.3 Number of effective pods plant^{-1}

Number of effective pods plant^{-1} was significantly influenced by variety. Number of effective pods plant^{-1} was recorded in BARI Masur-6 which was statistically similar to BARI Masur-5 (V_3). The lowest result was observed in BARI Masur-1 (V_1) (Table 17).

Potassium had significant effect on the number of effective pods plant^{-1}. From Table 18, it was observed that number of effective pods plant^{-1} was highest (78.167) in three splits of potassium application (35 kg K ha^{-1}). Two and four splits of potassium application gave statistical identical results. The lowest result was observed (56.771) in K_0 treatment (0 kg K ha^{-1}).

Number of effective pods plant-^{1} showed no significant variation due to interaction of variety and potassium level. The higher number of effective pods plant^{-1} was found in BARI Masur-6 with 35 kg K ha^{-1} ($V_4 \times K_3$) treatment combination and the lower value was in $V_1 \times K_0$ treatment combination (Table 19).

4.3.4 Number of non-effective pods plant^{-1}

Number of non-effective pods plant^{-1} varied significantly. Table 17 showed that BARI Masur-4 gave the highest value of non-effective pods plant-^{1} (3.961) and the lowest value was found in BARI Masur-1.

Potassium levels had significant effect on number of non-effective pods plant^{-1}. The highest number was produced by control treatment (4.418) and the lowest one (2.251) was obtained in three splits (35 kg k ha^{-1}) of potassium (Table 18).

Table 19 showed the interaction effect of variety and potassium level on yield and yield contributing characters of lentil. Number of non-effective pods plant^{-1} varied significantly due to interaction effect of variety and potassium level. The highest result was obtained from $V_2 \times K_1$ treatment combination. Similar result was obtained from $V_2 \times K_0$ treatment combination. The lowest value was observed in $V_4 \times K_3$ treatment combination, which was identical with $V_1 \times K_3$ treatment combination.

4.3.5 Number of seeds pod^{-1}

The effect of variety was found to be non-significant in respect of number of seeds pod^{-1} in the experiment. The maximum number of seeds pod^{-1} was obtained from BARI Masur-5 which was similar to others. The minimum number of seeds pod^{-1} was found in BARI Masur-1 (Table 17).

Number of seeds pod^{-1} varied significantly due to potassium level. Three splits of potassium levels (35 kg K ha^{-1}) produced highest number of seeds pod^{-1} which was identical with two splits (25 kg K ha^{-1}) and four splits (45 kg K ha^{-1}). The lowest value of seeds pod^{-1} was found in control treatment (0 kg K ha^{-1}) (Table 18).

The interaction effect of variety and potassium was found to be non-significant in respect of number of seeds pod^{-1} (Table 19).

4.3.6 Length of the pod (mm)

Length of the pod was significantly affected by the variety. The tallest length of the pod was obtained in BARI Masur-1 (V_1) is 1.227 mm which was statistically similar to V_3 and V_4. The smallest length (1.097 mm) of the pod was found in BARI Masur-4 (V_2) (Table 17).

Potassium level had significant effect on length of the pod. The highest potassium (35 kg K ha^{-1}) and the lowest result were obtained from control treatment (0 kg K ha^{-1}) and one split of potassium (15 kg K ha^{-1}) (Table 18).

The interaction of variety and potassium level had significant effect on length of the pod. $V_1 \times K_3$ and $V_1 \times K_4$ treatment combination gave the highest result which was statistically identical to $V_1 \times K_2$ and $V_4 \times K_3$. The lowest one was observed in $V_1 \times K_0$ treatment combination (Table 19).

4.3.7 1000 seed weight (g)

1000 seed weight differed significantly due to variety. The 1000 seed weight (20.320g) was found in BARI Masur-6 which was statistically similar to BARI Masur-5. The lowest 1000 seed weight (16.373 g) was recorded in BARI Masur-1 (Table 17).

1000 seed weight was significantly affected by potassium level. The highest 1000 seed weight (20.458g) was observed in K_3 (35 kg K ha^{-1})

treatment. The lowest 1000 seed weight (18.257g) was observed in control treatment (0 kg K ha^{-1}) which was identical to K_1 (15 kg K ha^{-1}) (Table 18).

1000 seed weight did not show significant variation by the interaction of variety and potassium level. The higher result was obtained in $V_3 \times K_3$ treatment combination and the lower value was observed in $V_1 \times K_1$ treatment combination (Table 19).

4.3.8 Grain yield (t ha^{-1}):

Grain yield differed significantly due to varietal effect. The highest Grain yield (1.629 t ha^{-1}) was recorded in V_4 (BARI Masur-6). The lower value of grain yield (1.164 t ha^{-1}) was found in BARI Masur-1 (Table 17).

Result showed that potassium had significant effect on grain yield. The highest grain yield (1.732) was observed in three splits of potassium (35 kg k ha^{-1}). The lowest grain yield (1.106) was found in control treatment (0 kg K ha^{-1}) (Table 18).

The interaction of variety and potassium had no significant effect on grain yield. The highest grain yield was obtained in $V_4 \times K_3$ treatment combination. The lowest grain yield was obtained in $V_1 \times K_0$ treatment combination (Table 19).

4.3.9 Stover yield / Straw yield (t ha^{-1})

Straw yield varied significantly due to variety. The highest straw yield (2.47) was recorded in V_4 which indicates BARI Masur-6 and the lowest value (1.797) was obtained in V_1 which indicates BARI Masur-1 (Table 17).

Straw yield significantly influenced by potassium level. The highest straw yield (2.468) was found in three splits of potassium. This result was statistically identical with four splits of potassium. The lowest straw yield (1.753) was obtained on control treatment (Table 18).

The interaction effect between variety and potassium level was not found to be significant effect in respect of straw yield (Table 19). The highest value was obtained in $V_4 \times K_3$ treatment combination.

4.3.10 Biological yield (t ha^{-1})

Biological yield significantly influenced by varieties of lentil. From Table 17, result showed that, BARI Masur-6 variety gave the highest Biological yield (4.099) and BARI Masur-1 gave the lowest Biological yield (2.961).

Potassium level had significant effect on biological yield. Table 18 showed that, the highest biological yield (4.200) was found with three splits of potassium (35 kg K ha^{-1}). The lowest biological yield (2.950) was obtained in control treatment (0. kg K ha^{-1}).

The interaction between variety and potassium levels was not significant in respect of biological yield. The highest value was obtained in $V_4 \times K_3$ treatment combination and the lowest value was found in $V_1 \times K_0$ treatment combination (Table 19).

4.3.11 Harvest index (%)

Harvest index had no significant effect due to variety of lentil. All the varieties showed similar results (Table 17).

Effect of different potassium levels had significant effect on harvest index of lentil. Three splits (K_3) of potassium levels showed higher harvest index

(41.188) and the lower harvest index was observed in control treatment (K_0) (Table 18).

Interaction effect of variety and potassium showed significant effect of lentil. Higher value of harvest index was found in $V_2 \times K_3$ treatment combination and the lower value was observed in $V_4 \times K_0$ treatment combination which was statistically similar with $V_1 \times K_0$ treatment combination (Table19).

Table 17: Effect of variety on the yield and yield contributing characters of lentil

Variety	Plant height (cm)	Number of branches plant^{-1}	Number of effective pods plant^{-1}	Number of non-effective pods plant^{-1}	Number of seeds pod^{-1}	Length of the pod (mm)	1000 seed weight (g)	Grain yield (t ha^{-1}	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	30.157	8.367c	55.730b	2.687b	1.840	1.227a	16.373c	1.164c	1.797c	2.961c	39.121
V_2	30.220	12.340bc	67.787ab	3.961a	1.853	1.097b	19.640b	1.521b	2.301b	3.829b	39.531
V_3	29.355	12.283ab	71.510a	3.330ab	1.880	1.137ab	20.267a	1.553b	2.304b	3.924b	39.477
V_4	30.773	13.267a	78.520a	2.900ab	1.860	1.160ab	20.320a	1.629a	2.470a	4.099a	39.557
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01	0.01	0.01	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

NS = Non significant, LS= Level of Significance

Table 18: Effect of different potassium levels on the yield and yield contributing characters of lentil

Potassium levels	Plant height (cm)	Number of branches plant^{-1}	Number of effective pods plant^{-1}	Number of non-effective pods plant^{-1}	Number of seeds pod^{-1}	Length of the pod (mm)	1000 seed weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
K_0	28.192d	9.988c	56.771c	4.418 a	1.567b	1.017c	18.275c	1.106e	1.753d	2.950e	37.478d
K_1	30.720b	11.142b	63.712bc	3.321b	1.733ab	1.071c	18.567c	1.358d	2.123c	3.481d	38.951c
K_2	30.054c	12.250a	71.058ab	3.271b	1.992a	1.192b	19.142b	1.546c	2.325b	3.871c	39.820b
K_3	31.437a	13.242a	78.167a	2.251c	2.000 a	1.275a	20.458a	1.732a	2.468a	4.200a	41.188a
K_4	30.227b	11.200b	72.225ab	2.837bc	2.000a	1.221ab	19.308b	1.593b	2.421a	4.014b	39.668b
LS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

LS = Level of Significance

Table 19: Interaction effect of variety and potassium level on the yield and yield contributing characters of lentil

Integration of Variety and potassium level	Plant height (cm)	Number of branches $plant^{-1}$	Number of effective pods $plant^{-1}$	Number of non-effective pods $plant^{-1}$	Number of seeds pod^{-1}	Length of the pod (mm)	1000 seed weight (g)	Grain yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
V_1K_0	28.867	6.400	47.400	4.163(a-c)	1.467	0.867c	16.000	0.827	1.377	2.204	37.517i
V_1K_1	29.887	7.833	50.850	2.333(d-f)	1.733	1.017bc	15.900	1.072	1.700	2.773	38.640h
V_1K_2	29.950	9.333	57.567	2.667(d-f)	2.000	1.383ab	15.967	1.116	1.783	2.900	38.523h
V_1K_3	31.413	11.200	62.667	2.037f	2.000	1.433a	18.133	1.418	2.070	3.488	40.620cd
V_1K_4	30.667	7.067	60.167	2.233ef	2.000	1.433a	15.867	1.387	2.054	3.440	40.303de
V_2K_0	29.733	10.667	57.267	4.733ab	1.567	1.050(a-c)	18.867	1.106	1.796	2.936	37.663i
V_2K_1	30.280	12.333	64.667	5.067a	1.700	1.067(a-c)	19.333	1.351	2.170	3.520	38.393h
V_2K_2	30.967	12.600	69.867	4.267(a-c)	2.000	1.117(a-c)	19.967	1.726	2.500	4.226	40.850bc
V_2K_3	30.600	13.500	77.600	2.600de	2.000	1.150(a-c)	20.300	1.854	2.540	4.394	42.210a
V_2K_4	29.520	12.600	69.533	3.140(c-f)	2.000	1.100 (a-c)	19.733	1.568	2.499	4.067	38.537h
V_3K_0	27.567	11.417	60.817	4.443(a-c)	1.633	1.083 (a-c)	18.533	1.247	1.734	3.314	37.637i
V_3K_1	31.260	12.333	64.333	2.350(d-f)	1.800	1.100 (a-c)	19.267	1.439	2.242	3.681	39.060 g
V_3K_2	28.080	12.467	74.533	3.817(a-d)	1.967	1.117(a-c)	20.267	1.645	2.467	4.111	39.983ef
V_3K_3	30.910	13.800	79.667	2.433(d-f)	2.000	1.217(a-c)	22.433	1.766	2.567	4.333	40.777c
V_3K_4	28.957	11.400	78.200	3.607(a-e)	2.000	1.167(a-c)	20.833	1.670	2.511	4.182	39.927f
V_4K_0	26.600	11.467	61.600	4.333(a-c)	1.600	1.067(a-c)	19.700	1.242	2.103	3.346	37.097 j
V_4K_1	31.453	12.067	75.000	3.533(b-e)	1.700	1.100(a-c)	19.767	1.570	2.380	3.950	39.710f
V_4K_2	31.220	14.600	82.267	2.333ef	2.000	1.150(a-c)	20.367	1.698	2.550	4.248	39.923f
V_4K_3	32.823	14.467	92.733	1.933f	2.000	1.300ab	20.967	1.889	2.696	4.585	41.147b
V_4K_4	31.767	13.733	81.000	2.367(d-f)	2.000	1.183(a-c)	20.800	1.746	2.619	4.365	39.907f
LS	NS	NS	NS	0.01	NS	0.01	NS	NS	NS	NS	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

K_0 = 0 kg K ha^{-1} (control), K_1 = 15 kg K ha^{-1}, K_2 = 25 Kg K ha^{-1}, K_3 = 35 Kg K ha^{-1}, K_4 = 45 Kg K ha^{-1}

NS = Non significant, LS = Level of Significance

4.4 Correlation analysis for yield and yield attributing characters of lentil

Yield is the expression as a whole of the performance of various yield contributing characters and the results of the interaction among them. Hence, it is of almost importance to know the quality of inter relationship among the yield and yield contributing characters. The simple correlation coefficient is done to know the relation between different yield and yield characters at harvest. The correlation matrix of selected parameters is presented in (Table 20).

The correlation coefficient result indicated that plant height were positively correlated with number of branches plant^{-1}, number of effective pods plant^{-1}, number of seeds pod^{-1}, length of the pod, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of branches plant^{-1} was positively correlated with number of effective pods plant^{-1}, length of the pod, number of seeds pod^{-1}, weight of seeds plant^{-1}, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of effective pods plant^{-1} was positively correlated length of the pod, number of seeds pod^{-1}, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of non-effective pods plant^{-1} was negatively correlated with length of the pod, number of seeds pod^{-1}, 1000-seed weight and grain yield. Length of the pod was positively correlated with number of seeds pod^{-1}and grain yield. Number of seeds pod^{-1} was positively correlated with 1000-grains weight and grain yield. 1000 seed weight was positively correlated with grain yield.

Table 20. Simple correlation coefficient between yield and yield contributing characters of lentil as influenced by variety and potassium levels.

Characters	Plant height (cm)	Number of branches plant^{-1}	Number of effective pods plant^{-1}	Number of non-effective pods plant^{-1}	Number of seeds pod^{-1}	Length of the pod (mm)	1000 seed weight (g)	Grain yield (t ha^{-1})
Plant height (cm)	-	.231	.304*	-.393**	.236	.239	.073	.287*
Number of branches plant^{-1}		-	.796**	-.105	.376**	.060	.708**	.739**
Number of effective pods plant^{-1}			-	-.317*	.597**	.259*	.692**	.857**
Number of non-effective pods plant^{-1}				-	-.574**	-.549**	-.039	-.363**
Number of seeds pod^{-1}					-	.568**	.247	.632**
Length of the pod (mm)						-	.137	.393**
1000 seed weight (g)							-	.785**
Grain yield (t ha^{-1})								-

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

RESULTS

Experiment no. 2: Effect of boron on the growth, development and yield of lentil

4.1 Growth parameters

4.1.1 Total dry meter (TDM)

Total dry matter (TDM) was significantly affected by the variety of lentil at the period of 30, 45, 60, 75, 90 and 105 DAS except 15 DAS. Table 21 showed that TDM was slow at early stage, but it increasing with the increasing of days and it reached to maximum level at 105 DAS. V_4 (BARI masur-6) gave the highest value of TDM and the lowest value of TDM was observed in V_1 (BARI masur-1) at 30, 45, 60, 75, 90 and 105 DAS (Figure 5 and Table 21).

Boron level had significant effect on TDM at 30, 45, 60, 75, 90 and 105 DAS except 15 DAS. At 15 DAS, TDM of lentil are more less similar at different level of boron. But at 30 DAS, the highest TDM was produced by B_3 (1.5 kg B ha^{-1}) which was statistically identical with B_2 (1 kg B ha^{-1}) and B_4 (2 kg B ha^{-1}). At 45 and 60 DAS, three split of boron gave the highest result and control treatment gave the lowest. At 75 DAS, three split of boron gave the highest TDM which was statistically similar with four split of boron. At 90 DAS, B_3 (1.5 kg B ha^{-1}) gave the highest result and B_0 (0 kg B ha^{-1}) gave the lowest result respectively. From the table 22, the highest value of TDM was obtained from three split (B_3=1.5 kg B ha^{-1}) of boron at 105 DAS. The lowest value was observed in control treatment (B_0= 0 kg B ha^{-1}) at all sampling dates (Figure 6 and Table 22).

TDM was significantly affected by the interaction of variety and boron level at 30 and 45 DAS. While interaction effect of variety and boron did not vary significantly at 15, 60, 75, 90 and 105 DAS. At 30 DAS the highest TDM was produced by $V_4 \times B_3$ treatment combination which was statistical similar with the treatment combination $V_3 \times B_3$, $V_4 \times B_2$ and $V_4 \times B_4$. At 45 DAS, the highest TDM was observed in the treatment combination of BARI Masur-6 with 1.5 kg B ha^{-1} which was statistically identical with the treatment combination $V_3 \times B_3$. The other results at 15, 60, 75, 90 and 105 DAS was not significant. But the highest TDM value was marked at 105 DAS in all interaction and the lowest one was found in control at all sampling dates (Table 23).

Table 21. Effect of variety on TDM (g $plant^{-1}$) at different days after sowing

Variety	TDM (g $plant^{-1}$) at different DAS						
	15	30	45	60	75	90	105
V_1	0.016	0.035c	0.123c	0.218d	0.498c	1.192d	1.592d
V_2	0.017	0.038bc	0.135b	0.231c	0.498c	1.243c	1.676c
V_3	0.013	0.040b	0.144a	0.257b	0.531b	1.283b	1.728b
V_4	0.016	0.047a	0.141a	0.293a	0.577a	1.348a	1.775a
LS	NS	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

LS = Level of significance, DAS = Days after sowing, TDM= Total dry matter

Table 22. Effect of boron on TDM (g $plant^{-1}$) at different days after sowing

Treatment	TDM (g $plant^{-1}$) at different DAS						
	15	30	45	60	75	90	105
B_0	0.014	0.029d	0.095e	0.172d	0.401e	1.117d	1.574d
B_1	0.016	0.037c	0.140c	0.251c	0.526d	1.222c	1.681c
B_2	0.016	0.042b	0.147b	0.268b	0.550c	1.307b	1.721b
B_3	0.017	0.049a	0.160a	0.291a	0.597a	1.365a	1.766a
B_4	0.015	0.042b	0.136d	0.267b	0.556b	1.322b	1.721b
LS	NS	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}, B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}

NS = Non significant, LS = Level of significance, DAS = Days after sowing, TDM= Total dry matter

Table 23. Interaction effect of variety and boron on TDM (g $plant^{-1}$) at different days after sowing

Interaction of variety and boron level	TDM (g $plant^{-1}$) at different DAS						
	15	30	45	60	75	90	105
V_1B_0	0.016	0.024l	0.077k	0.154	0.370	1.050	1.462
V_1B_1	0.017	0.032(i-k)	0.131g	0.219	0.480	1.140	1.569
V_1B_2	0.017	0.039(f-h)	0.130g	0.231	0.527	1.234	1.600
V_1B_3	0.018	0.045cd	0.144ef	0.251	0.553	1.273	1.699
V_1B_4	0.015	0.035(h-j)	0.132g	0.234	0.557	1.264	1.628
V_2B_0	0.017	0.029k	0.089j	0.155	0.381	1.091	1.558
V_2B_1	0.017	0.036(g-j)	0.135g	0.238	0.516	1.197	1.639
V_2B_2	0.017	0.038(f-h)	0.150(d-f)	0.242	0.509	1.292	1.729
V_2B_3	0.017	0.047bc	0.156(b-d)	0.269	0.574	1.344	1.736
V_2B_4	0.017	0.041(d-f)	0.146ef	0.254	0.513	1.293	1.719
V_3B_0	0.011	0.031jk	0.102i	0.185	0.397	1.107	1.597
V_3B_1	0.013	0.037(f-i)	0.143f	0.253	0.512	1.251	1.726
V_3B_2	0.014	0.040(e-h)	0.153cd	0.280	0.569	1.332	1.767
V_3B_3	0.017	0.050b	0.162b	0.309	0.613	1.393	1.789
V_3B_4	0.012	0.040(e-h)	0.157bc	0.257	0.567	1.334	1.760
V_4B_0	0.013	0.030k	0.111h	0.195	0.457	1.221	1.681
V_4B_1	0.016	0.044(c-e)	0.150de	0.294	0.596	1.300	1.790
V_4B_2	0.016	0.051b	0.156(b-d)	0.318	0.597	1.371	1.790
V_4B_3	0.016	0.056a	0.177a	0.335	0.647	1.449	1.841
V_4B_4	0.017	0.051b	0.109h	0.322	0.587	1.398	1.772
LS	NS	0.01	0.01	NS	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}, B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}

NS = Non significant, LS = Level of Significance, DAS = Days after sowing, TDM= Total dry matter

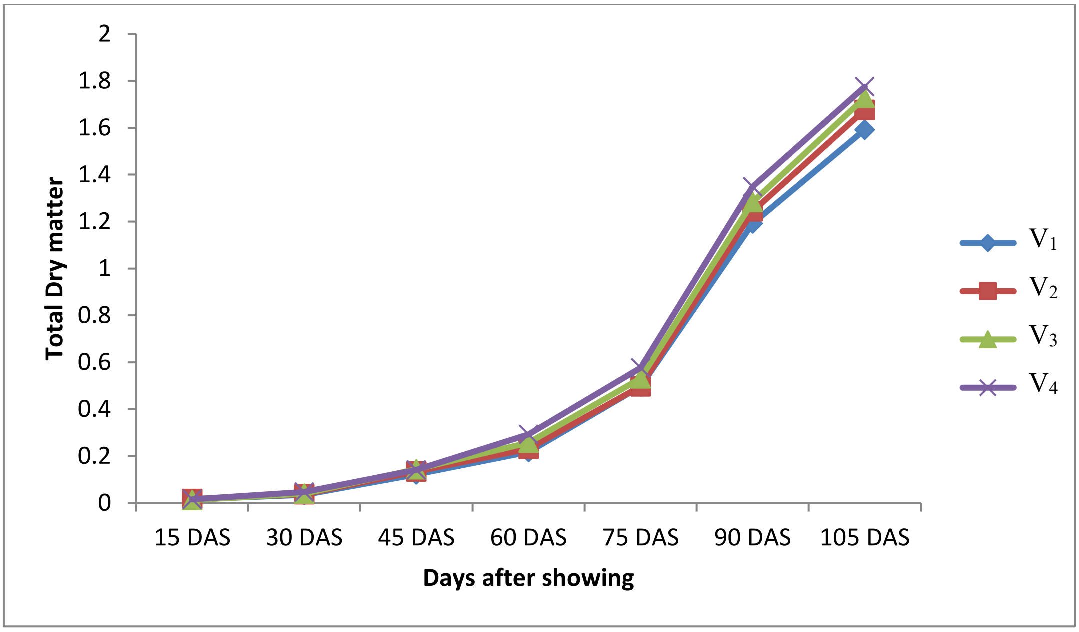

Figure 5. Effect of variety on TDM (g plant^{-1}) at different days after sowing

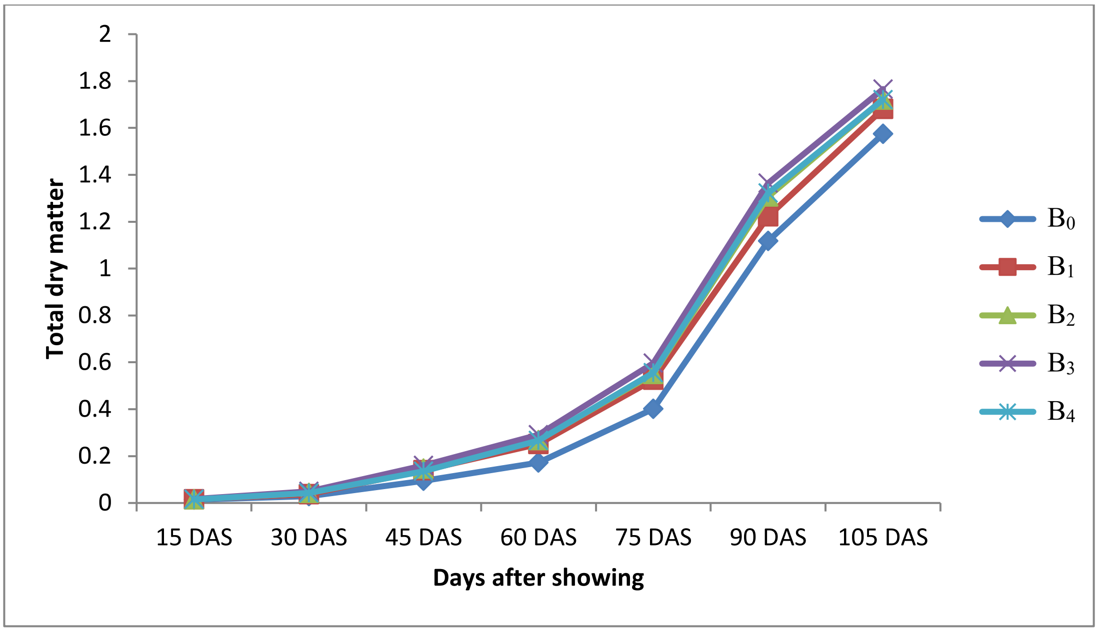

Figure 6. Effect of boron on TDM (g plant^{-1}) at different days after sowing

4.1.2 Crop growth rate (CGR)

There was significant effect of varieties on CGR within the period of 15-30, 30-45 and 45-60 DAS. On the other hand CGR was not influenced by the varieties significantly at 60-75, 75-90 and 90-105 DAS. CGR was slow at early stages and reached to maximum level at 75-90 DAS, and then declined. During the period of 15-30 DAS, BARI masur-6 (V_4) varieties gave the highest CGR. The highest Crop growth rate was found in BARI masur-5 at 30-45 DAS. Within 45-60 DAS, the highest CGR was produced by V_4 (BARI masur-6). The higher CGR was obtained in BARI masur-6 at 75-90 DAS which was not significant. The lowest CGR was found 15-30, 30-45, 45-60, 75-90 and 90-105 DAS in BARI masur-1 (Figure 7 and Table 24).

Boron level showed significant effect on CGR at 15-30, 30-45, 45-60 and 60-75 DAS. On the other hand, in 75-90 DAS and 90-105 DAS, the effect of boron level on CGR showed non-significant. Within 15-30 DAS, 1.5 kg B ha^{-1} showed the highest value (0.217) and lowest result was obtained from one split and control application of boron. Within 30-45 DAS, 45-60 DAS and 60-75 DAS, three splits of boron (1.5 kg B ha^{-1}) showed the highest results. In case of 45-60 DAS, four splits of boron gave the similar results and the lowest crop growth rate was found in control treatment (B_0). Within 60-75 DAS, control treatment of boron gave the lowest results. The higher crop growth rate was found in three splits of boron at 75-90 DAS. Table 25 showed that. The crop growth rate was decreased after 75-90 DAS (Figure 8 and Table 25).

CGR was influenced significantly due to the interaction between variety and boron level at 30-45 and 45-60 DAS. While there was no significant effect of interaction at 15-30, 60-75, 75-90 and 90-105 DAS. Within 15-30 DAS, interaction between variety and boron level on CGR not significantly varied. Within 30-45 DAS, the highest CGR was obtained from BARI masure-6 with three splits of boron application which was statistically similar to BARI masur-5 with the application of 2.0 kg B ha^{-1} ($V_3 \times B_4$) while the lowest result was found in BARI masur-1 with control treatment combination ($V_1 \times B_0$). Within 45-60 DAS, the highest CGR was obtained from treatment combination of BARI masur-6 with the application of 2.0 kg B ha^{-1} ($V_4 \times B_4$) which was statistically similar to BARI Masur-6 with the application of 1.5 kg B ha^{-1} ($V_4 \times B_3$) and 1.0 kg B ha^{-1} ($V_4 \times B_2$) while the lowest result was obtained in BARI masur-4 with control treatment. 60-75, 75-90 and 90-105 DAS not significantly varied between the variety and boron interaction effect on CGR. After 75-90 DAS, the crop growth rate was decreased (Table 26).

Table 24. Effect of variety on CGR (g m^{-2} day^{-1}) at different days after sowing

Variety	CGR (g m^{-2} day^{-1}) at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1	0.125d	0.583c	0.634c	1.866	4.629	1.664
V_2	0.141c	0.647b	0.641c	1.780	4.966	1.886
V_3	0.174b	0.694a	0.753b	1.833	5.013	1.964
V_4	0.208a	0.626b	1.014a	1.893	5.140	1.864
LS	0.01	0.01	0.01	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

NS = Non significant, LS = Level of significance, DAS = Days after sowing, CGR= Crop growth rate

Table 25. Effect of boron on CGR (g $m^{-2}$$day^{-1}$) at different days after sowing

Treatment	CGR (g m^{-2} day^{-1}) at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
B_0	0.098d	0.439d	0.516d	1.528d	4.773	1.496
B_1	0.144c	0.685b	0.739c	1.833c	4.640	1.601
B_2	0.175b	0.701b	0.804b	1.884bc	5.045	1.761
B_3	0.217a	0.736a	0.872a	2.041a	5.119	1.678
B_4	0.176b	0.627c	0.871a	1.930b	5.108	1.652
LS	0.01	0.01	0.01	0.01	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}, B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}
NS = Non significant, LS = Level of significance, DAS = Days after sowing, CGR=Crop growth rate

Table 26: Interaction effect of variety and boron on CGR (g m^{-2} day^{-1}) at different days after sowing

Interaction of variety and boron level	CGR (g m^{-2} day^{-1}) at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1B_0	0.056	0.350k	0.516k	1.443	4.528	1.749
V_1B_1	0.103	0.660f	0.588ij	1.738	4.400	1.860
V_1B_2	0.148	0.606g	0.676gh	1.973	4.709	1.440
V_1B_3	0.183	0.660f	0.710(e-h)	2.018	4.798	1.842
V_1B_4	0.134	0.641f	0.681(f-h)	2.158	4.711	1.429
V_2B_0	0.085	0.396j	0.439l	1.507	4.738	2.111
V_2B_1	0.123	0.663f	0.685(f-h)	1.854	4.540	1.949
V_2B_2	0.141	0.743cd	0.616i	1.778	5.222	1.911
V_2B_3	0.201	0.725de	0.750e	2.034	5.132	1.616
V_2B_4	0.156	0.707e	0.715(e-g)	1.727	5.200	1.844
V_3B_0	0.134	0.472i	0.554jk	1.411	4.736	2.269
V_3B_1	0.159	0.713e	0.727ef	1.729	4.929	2.165
V_3B_2	0.177	0.755bc	0.842d	1.926	5.089	1.900
V_3B_3	0.217	0.751cd	0.976c	2.027	5.200	1.644
V_3B_4	0.186	0.780ab	0.664h	2.071	5.111	1.842
V_4B_0	0.119	0.538h	0.556jk	1.749	5.091	1.067
V_4B_1	0.191	0.706e	0.958c	2.013	4.691	1.267
V_4B_2	0.234	0.700e	1.081b	1.857	5.161	1.793
V_4B_3	0.268	0.806a	1.051b	2.084	5.345	1.611
V_4B_4	0.229	0.382j	1.425a	1.762	5.411	1.494
LS	NS	0.01	0.01	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6
B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}, B_3 = 1.5 Kg B ha^{-1}, B_4 = 2.0 Kg B ha^{-1}

NS = Non significant, LS= Level of Significance, DAS = Days after sowing, CGR=Crop growth rate

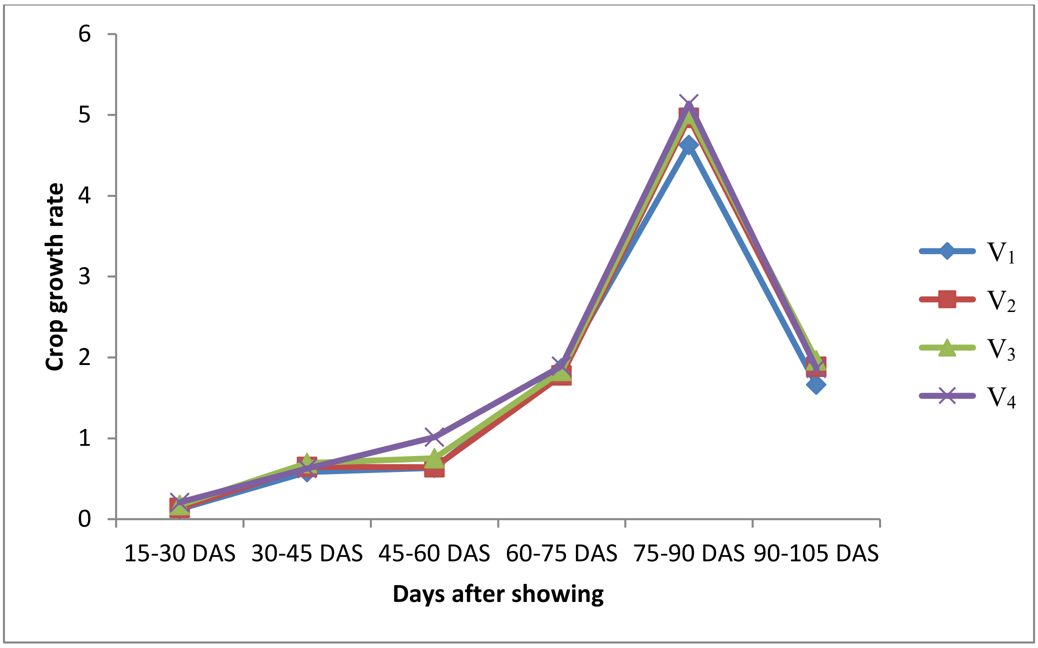

Figure 7. Effect of variety on CGR (g m^{-2} day^{-1}) at different days after sowing

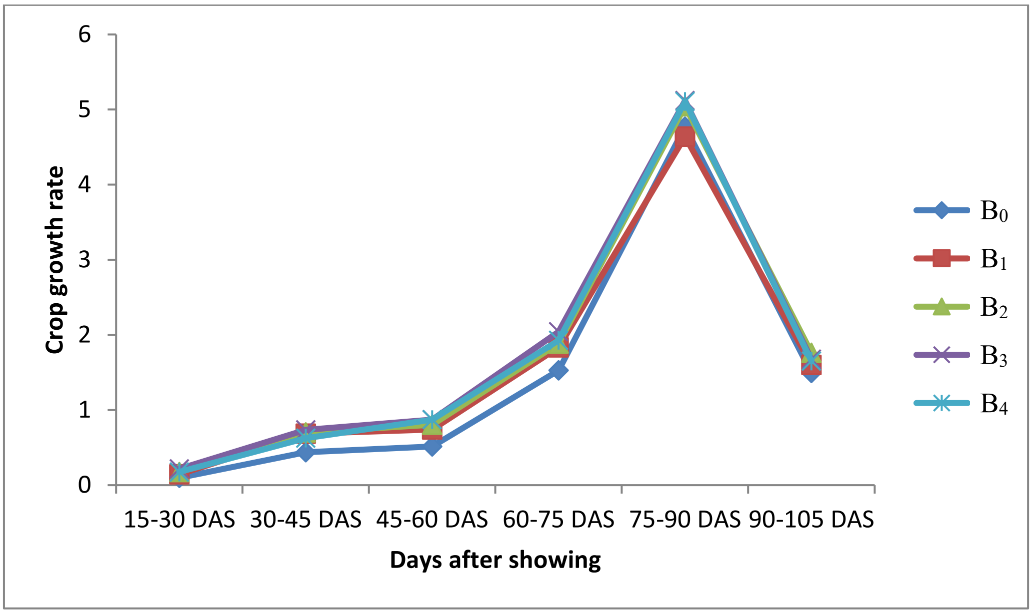

Figure 8. Effect of boron on CGR (g $m^{-2}day^{-1}$) at different days after sowing

4.2 Development parameters

4.2.1 Leaf production rate (LPR)

LPR varied significantly due to variety of lentil 15-30 and 60-75 DAS. At 30-45, 45-60, 75-90 and 90-105 DAS variety had not significant effect on LPR. Within 15-30 DAS, BARI Masur-5 and BARI Masur-6 showed higher LPR value and BARI Masur-1 showed lower LPR value. Within 60-75 DAS, BARI masur-5 gave the highest LPR value and BARI masur-1 gave the lowest LPR value. At 75-90 DAS the highest LPR were found in all varieties which was not significant. The highest value of LPR was observed in BARI Masur-6 and the lowest value of LPR was found in BARI Masur-1 at 15-30, 30-45 and 45-60 DAS (Table 27).

LPR was significantly influenced due to boron levels at 15-30, 30-45, 45-60 and 60-75 DAS. On the other hand there was no significant effect of boron level on LPR at 75-90 and 90-105 DAS. Within 15-30 and 30-45 DAS, the highest LPR was observed in 1.5 kg B ha^{-1} which was statistically similar with 1 kg and 2 kg B ha^{-1}. Here, the lowest LPR was obtained in control treatment. At 45-60 DAS, the highest LPR was found in three splits of boron which was statistically similar with one and two splits of boron. Here, the lowest value also found in control treatment (0 kg B ha^{-1}). At 60-75 DAS the highest LPR was found in four splits of boron which was similar to three splits of boron. Here the lowest LPR was observed in control treatment (Table 28).

LPR was not significantly influenced due to the interaction of variety and boron level at all sampling dates (Table 29).

Table 27. Effect of variety on LPR at different days after showing

Variety	LPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1	0.277b	0.732	0.944	1.398c	2.365	1.156
V_2	0.324b	0.747	0.984	1.593b	2.425	1.140
V_3	0.443a	0.760	0.990	1.748a	2.359	1.221
V_4	0.424a	0.781	1.077	1.528bc	2.484	1.279
LS	0.01	NS	NS	0.01	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6, NS = Non significant,

LS= Level of Significance, DAS = Days after sowing. LPR=Leaf Production Rate

Table 28. Effect of boron on LPR at different days after showing

Treatment	LPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
B_0	0.231d	0.591c	0.791c	0.898d	2.440	1.299
B_1	0.331c	0.752b	1.087ab	1.489c	2.571	1.223
B_2	0.404b	0.789ab	1.023ab	1.733b	2.384	1.137
B_3	0.470a	0.855a	1.112a	1.804ab	2.356	1.199
B_4	0.401b	0.787ab	0.975b	1.910a	2.291	1.137
LS	0.01	0.01	0.01	0.01	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}, B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}

NS = Non significant, LS= Level of Significance, DAS = Days after sowing, LPR= Leaf Production Rate

Table 29. Interaction effect of variety and boron on LPR at different days after showing

Interaction of variety and boron level	LPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1B_0	0.176	0.567	0.807	0.806	2.333	1.342
V_1B_1	0.280	0.680	1.107	1.273	2.396	1.302
V_1B_2	0.284	0.782	0.958	1.549	2.298	0.976
V_1B_3	0.354	0.864	0.947	1.598	2.398	1.340
V_1B_4	0.293	0.767	0.904	1.764	2.400	0.820
V_2B_0	0.175	0.562	0.831	0.804	2.475	1.251
V_2B_1	0.245	0.773	1.014	1.747	2.449	1.124
V_2B_2	0.387	0.764	1.040	1.631	2.485	1.087
V_2B_3	0.442	0.856	1.058	1.913	2.278	1.033
V_2B_4	0.369	0.778	0.978	1.871	2.440	1.202
V_3B_0	0.287	0.616	0.760	0.871	2.622	1.349
V_3B_1	0.418	0.724	1.089	1.889	2.471	1.229
V_3B_2	0.484	0.782	0.982	2.009	2.262	1.164
V_3B_3	0.520	0.862	1.156	1.880	2.391	1.158
V_3B_4	0.507	0.813	0.964	2.093	2.049	1.209
V_4B_0	0.285	0.620	0.764	1.111	2.329	1.255
V_4B_1	0.380	0.831	1.138	1.049	2.969	1.236
V_4B_2	0.460	0.829	1.111	1.744	2.491	1.322
V_4B_3	0.564	0.836	1.289	1.825	2.356	1.265
V_4B_4	0.433	0.789	1.053	1.911	2.276	1.318
LS	NS	NS	NS	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6.B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}, B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}

NS = Non significant, LS= Level of Significance, DAS = Days after sowing

LPR= Leaf Production Rate

4.2.2 Branch production rate

Branch production rate (BPR) varied significantly due to variety of lentil at 15-30 and 30-45 DAS. While effect of variety did not differed significantly at 45-60, 60-75, 75-90 and 90-105 DAS. Branch production rate was higher in BARI Masur-6 and lower in BARI Masur-1 within 15-30 DAS (Table 30). Table 30 also showed that within 30-45 DAS, BARI Masur-5 producing high branches and BARI Masur-1 showed low branch production rate. No significant effect was found in the other sampling dates. At 75-90 DAS the highest result of BPR was obtained and then declined.

Boron level had significant effect on branch production Rate at 15-30, 30-45, 45-60 and 75-90 DAS while at 60-75 and 90-105 DAS, there was no significant effect. At 15-30 DAS, 1.5 kg B ha^{-1} gave the highest branch production rate whereas lowest branch production rate should be obtained from control (B_0) treatment. Within 30-45 DAS the highest branch production rate was observed in 1.5 kg B ha^{-1} application which was statistically similar to B_1 (0.5 kg B ha^{-1}) and B_4 (2.0 kg B ha^{-1}) treatment. At 45-60 DAS, the highest BPR was found in three splits of boron which was statistically similar to four splits of boron levels while 0 kg B ha^{-1} gave lower value at 45-60 DAS. At 75-90 DAS the highest result was obtained in three splits boron level and the lowest are remarked in control. The branch production rate reached its maximum stage at 75-90 DAS and then the value was decline (Table 31).

BPR was not significantly influenced due to the interaction of variety and boron level at all sampling dates (Table 32).

Table 30. Effect of variety on BPR at different days after showing

Variety	BPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1	0.033d	0.146c	0.202	0.136	0.306	0.152
V_2	0.044c	0.152bc	0.193	0.161	0.282	0.161
V_3	0.055b	0.162a	0.204	0.172	0.268	0.149
V_4	0.067a	0.161ab	0.209	0.179	0.262	0.146
LS	0.01	0.01	NS	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6, NS = Non significant, LS= Level of Significance, DAS = Days after sowing, BPR= Branch Production Rate

Table 31. Effect of boron on BPR at different days after showing

Treatment	BPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
B_0	0.034d	0.138cb	0.151c	0.163	0.251b	0.139
B_1	0.041cd	0.160a	0.184bc	0.141	0.279b	0.157
B_2	0.053b	0.153a	0.227a	0.169	0.276b	0.154
B_3	0.069a	0.164a	0.234a	0.166	0.326a	0.150
B_4	0.052bc	0.161a	0.215ab	0.170	0.266b	0.160
LS	0.01	0.01	0.01	NS	0.05	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}. B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}

NS= Non significant, LS= Level of Significance, DAS = Days after sowing, BPR= Branch Production Rate

Table 32. Interaction effect of variety and boron on BPR at different days after showing

Interaction of variety and boron level	BPR at different DAS					
	15-30	30-45	45-60	60-75	75-90	90-105
V_1B_0	0.025	0.136	0.142	0.142	0.289	0.140
V_1B_1	0.031	0.151	0.186	0.134	0.300	0.151
V_1B_2	0.033	0.147	0.207	0.155	0.302	0.149
V_1B_3	0.045	0.153	0.242	0.129	0.338	0.162
V_1B_4	0.033	0.144	0.235	0.120	0.300	0.155
V_2B_0	0.031	0.136	0.131	0.160	0.251	0.153
V_2B_1	0.029	0.151	0.189	0.147	0.289	0.153
V_2B_2	0.046	0.151	0.216	0.169	0.260	0.171
V_2B_3	0.062	0.165	0.231	0.164	0.331	0.144
V_2B_4	0.051	0.158	0.200	0.164	0.278	0.184
V_3B_0	0.033	0.140	0.164	0.173	0.238	0.140
V_3B_1	0.047	0.176	0.178	0.147	0.260	0.160
V_3B_2	0.060	0.158	0.236	0.160	0.299	0.142
V_3B_3	0.078	0.158	0.231	0.191	0.311	0.147
V_3B_4	0.058	0.180	0.211	0.187	0.240	0.158
V_4B_0	0.047	0.140	0.169	0.178	0.224	0.122
V_4B_1	0.058	0.178	0.182	0.138	0.269	0.162
V_4B_2	0.073	0.158	0.249	0.191	0.249	0.153
V_4B_3	0.091	0.166	0.231	0.178	0.324	0.147
V_4B_4	0.064	0.162	0.213	0.209	0.244	0.144
LS	NS	NS	NS	NS	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6
B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}. B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}
NS = Non significant, LS= Level of Significance, DAS = Days after sowing
BPR= Branch Production Rate

4.2.3 Rate of flowering (FR)

FR was significantly influenced due to variety of lentil both at 60-75 and 75-90 DAS. For flowering rate, within 60-75 DAS, BARI Masue-6 showed higher flower production rate, which was identical with BARI Masur-5. Within 75-90 DAS, V_4 (BARI Masur-6) continue it's superiority than other varieties (Table 33)

Boron had significant effect on FR at 60-75 and 75-90 DAS. Within 60-75 DAS, three splits of boron gave the higher flowering rate which was similar with three and four splits of boron at 75-90 DAS (Table 34).

FR showed significant variation due to interaction of variety and boron level during 60-75 and 75-90 DAS. At 60-75 DAS, the highest FR was found in the treatment combination $V_4 \times B_3$ which was statistically identical with $V_4 \times B_2$ treatment combination. During 75-90 DAS, the highest FR was obtained in $V_4 \times B_4$ treatment combination which was statistically identical with $V_2 \times B_2$ treatment combination (Table 35).

4.2.4 Days to 50% flowering and days to maturity

Days to 50% flowering and days to maturity was significantly influenced due to varieties. For 50% flowering time and days to maturity, BARI Masur-1 took shorter time and BARI Masur-6 took comparatively longer time than the other varieties (Table 33).

Boron had significant effect on days to 50% flowering and days to maturity. 0.5 kg B ha^{-1} gave earlier 50% flower emergence and days to maturity while 1.5 kg B ha^{-1} application showed delayed (Table 34).

Days to 50% flowering and Days to maturity was significantly influenced due to interaction of variety and boron level. The highest value of days to 50% flowering was observed in $V_4 \times B_2$, $V_4 \times B_3$ and $V_4 \times B_4$ treatment combination and the lowest value was observed in $V_1 \times B_0$, $V_1 \times B_1$, $V_1 \times B_2$, and $V_1 \times B_4$ treatment combination. In case of days to maturity, $V_4 \times B_0$ $V_4 \times B_1$ $V_4 \times B_2$ $V_4 \times B_3$ and $V_4 \times B_4$ showed the higher value and BARI Masur-1 with control treatment showed lower value which was similar with $V_1 \times B_1$ treatment combination (Table 35).

Table 33. Effect of variety on FR at different days after showing, days to 50% flowering and days to maturity

Variety	FR at different DAS		Days to 50% flowering	Days to maturity
	60-75	75-90		
V_1	1.035b	1.075b	61.600d	113.600d
V_2	0.982b	1.438ab	64.800b	114.333c
V_3	1.153ab	1.380ab	64.400c	115.267b
V_4	1.188a	1.487a	67.200a	117.333a
LS	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6, LS= Level of Significance, DAS = Days after sowing, FR= Rate of flowering

Table 34. Effect of boron on FR at different days after showing, days to 50% flowering and days to maturity

Treatment	FR at different DAS		Days to 50% flowering	Days to maturity
	60-75	75-90		
B_0	0.536c	0.726c	63.500b	114.917b
B_1	1.145b	1.478b	63.500b	114.917b
B_2	1.251ab	1.463b	65.083a	115.333a
B_3	1.385a	1.524a	65.167a	115.333a
B_4	1.131b	1.533a	65.250a	115.167ab
LS	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}. B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}, LS= Level of Significance, DAS = Days after sowing, FR= Rate of flowering

Table 35. Interaction effect of variety and boron on FR at different days after showing, days to 50% flowering and days to maturity

Interaction of variety and boron level	FR at different DAS		Days to 50% flowering	Days to maturity
	60-75	75-90		
V_1B_0	0.407i	0.707f	61.000f	113.000e
V_1B_1	1.073(d-g)	1.262(c-e)	61.000f	113.000e
V_1B_2	1.163(c-g)	1.190(c-f	61.667ef	114.000d
V_1B_3	1.300(a-e)	1.153(d-f)	62.000e	114.000d
V_1B_4	1.233(b-g)	1.065ef	62.000df	114.000d
V_2B_0	0.458i	0.702f	64.000c	114.333d
V_2B_1	1.050(e-g)	1.490(b-e)	64.000c	114.333d
V_2B_2	0.977g	1.812ab	65.333b	114.333d
V_2B_3	1.407(a-c)	1.630(a-d)	65.333b	114.333d
V_2B_4	1.018fg	1.555(a-e)	65.333b	114.333d
V_3B_0	0.565hi	0.766f	63.000d	115.000c
V_3B_1	1.210(b-g)	1.565(a-e)	63.000d	115.000c
V_3B_2	1.423(a-c)	1.367(b-e)	65.333b	115.667b
V_3B_3	1.320(a-d)	1.705(a-c)	65.333b	115.667b
V_3B_4	1.245(b-f)	1.497(b-e)	65.333b	115.000c
V_4B_0	0.715h	0.728f	66.000b	117.333a
V_4B_1	1.247(b-f)	1.597(a-d)	66.000b	117.333a
V_4B_2	1.440ab	1.483(b-e)	68.000a	117.333a
V_4B_3	1.510a	1.610(a-d)	68.000a	117.333a
V_4B_4	1.027fg	2.015a	68.000a	117.333a
LS	0.01	0.01	0.01	0.05

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}. B_3 = 1.5 Kg B ha^{-1}, B_4= 2.0 Kg B ha^{-1}

LS= Level of Significance, DAS = Days after sowing, FR= Rate of flowering

4.3 Yield and Yield contributing characters

4.3.1 Plant height:

Plant height varied significantly due to variety. The tallest plant (31.107 cm) was resulted from BARI masur-6 and the lowest plant height (29.716 cm) was found in BARI masur-5 (Table 36).

Boron levels had no significant effect on plant height. The higher plant height (31.52 cm) was found in B_3 (1.5 kg B ha^{-1}) treatment and lower result obtained in control treatment (Table 37).

Plant height did not differ significantly due to interaction effect of variety and boron level (Table 38).

4.3.2 Number of branches $plant^{-1}$

Variety had significant effect on number of branches $plant^{-1}$. The highest numbers of branches plant-1 (13.23) were observed in V_4 which means BARI masur-6. The lowest number of branches $plant^{-1}$ was recorded (8.46) in V_1 (BARI masur-1) (Table 36).

Boron levels had significant effect on number of branches $plant^{-1}$ in the trials. The highest number of branches $plant^{-1}$ was found in three splits of boron. The result was statistically identical with two splits of boron. From table 37, it was observed that the lowest result was obtained from control (B_0) treatment (Table 37).

The interaction effect of variety and boron was significant for number of branches $plant^{-1}$. Treatment combination $V_4 \times B_2$ gave the highest number of branches $plant^{-1}$. The lowest number of branches $plant^{-1}$ was found in $V_1 \times B_0$ treatment combination (Table 38).

4.3.3 Number of effective pods plant^{-1}

Number of effective pods plant^{-1} was significantly influenced by variety. The highest number of effective pods plant^{-1} was recorded in V_4 (BARI masur-6) and lowest one in V_1 that means BARI masur-1 (Table 36).

Boron had significant effect on the number of effective pods plant^{-1}. The highest number of effective pods plant^{-1} was recorded in three splits of boron which was statistically identical with two and four splits of boron. The lowest number of effective pods plant^{-1} was observed in control (Table 37).

Number of effective pods plant^{-1} showed significant variation due to interaction of variety and boron level. The highest number of effective pods plant^{-1} was found in $V_4 \times B_3$ treatment combination and the lower value was in $V_1 \times B_0$ treatment combination (Table 38).

4.3.4 Number of non-effective pods plant^{-1}

Number of non-effective pods plant^{-1} varied significantly due to variety BARI masur-4 gave the highest value of non-effective pods plant^{-1} and the lowest value was found in BARI masur-6 (Table 36).

Boron levels had significant effect on number of non-effective pods plant^{-1}. The highest number of non-effective pods plant^{-1} was produced by control treatment and the lowest one was obtained in three splits of boron (Table 37).

The interaction effect of variety and boron level was found to be significant in respect of non-effective pods plant^{-1}. $V_2 \times B_1$ treatment combination gave the highest number of non-effective pods plant^{-1} and the lowest one was found in $V_4 \times B_3$ treatment combination (Table 38).

4.3.5 Number of seeds pod^{-1}

The effect of variety was found to be significant in respect of number of seeds pod^{-1} in the experiment. Significantly the highest number of seeds pod^{-1} was obtained in BARI masur-5 which was statistically similar to BARI masur-4. The lowest number of seeds pod^{-1} was found in BARI masur-1 (Table 36).

Number of seeds pod^{-1} varied significantly due to boron levels. Four and three splits of boron levels produced highest number of seeds pod^{-1} and the lowest value of seeds pod^{-1} were found in control (Table 37).

The interaction effect of variety and boron was found to be significant in respect of number of seeds pod^{-1}. The highest number of seeds pod^{-1} was observed in $V_1 \times B_2$, $V_1 \times B_3$, $V_1 \times B_4$, $V_2 \times B_2$, $V_2 \times B_3$, $V_2 \times B_4$, $V_3 \times B_3$, $V_3 \times B_4$, $V_4 \times B_2$, $V_4 \times B_3$ and $V_4 \times B_4$ treatment combination and the lowest one in $V_1 \times B_0$ treatment combination (Table 38).

4.3.6 Length of the pod (mm)

Length of the pod was significantly affected by variety. The tallest length of the pod was obtained in BARI masur-1(V_1) which was statistically similar to V_3 and V_4. The smallest length of the pod was found in V_2 that indicates BARI masur-4 (Table 36).

Boron levels had significant effect on length of the pod. The highest result was recorded in three splits of boron and the lowest one in control (Table 37).

The interaction of variety and boron level had significant effect on length of the pod. $V_1 \times B_3$ and $V_1 \times B_4$ treatment combination gave the highest result which was statistically similar to $V_1 \times B_2$ treatment combination and the lowest one in $V_1 \times B_1$ treatment combination (Table 38).

4.3.7 1000 seed weight

Thousand seed weight differed significantly due to variety. The highest 1000 seed weight (20.44g) was found in BARI masur-6 which was statistically similar to BARI masur-5. The lowest 1000 seed weight (16.34 g) was recorded in BARI masur-1 (Table 36).

Thousand grain weight was significantly affected by boron levels. The highest 1000 seed weight (20.58) was observed in B_3 treatment. The lowest 1000 seed weight was found in control (Table 37).

Thousand seed weight did not show significant variation by the interaction of variety and boron level (Table 38).

4.3.8 Grain yield

Grain yield differed significantly due to variety. The highest grain yield (1.63) was recorded in V_4 which indicates BARI masur-6. The lower value of grain yield was found in BARI masur-1 (Table 36).

Result showed that boron levels had significant effect on grain yield. The highest grain yield was observed in three splits of boron which was statistically identical with four splits of boron. The lowest grain yield was found in control (Table 37).

The interaction of variety and boron significantly affect the grain yield. The highest grain yield was found in $V_4 \times B_3$ treatment combination. This result was statistically similar to $V_2 \times B_3$ treatment combination. The lowest grain yield was obtained in $V_1 \times B_0$ treatment combination (Table 38).

4.3.9 Stover yield/straw yield:

Straw yield varied significantly due to variety. The highest straw yield was recorded in V_4 which in indicates BARI masur-6 and the lowest value was obtained in BARI masur-1 (Table 36).

Straw yield significantly influenced by boron level. The highest straw yield was found in three splits of boron. This result was statistically identical with four splits of boron. The lowest straw yield was obtained in control (Table 37).

The interaction effect between variety and boron level was not found to be significant effect in respect of straw yield (Table 38).

4.3.10 Biological yield:

Biological yield significantly influenced by variety of lentil. Result showed that V_4 (BARI masur-6) gave the highest biological yield and V_1 (BARI masur-1) gave the lowest biological yield (Table 36).

Boron levels had significant effect on biological yield. The highest biological yield was found with three splits of boron which was statistically identical with four splits of boron. The lowest biological yield was obtained in control (Table 37).

The interaction between variety and boron levels was found to be significant in respect of biological yield. The highest value of biological yield was found in $V_4 \times B_3$ treatment combination. This was followed by $V_4 \times B_2$ and $V_4 \times B_4$ treatment combination. The lowest biological yield was observed in $V_1 \times B_0$ treatment combination (Table 38).

4.3.11 Harvest index (%)

Harvest index had significant effect due to variety of lentil. From the Table 36, result showed that BARI masure-6 gave the highest harvest index and BARI masure-1 gave the lowest harvest index.

Effect of different boron levels had significant effect on harvest index of lentil. Three splits (B_3) of boron levels showed higher harvest index (41.165) and the lower harvest index was observed in control treatment (B_0) (Table 37).

Interaction effect of variety and boron showed significant effect of lentil. Higher value of harvest index was found in $V_2 \times B_3$ treatment combination which was statistically similar to $V_4 \times B_3$ treatment combination. The lower value was observed in $V_4 \times B_0$ treatment combination (Table 38).

Table 36. Effect of variety on the yield and yield contributing characters of lentil

Variety	Plant height (cm)	Number of branches plant^{-1}	Number of effective pods plant^{-1}	Number of non-effective pods plant^{-1}	Number of seeds pod^{-1}	Length of the pod (mm)	1000 seed weight (g)	Grain yield (t ha^{-1}	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	29.979c	8.465c	55.728c	2.710c	1.835d	1.223a	16.345c	1.165d	1.811d	2.976c	38.948c
V_2	30.442b	12.340b	67.990b	3.982a	1.850b	1.098b	19.670b	1.511c	2.298c	3.814b	39.400ab
V_3	29.716d	12.213b	71.685b	3.345b	1.895a	1.130ab	20.275a	1.546b	2.321b	3.917b	39.378b
V_4	31.107a	13.230a	78.420a	2.875c	1.840c	1.160ab	20.445a	1.630a	2.478a	4.108a	39.494a
LS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

LS= Level of Significance

Table 37. Effect of different boron levels on the yield and yield contributing characters of lentil

Boron levels	Plant height (cm)	Number of branches plant^{-1}	Number of effective pods plant^{-1}	Number of non-effective pods plant^{-1}	Number of seeds pod^{-1}	Length of the pod (mm)	1000 seed weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
B_0	28.220	10.028d	56.706d	4.486a	1.562d	1.013e	18.262d	1.095d	1.766e	2.930e	37.361e
B_1	30.991	11.119c	63.709c	3.256b	1.725c	1.069d	18.587c	1.354c	2.123d	3.477d	38.867d
B_2	30.521	12.400b	71.038b	3.331b	1.988b	1.191c	19.175b	1.547b	2.334c	3.889c	39.738b
B_3	31.522	13.175a	78.525a	2.257d	2.000a	1.272a	20.581a	1.740a	2.482a	4.221a	41.165a
B_4	30.293	11.088c	72.300b	2.810c	2.000a	1.219b	19.312b	1.579ab	2.429b	4.008b	39.394c
LS	NS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}, B_3 = 1.5 Kg B ha^{-1}, B_4 = 2.0 Kg B ha^{-1}

LS = Level of Significance, NS = Non significant

Table 38: Interaction effect of variety and boron level on the yield and yield contributing characters of lentil

Integration of Variety and boron level	Plant height (cm)	Number of branches plant^{-1}	Number of effective pods plant^{-1}	Number of non-effective pods plant^{-1}	Number of seeds pod^{-1}	Length of the pod (mm)	1000 seed weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1B_0	28.330	6.500n	47.500i	4.273c	1.450h	0.863o	15.975	0.823q	1.376	2.199i	37.398hi
V_1B_1	29.775l	7.925l	50.388i	2.250ij	1.725d	1.013n	15.900	1.068p	1.700	2.768h	38.550(e-h)
V_1B_2	30.100j	9.550k	58.300gh	2.700g	2.000a	1.388b	16.025	1.111n	1.788	2.898gh	38.343(f-h)
V_1B_3	31.320	11.200hi	61.950(f-h)	2.028ij	2.000a	1.425a	18.000	1.430j	2.103	3.533(d-f)	40.475bc
V_1B_4	30.370	7.150m	60.500(f-h)	2.300(h-j)	2.000a	1.425a	15.825	1.391k	2.090	3.482(f-h)	39.973(b-d)
V_2B_0	30.050	10.650j	57.100h	4.850ab	1.550h	1.050m	18.925	1.088o	1.787	2.900gh	37.508hi
V_2B_1	30.505	12.200f	65.700ef	4.950a	1.700e	1.075k	19.300	1.337l	2.177	3.515ef	38.068(g-i)
V_2B_2	31.450	12.850d	69.650de	4.400c	2.000a	1.113h	20.075	1.719d	2.500	4.219(a-c)	40.745bc
V_2B_3	30.250	13.600c	77.950bc	2.650gh	2.000a	1.150g	20.325	1.853b	2.530	4.383ab	42.288a
V_2B_4	29.955	12.400e	69.550de	3.060f	2.000a	1.100i	19.725	1.557i	2.497	4.054(a-e)	38.393(f-h)
V_3B_0	27.525	11.263h	61.925(f-h)	4.520bc	1.700e	1.075k	18.375	1.237m	1.800	3.287(f-h)	37.638hi
V_3B_1	31.645	12.500e	65.050(e-g)	2.325hi	1.825c	1.088j	19.225	1.428j	2.231	3.660(c-f)	38.998(d-g)
V_3B_2	28.715	12.500e	73.950cd	3.925d	1.950b	1.113h	20.250	1.649g	2.475	4.124(a-d)	39.973(b-d)
V_3B_3	31.423	13.750c	80.600bc	2.400(g-i)	2.000a	1.213d	22.675	1.760c	2.575	4.335ab	40.620bc
V_3B_4	29.273	11.050i	76.900bc	3.555e	2.000a	1.163f	20.850	1.658f	2.521	4.179(a-c)	39.663(c-f)
V_4B_0	26.975	11.700j	60.300(f-h)	4.300c	1.550g	1.063l	19.775	1.231m	2.101	3.333(f-h)	36.903i
V_4B_1	32.040	11.850j	73.700cd	3.500e	1.650f	1.100i	19.925	1.582h	2.385	3.967(b-e)	39.853(c-e)
V_4B_2	31.850	14.700a	82.250b	2.300(h-j)	2.000a	1.150j	20.350	1.711e	2.575	4.286ab	39.890(c-e)
V_4B_3	33.095	14.150b	93.600a	1.950j	2.000a	1.300c	21.325	1.915a	2.720	4.634a	41.278ab
V_4B_4	31.575	13.750c	82.250b	2.325hi	2.000a	1.188e	20.850	1.711e	2.607	4.317ab	39.548(c-f)
LS	NS	0.01	0.01	0.01	0.01	0.01	NS	0.01	NS	0.01	0.01

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

V_1 = BARI Masur-1, V_2 = BARI Masur-4, V_3 = BARI Masur-5, V_4 = BARI Masur-6

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 Kg B ha^{-1}, B_3 = 1.5 Kg B ha^{-1}, B_4 = 2.0 Kg B ha^{-1}

LS = Level of Significance, NS = Non significant

4.4 Correlation analysis for yield and yield attributing characters of lentil

Yield is the expression as a whole of the performance of various yield contributing characters and the results of the interaction among them. Hence, it is of at most importance to know the quality of interrelationship among the yield and yield contributing characters. The correlation coefficient is done to know the relation between different yield and yield characters at harvest. The correlation matrix of selected parameters is presented in (Table 39).

The correlation coefficient result indicated that plant height were positively correlated with number of branches plant^{-1}, number of effective pods plant^{-1}, number of seeds pod^{-1}, length of the pod, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of branches plant^{-1} was positively correlated with number of effective pods plant^{-1}, length of the pod , number of seeds pod^{-1}, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of effective pods plant^{-1} was positively correlated length of the pod, number of seeds pod^{-1}, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of non-effective pods plant^{-1} was negatively correlated with length of the pod, number of seeds pod^{-1}, 1000-seed weight and grain yield. Length of the pod was positively correlated with number of seeds pod^{-1}and grain yield. Number of seeds pod^{-1} was positively correlated with 1000-seed weight and grain yield. 1000 seed weight was positively correlated with grain yield.

Table 39. Simple correlation coefficient between yield and yield contributing characters of lentil as influenced by variety and boron levels.

Characters	Plant height (cm)	Number of branches plant^{-1}	Number of effective pods plant^{-1}	Number of non-effective pods plant^{-1}	Number of seeds pod^{-1}	Length of the pod (mm)	1000 seed weight (g)	Grain yield (t ha^{-1})
Plant height (cm)	-	.439**	.545**	-.529**	.460**	.380**	.283*	.526**
Number of branches plant^{-1}		-	.831**	-.150	.440**	.095	.843**	.794**
Number of effective pods plant^{-1}			-	-.363**	.614**	.295*	.807**	.923**
Number of non-effective pods plant^{-1}				-	-.633**	-.582**	-.036	-.392**
Number of seeds pod^{-1}					-	.680**	.320*	.715**
Length of the pod (mm)						-	.027	.369**
1000 seed weight (g)							-	.802**
Grain yield (t ha^{-1})								-

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

CHAPTER FIVE

DISCUSSION

This chapter revealed with the discussion of results of the experiments with relation to crop growth, physiological development, and yield and yield components of lentil as influenced by variety, potassium and boron levels and their interaction.

A variation of total dry matter was slow at the early stages of plant growth and widen at later growth stages. The total dry matter increased with the advancement of plant age. The cause of rapid increase of TDM at later stage was possible due to the development of considerable number of late branches. The highest TDM was found in V_4 (BARI masur-6) in both the experiments. The results were reported by Hossain *et al.* (2007) and Mondal *et al.* (2014). With some exceptions significantly the highest TDM was found in three splits of both potassium and boron application. This might be due to steady availability of potassium and boron during growth period. TDM production was significantly higher in K_3 (35 kg K ha^{-1}) treatment than other treatment. A the result was reported by Kumar *et al.*(1993) and Zahan *et al.* (2009). The highest TDM was found in B_3 (1.5 kg Bha^{-1}) treatment. The result was reported by Nappakoonwony *et al.* (1997). Potassium is a macronutrient requiring for plant growth relatively higher amount and boron is a micronutrient requiring for plant growth relatively to a smaller amount. The cultivars were not well grown under potassium and boron deficiency and toxic application. The highest TDM was observed in the treatment combination of $V_3 \times K_3$ and $V_4 \times K_3$.This result were partially supported with the findings of Awal and Roy (2015). In case of boron in relation to variety, the highest TDM was observed in the $V_4 \times B_3$ treatment combination.

Crop growth rate (CGR) increased slowly at the early stages of plant growth and reached the peak at 75-90 DAS and thereafter it declined. This was possible due to the maximum production of dry matter at the initial stages of growth. In present study, varietal differences had significant effect on CGR. The crop growth rate varies with different varieties and with a few exceptions, V_4 (BARI masure-6) showed the highest CGR in both the year. The results were supported by Evan (1975). CGR was significantly influenced by different levels of potassium. CGR increased with the increasing level of potassium up to 75-90 DAS and then the CGR decreased. The highest CGR was obtained in K_3 (35 kg K ha^{-1}) treatment with a few exceptions. The similar result was reported by Rahman and Parvej (2009). In case of boron, the highest CGR was found in B_3 (1.5 kg B ha^{-1}) treatment. Here, CGR increased with the increasing level of boron up to 75-90 DAS, than it decline. The similar result was reported by Balachandra *et al* . (2003) and Bhuyan *et al.* (1998). With a few exceptions, significantly highest CGR was found in $V_1 \times K_3$, $V_2 \times K_4$ and $V_3 \times K_3$ treatment combination in case of potassium and $V_4 \times B_3$ and $V_4 \times B_4$ treatment combination in case of boron application.

Leaf production rate (LPR) was slow at early growth stages and it increased with the days and reached at the maximum at 75-90 DAS and there after it declined. The highest branch production rate was found in V_4 (BARI masur-6) with some exceptions in both the experiments. This was possible due to the higher growth rate of the plant at early growth stage and maximum branching ability of the plant. The obtained results are in partially agreement with that of Tariq *et al.* (2001) in Mungbean. Effect of potassium on leaf production rate increase slowly at early growth stages and it reached at maximum at 75-90 DAS and then the rate was decreased. The higher leaf production rate was found in K_3 (35 kg K ha^{-1}) and K_4 (45 kg K ha^{-1}) treatment within 75-90 DAS. This may be due to the varieties get optimum essential nutrient for their growth at K_3 (35 kg K ha^{-1}) and K_4 (45 kg K ha^{-1}) treatment. But, this treatment level is required for the plant within a certain limit of time that is why, after 75-90 DAS, the LPR does not increase at optimum level. The similar findings were reported by Chiang and hubbel (1997) found that potassium treatment significantly increased the number of leaves over controlled. LPR was significantly influenced by different levels of boron. LPR increase with increasing levels of boron up to 75-90 DAS and after that, the rate was declined. The highest LPR was obtained in B_3 (1.5 kg B ha^{-1}) treatment level with a few exceptions. Here, also the micronutrient is required for the production of leaf at a certain level B_4 (2.0 kg Bha^{-1}) and exceed of that level, boron had no positive impact on the leaf production rate. Interaction between variety and potassium, significantly the highest result was obtained from $V_4 \times K_3$, $V_4 \times K_2$ and $V_4 \times K_4$ treatment combination. Interaction between variety and Boron, the highest result was obtained from $V_4 \times B_3$ treatment combination with a few exceptions.

Branch production rate (BPR) increased at the early stage of plant growth and reached the peak at 45-60 DAS and there after it declined by at 75-90 DAS. BPR suddenly increased and then again decreased. The highest branch production rate was found in V_4 (BARI masur-6) with some exceptions in both the experiment. A similar pattern of branches production was observed in lentil plant by Nahar (1995). This was possible due to varietal differences. Effect of potassium on branch production rate increased at the early growth stage and reached at the maximum at 45-60 DAS and there after it decline but at 75-90 DAS, BPR was increased and after that the rate was decreased. With a few exceptions, significantly the highest BPR was found in K_3 (35 kg K ha^{-1}) treatment. The result with those obtained by sing *et al.* (2013). Mannan *et al*. (1992) also observed that number of branches per plant was greater influenced by potassium application on mungbean. Effect of boron on BPR increased slowly at the early growth stages of plant growth and reached the peak at 75-90 DAS and thereafter it declined. These are possible due to varietal characteristics and response of the variety to the micronutrients. The highest branch production rate was observed in B_3 (1.5 kg B ha^{-1}) treatment at 75-90 DAS. Interaction effect between variety and potassium, the highest result was observed from $V_4 \times K_3$ and $V_4 \times K_4$ treatment combination. These may be possible due to V_4 (BARI masur-6) may have good response on 35 kg K ha^{-1} and 45 kg K ha^{-1} respectively, which may gave higher branch production rate. Interaction effect between variety and boron, BPR increased gradually and it reached at maximum level at 75-90 DAS. With some exceptions the highest result was obtained from $V_1 \times B_3$ and $V_4 \times B_3$treatment combination. These may be possible due to 1.5 kg B ha^{-1} is optimum level for lentil varieties and these level produced higher BPR in case of lentil.

Rate of flowering varied significantly due to varietal performance. Flower production rate reached its maximum stage at 75-90 DAS. Higher flowering rate was observed in V_4 (BARI masure-6) in both the experiments. It may be possible due to varietal characteristics and V_4

(BARI masur-6) has the capacity to maximum utilization of nutrients and natural resources. In case of days to 50% flowering, V_1 (BARI masur-1) was the early flowering variety. For days to maturity, V_1 (BARI masur-1) was the early mature variety. The result obtained from the study is in partially agreement with Awal and Roy (2015), Saleeb and Al Assily (2001), Turk and Tawaha (2002). Flowering rate varied significantly due to effect of potassium and boron treatment. Flowering rate reached its maximum stage at 75-90 DAS for both potassium and boron treatment. In case of potassium, K_3 (35 kg K ha^{-1}) treatment showed higher flowering rate at 75-90 DAS and In case of boron, B_3 (1.5 kg B ha^{-1}) showed higher flowering rate at the similar DAS. Interaction effect between variety and Potassium treatment, $V_4 \times K_4$ treatment combination produced higher flowering rate. This may be possible due to the V_4 (BARI masur-6) had good response at the K_4 (45 kg K ha^{-1}) treatment and utilization of other natural resource is good. For days to 50 flowering, $V_1 \times K_1$ treatment combination showed early flowering rate nature. For days to maturity, $V_1 \times K_1$ treatment combination showed early mature. Interaction effect between variety and boron treatment, $V_4 \times B_3$ and $V_4 \times B_4$ treatment combination produced higher flowering rate. This may be possible due to the V_4 (BARI masur-6) had good response at the B_3 (1.5 kg B ha^{-1}) and B_4 (2 kg B ha^{-1}) treatment. For days to 50% flowering and days to maturity, $V_4 \times B_2$, $V_4 \times B_3$ and $V_4 \times B_4$ treatment combination showed the highest result.

Plant height increased progressively with the advancement of time and growth stage. The tallest plant was found in V_4 (BARI masur-6) in both the experiments. The results are in partially conformity with the work of Awal and Roy (2015). Plant height was significantly influence due to potassium levels. K_3 (35 kg K ha^{-1}) treatment gave the tallest plant. Similar results were showed by Biswash *et al.* (2014) in case of mungbean. Boron level plays a vital role in the physiological process of plant. The tallest plant was recorded in B_3 (1.5 kg B ha^{-1}) treatment. The highest plant height was found in $V_4 \times K_3$ treatment combination. This result showed partially conformity with the agreement of Datta *et al.* (2013).

Variety had significant effect on number of branches $plant^{-1}$. Significantly the highest number of branches $plant^{-1}$ was observed from V_4 (BARI masur-6) in both the experiments. Similar observation was also seen by Zahan *et al.* (2009) and Tariq *et al.* (2001). Number of branches $plant^{-1}$ was significantly influenced by the potassium application. The highest number of branches $plant^{-1}$ was produced in K_2 (25 kg K ha^{-1}) and K_3 (35 kg K ha^{-1}) treatment. The results were found in the observation of Tariq *et al.* (2001) and Zahan *et al.* (2009). It has been observed that significantly the highest number of branches $plant^{-1}$ was produced by B_3 (1.5 kg B ha^{-1}) treatment. Similar result was supported by Rahman *et al.* (1993) in case of mustard. The number of branches $plant^{-1}$ had different significantly due to the interaction effect of variety and boron level. The highest number of branches $plant^{-1}$ was obtained from $V_4 \times B_2$ treatment combination.

Significantly the highest number of effective pods plant was observed from V_4 in both the experiments. This result showed partially conformity with the agreement of Datta *et al*. (2013), Ashraf and Zafar (1997) and Khan *et al*. (1993). The number of effective pods $plant^{-1}$ was significantly influenced by the potassium application. The highest number of effective pods $plant^{-1}$ was produced in K_3 (35 kg K ha^{-1}) treatment. The result was supported by Zahan *et al.* (2009). It has been observed that significantly the highest number of effective pods plant^{-1} was produced by B_3 (1.5 kg B ha^{-1}) treatment. The result was supported by Quddus *et al.* (2014). The highest number of effective pods plant^{-1} was recorded from $V_4 \times K_3$ treatment combination. The number of effective pods plant^{-1} had differed significantly due to the interaction effect of variety and boron levels. The highest number of effective pods plant^{-1} was obtained from $V_4 \times B_3$ treatment combination.

The number of non-effective pods plant^{-1} had differed significantly due to the varieties in both the experiments. The lowest number of non-effective pods plant^{-1} was produced by V_4 (BARI masure-6) and the highest number of non-effective pods plant was produced from V_2 (BARI masur-4). Similar result was showed by Bhuiya *et al.* (2009) and Khan *et al.* (1993). The number of non-effective pods plant^{-1} was significantly influenced by different levels potassium. The lowest number of Non-effective pods plant^{-1} was recorded when 35 Kg K ha^{-1} was applied. On the other hand the highest number of non-effective pods plant^{-1} was recorded in control. Similar result was found by Yamur *et al.* (2005) and *Mian et al.* (2003) in chickpea. The application of 1.5 kg B ha^{-1} produced the lowest number of non-effective pods plant^{-1} and the highest number of non-effective pods plant was produced from control treatment.

It can be seen that variety had significant effect on 1000-seed weight in both the experiments. V_4 (BARI masur-6) produced the highest 1000 seed weight. The result was obtained in the study were supported by Bhuiya *et al.* (2009) and Mohammadjanloo *et al.* (2009). The result was also supported by Yamur *et al.* (2005) was stated that 1000 seed weight highly varied due to lentil variety Sazak-91. Potassium levels had significant effect on 1000-seed weight. The highest 1000-seed weight was produced by K_3 (35 kg K ha^{-1}) treatment. The result was reported by Zahan *et al.* (2009) and Mohammadjanloo *et al.* (2009). The 1000-seed weight was significantly affected by boron levels. The higher 1000-seed weight was recorded when 1.5 kg B ha^{-1} was applied. The result was supported by Quddus *et al.* (2014).

Grain yield is ultimate goal of lentil cultivation. Grain yield is associated with the number of effective pods $plant^{-1}$and 1000-seed weight. Significantly the highest grain yield was produced by V_4 (BARI masur-6) in both the experiments. BARI masur-6 was produced the highest grain yield because number of effect pods $plant^{-1}$ and 1000 seed weight of the highest among other varieties. The result obtained from the study is in agreement with those obtained by Zahan *et al.* (2009), Datta *et al.* (2013) and Wasiq (2006). Lentil crops showed yield benefits from potassium application. Increased potassium supply also enhances biological nitrogen fixation and potassium nutrition is associated with grain quality including protein content of lentil grain. Potassium increases the number of effective pods $plant^{-1}$ and 1000 seed weight which ultimately led to increase grain yield. Potassium levels showed significant variation is grain yield. Significantly the highest grain yield was recorded from K_3 (35 kg K ha^{-1}) treatment. This result was supported by Biswash *et al.* (2014), Zahan *et al.* (2009) and Ghosal *et al.* (1994). The application of 1.5 Kg B ha^{-1} produced the highest grain yield. Boron is essential for growth of new cells. Without adequate supply of boron, the number and retention of flowers reduce and pollen tube growth is less; consequently less pod are developed, less grain yield appearance. The enhancement of grain yield in lentil due to application of boron has been reported by many researchers viz. Quddus *et al.* (2014); Mondol *et al*. (2010), Kumar *et al.* (2009), Bhuiyan *et al.* (2008). Sing *et al.* (2004). The result was also supported by Karan *et al*. (2014). Grain yield was significantly influenced by the interaction effect of variety and boron levels. The maximum grain yield was recorded from the $V_4 \times B_3$ treatment combination.

Trend of straw yield due to different variety was very much to grain yield in both the experiments. V_4 produced the highest straw yield in both the experiments. The cause of increase in straw yield might be due to increasing number of branches and plant height of lentil. The result was supported by Wasiq (2006), Zahan *et al.* (2009) and Reddy and Ahlawat (1996) and Reddy and Ahlawat (2001). The effect of potassium on straw yield of lentil was significant. The rate of 35 kg K ha^{-1} produced the highest straw yield. The result was also supported by Singh *et al.* (2013) and Zahran *et al.* (1998). Straw yield was significantly influenced by different levels of boron application. The maximum straw yield was observed when 1.5 kg B ha^{-1} was applied as basal dose. This result was also supported by Quddus *et al*. (2014) and Sing *et al.* (2004).

Biological yield had differed significantly due to the varieties in both the experiment. The highest biological yield was produced by V_4 (BARI masur-6). The results were conformity with the findings of Bhuiya *et al.* (2009). Potassium levels had significant effect on biological yield. The highest biological yield was produced by K_3 (35 kg K ha^{-1}) treatment. Sing and Pathak (2003) reported that grain and straw yield as biological yield increased with increasing the potassium level at 35 kg K_2O ha^{-1}. The higher biological yield was recorded when 1.5 kg B ha (B_3) was applied.

These results are in partial conformity of the work of Karan *et al.* (2014) and Bhuiyan *et al.* (1998). The highest biological yield was found in $V_4 \times K_3$ treatment combination in 2010-2011. Combination effect of variety and boron levels had significant effect on biological yield. Maximum biological yield was recorded when $V_4 \times B_3$ treatment combination.

The correlation coefficient result indicated that plant height were positively correlated with number of branches plant^{-1}, number of effective pods plant^{-1}, number of seeds pod^{-1}, length of the pod, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of branches plant^{-1} was positively correlated with number of effective pods plant^{-1}, length of the pod, number of seeds pod^{-1}, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of effective pods plant^{-1} was positively correlated length of the pod, number of seeds pod^{-1}, 1000-seed weight and grain yield and negatively correlated with number of non-effective pods plant^{-1}. Number of non-effective pods plant^{-1} was negatively correlated with length of the pod, number of seeds pod^{-1}, 1000-seed weight and grain yield. Length of the pod was positively correlated with number of seeds pod^{-1} and grain yield. Number of seeds pod^{-1} was positively correlated with 1000-seed weight and grain yield. 1000 seed weight was positively correlated with grain yield.

Vinay *et al.* (2006) reported that seed yield was positively associated with pod length number of pod plant^{-1}. Yadav *et al.* (2005) also reported that yield of lentil significant positive association with biological yield plant^{-1} and harvest index.

CONCLUSION

From the above discussion, it could be concluded that among lentil varieties BARI masur-6 produced the highest growth & development parameters and also yield components. The growth & development parameters and yield components were highest when 35 kg K ha^{-1} and 1.5 kg B ha^{-1} was applied to the soil with a few exceptions. BARI mosur-6 produced highest grain yield when the field was fertilized with 35 kg K ha^{-1} and 1.5 kg B ha^{-1}.

REFERENCES

Abedin, S. 2010. Effect of potassium on the growth and yield of lentil. M.S. Thesis, Dept. Agron. Agril. Ext^{n}. Rajshahi University, Rajshahi.

Ali, M. A., Hussain, M., Malik, W.H. and Tahir, M. 2004. Evaluation of the effect of rhizobium inoculation and potassium on grain yield and nodulation behavior of *Lens culinaris.* Pak. J. Life Soc. Sci. 22. p. 112-114.

Anonymous. 1984. A Guide Book on Production of Pulses in Bangladesh. FAO/UNDP Project strengthening the agriculture extension sendee. Khamarbari. Farmgate. Dhaka. Bangladesh.

Anonymous. 2006. FAO (Food and Agriculture Organization). Statistical year book. Rome. Italy.

Ashraf, M. and Zafar, Z.U. 1997. Effects of potassium deficiency on growth, and some biochemical characteristics in two lines of lentil (*Lens culinaris* Medic.). Acta Physiology Plantarum. 19(1): 9-15.

Awal, M.A. and Roy, A. 2015. Effect of weeding on the growth and yield of three varieties of lentil (*Lens culinaris* L.). *American J. Food Sci. Nutrition Res*. 2(2): 26-31.

Balachandra, D., Nagrajan P., and Ganasekaran, S., 2003. Effect of micro nutrients on nodulation and yield of black gram in acid soil conditions. *Legume Res*. 26 (2): 153-154.

BARI, 2000. Bangladesh Agricultural Research Institute. Annual Report, 1999-2000. Gazipur. p. 151-153.

BARI, 2001. Bangladesh Agricultural Research Institute. Annual Report, 2000-2001. Gazipur. p. 316.

BARI, 2003. Effect of some varietals performance on the yield of lentil. Annual Report, 2002-2003. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur.

BARI, 2009. Pluse and Oilseed Strengthening Project of BARI, Early Novermber 2009. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur.

BBS, 2002. Statistical Yearbook of Bangladesh. Statistics Div. Ministry Plann. Govt. People's Repub. Bangladesh. Dhaka.

Bhuiya, M.S.U., Barman, S. and Haque, M.Z. 2009. Effects of variety and source of compost on the yield and yield components of lentil. J. Agrofor. Environ. 3 (1): 13-15.

Bhuiyan, M.A.H., Khanam D., Khatun M.R. and Hussain M.S. 1998. Effect of molybdenum, boron and Rhizobium on nodulation, growth and yield of chickpea. Bulletin of the Institute of Tropical Agriculture, Kayushu University 21 : 1-7.

Bhuiyan, M.A.H., Khanam, D., Ali, M.E., Zaman M.K. and Islam, M.S. 2008. Response of lentil to biofertilizer and chemical fertilizers in the farmer’s field. Annual Research Report, 2007-2008, Soil Science Division, BARI, Gazipur.

Biswash, M., Romel, M., Rahman, M.W., Haque, M.M., Sharmin, M., and Barua, R. 2014. Effect of potassium and vermicompost on the growth, yield and nutrient contents of mungbean (BARI Mung 5). *Open Sci. J. Biosci. Bioengin*. 1(3): 33-39.

Boktiar, S.M., Chowdhury, S.N.A., Alam, M.J. and Khabir, M. L. 2001. Determination on site specific fertilizer requirement of sugarcane and intercrop (onion and lentil) under sugarcane-based cropping system. Indian J. Sugarcane Tech. 16 (2): 1-8.

Chakraborty, A., 2009. Growth and yield of lentil (*Lens culinaris* L.) as affected by boron and molybdenum application in lateritic soil. Regional Research Substation, Red and Laterite zone,,Bidhan Chandra Krishi Viswavidyalaya, Sekhampur, Birbhum. *J.* Crop and Weed, 5(1):88-91.

Chiang, M. Y. and Hubbel, J. N. 1997. Effect of potassium on mungbean yield. The 1st International Symposium on Mungbean. UPLB. pp. 93-96.

Crops Market Information - Canadian Industry. Retrieved 19 September 2014.

Datta, S.K., Sarkar, M.A.R. and Uddin, F.M.J. 2013. Effect of variety and level of phosphorus on the yield and yield components of lentil. Int. J. Agril. Res. Innov. & Tech. 3 (1): 78-82.

Dear, B.S. and Lipsett, J. 1987. The effect of boron supply on the growth and seed production of subterranean clover (*Trifolium subterraneum* L.). *Australian J. Agril. Res.* 38: 537-546.

Dell, B. and Huang, L. 1997. Physiological responses of plants to boron. Plant Soil. 193: 103-120.

Evans, L.T., 1975. Crop Physiology. Some Case Histories. 1st Edn. Cambridge Univ. Press, Cambridge, UK. ISBN: 0521 20422 4.

FRG (Fertilizer Recommendation Guide). 2012. Published by Bangladesh Agricultural Research Council (BARC), Dhaka, Bangladesh.

Gaur, P.M., Tripathi, S., Gowda, C.L.L., Ranga Rao G.V., Sharma, H.C., Pande, S., Sharma, M. 2010. Chickpea Seed Production Manual. Patancheru 502 324, Andhra Pradesh, India: ICRISAT, 28.

Gardner, S. P., Pearce, R. B. and Mipchtll, R. I. 1985. Physiology of Crop plants. Iowa State Uni. Press, Iowa. p.66.

Ghosal, C. L. L. and Kaul, A. K. 1994. Pulses in Bangladesh. FAO/BARI (Food and Agricultural Organization/Bangladesh Agricultural research Institute), Joydebpur, Dhaka.

Gomez, K. and Gomez, A.A. 1984. Statistical Procedure for Agricultural Research (2nd edn.). John Wiley and Sons. Inc. New York. U.S.A. pp. 97-115, 199-209.

Gupta, U.C. 1979. Boron nutrition of crops. Advanced Agron. 31: 273-307.

Hobson, K., Armstrong, R., Nicolas, M., Connor, D. and Materne, M. 2006. Response of lentil (*lens culinaris*) germplasm to high concentrations of soil potassium. J. Euphytica. Springer Netherlands Pub. 151 (3): 371-382.

Hossain, M. A., Khan, M. S. A., Islam, M. N., Kalimuddin, M. and Nag, B. L. 2007. Response of rainfed lentil (lens culinaris medic) to method of sowing, nutrient application and fertilizer placement. Pakistan J. Agril. Res. 7: 14-15.

Hussain, S. S., Mahamood, M. Y. and Zamir, M. S. I. 2000. Qualitative and quantitative response of three cultivars of lentil *(Lens culinaris Medic)* to phosphorus application. Int. J. Agri. Biol., 2 (3): 248-250.

Iqtidar, A. and Rahman, S.F. 1984. Effect of boron on the protein and amino acid composition of wheat grain. *J. Agric. Sci., UK*: 75-80.

Islam. Q.M.S. and Ali. M.O. 2002. Research report on pulses Socio-economics. A report of Pulses Research Centre. BARI. Ishurdi. Pabna. Bangladesh l-15p

Jahiruddin, M. and Islam, M.R. 2014. Requirement of micronutrients for crops and cropping patterns. Project Report. PIU-BARC (NATP Phase-I) project. Project ID No. 339.

Karan, D., Singh, S.B. and Ramkwal. 2014. Effect of zinc and boron application on yield of lentil and nutrient balance in the soil under indo-genetic plain zones, J. Agril. Res. 1(4): 206-209.

Khan, A. H. 1993. Effect of lentil varieties on plant height, length of pod, number of grain per pod, number of effective grains per pod. Grain yield and stover yield. Bangladesh Agron. J., 1 (1): 40-44.

Khatun, A., Bhuiyan, M.A.H. and Alam, M.S. 2010. Response of seed collection from different parts on the growth and yield of lentil. BD. J. Sci. Ind. 45(3):197-204.

Kumar, S., Singh, V. and Solanki, V. P.S. 2009. Effect of boron and phosphorus application on yield and uptake of nutrients in lentil. Ann. Agric. Res. New series. 30 (344): 108-110.

Kumar, S., Soomro, Z. A., Larik, A.S., Kumbhar, M.B. and Rajput, M.I. 1993. Effect of Rhizobium inoculation of lentil and potassium on grain yield. Pakistan J. Bot. 36 (4): 801-809.

Kurdali, F., and Al-Shammaa, M. 2010. Natural abundances of nitrogen and carbon indicative of growth and N_2 fixation in potassium fed lentil grown under water stress. J. Plant Nutrition. 33: 157-174.

Lentil (Lens culinaris). Pulse Canada. Retrieved 24 January 2015.

Mian, M. A. K., Islam, M. N., Matin, M.A. Ahammad, K. U. and Aziz, M. A. 2003. Response of chickpea to fertilizer management in Barind Tract. Bangladesh J. Bot. 32 (2): 77-79.

Mannan, M. A., D. T. Eligio and V. R. Carangal. 1992. The influenced of potassium on the growth and yield of mungbean cultivars. Bangladesh Agron. J. 3 (1-2): 13-18.

McKenzie, B. A., Andrews, M.A. and Hill, G.D. 2007. Nutrient (NPK) and irrigation management of lentil. Book: Lentil. Springer Netherlands Pub. p. 145-158.

MOA (Ministry of Agriculture). 2002. Agricultural Statistics of Bangladesh. Sector Monitoring Unit. Dhaka. Bangladesh.

Mohammad, S. 2008. The study of seed yield and seed yield components of lentil *(Lens culinaris* Medik) under normal and drought stress conditions. Pak. J. Biol. Sci. 11:758-762.

Mohammadjanloo, Mohseni, A., Gholipouri, A., Tobeh, A. and Mostafeai, H. 2009. Study of effects of different levels of nitrogen and potassium on yield and yield components of rain-fed Lentil.Int. J. Plant Ecophysiol. 2: 91-94.

Mondal, M. M. A., Puteh, A. B., Kashem, M. A., Haque, M. A.and Razzque, A. H. M. 2014. Growth and dry mass partitioning in plant parts of lentil. Legume Research: An Int. J. 37 (4):434-438.

Mondal, R.H., Anwar, Rafiuddin, B.M. and Hossain, M.A. 2010. Integrated nutrient management for sustaining soil fertility and yield of Lentil-Mungbean-T.Aman cropping pattern. Annual Research Report, 2009-2010. Pulse Research Centre, BARI, Gazipur.

Muehlbauer, F.J., Cubero, J.I. and Summerfield, R.J. 1985. Lentil (Lens culinaris Medic.). p. 266-311. In: R.J. Summerfield and E.H. Roberts (eds.), Grain Legume Crops. Collins, 8 Grafton Street, London, UK.

Nahar, Q. 1995. Growth and yield pattern of lentil under the year round transplanting. Field Crops Res., 37: 85-94.

Noppakoonwong, R.N., Rerkasem, B., Bell, R.W., Dell, B. and Loneragan, J.F. 1997. Prognosis and diagnosis of boron deficiency in black gram (*Vigna mungo* L. Hepper) in the field by using plant analysis. In Boron in Soils and Plants. Eds. R.W. Bell and R. Rerkasem. Kluwer Acad, Pub., Dordrecht. Netherlands.

Purseglove, J.W. 1968. *Tropical Crops Dicotyledons* 1. Longmann, Green and Co. Ltd. p. 279.

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

Rahman, A., Jahiruddin, M. and Mian, M.H. 1993. Response of two mustard varieties to added sulphur and boron in old Brahmaputra floodplain soils. *Bangladesh J. Nucl. Agric.* 9: 15-28.

Rahman, M. H. and Parvej, K. 2009. Compatibility, growth and production potentials of mustard/lentil intercrops. Int. J. Bot., 5: 100-106.

Reddy, S.V.K. and Ahlawat, I.P.S. 1996. Growth and yield response of lentil cultivars to phosphorus, zinc and bio-fertilizers. *J. Agron. and Crop Sci*. 177 (1) : 49-59.

Reddy, S.V.K. and Ahlawat, I.P.S. 2001. Dry matter accumulation and nutrient uptake in lentil in relation to cultivars, phosphorus, zinc and bio fertilizers. *Research on Crops* 2 (1):21-24.

Saleeb, S.R. and Al Assily, K.A. 2001. Effect of irrigation regime and some weed control treatments on lentil yield and associated weeds. Annals Agril. Sci. Cairo. 46(2): 605-617.

Sarker, A., Erskine, W., Hassan, M.S., Mian, W. and Debnath, N. 1999. Registration of 'BARI masur-2' lentil. Crop Sci. 39(3): 875

Sarker, A., Erskine, W., Hassan, M. S., Afzal, M. A. and Murshed, A. N. M. M. 1999. Registration of "BARI msaur-4" lentil. Crop Sci. 39 (3): 876.

Sekhon, H. S., Guriqbal, S., Brar, J. S. and Poonam, S. 1998. Effect of sulfur fertilization on growth and yield of lentil. Lens Newsletter. 25 (1/2): 30-32.

Sepat, N.K., Singh, N.P. and Sepat, R.N. 2006. Response of varieties and planting dates on growth and yield behavior of lentil *(Lens culinaris* Medik). Ann. Agril. Res. 27(1): 96-98.

Shing, V. B., and Pathak, S. 2003. Effect of potassium on grain and straw yield of lentil (*Lens culinaris* Medik). Trop. Agric. 76 (4): 246-249.

Singh, V. and Singh, S.P. 1983. Effect of applied boron on the chemical composition of lentil plants. *J. Indian Soci. Soil Sci.* 31: 169-1 70.

Sing, M., Rodino, A. P., Casquero, P.A. and Ron, A. M. D. 2001. Effect of NPK and organic fertilizer on yield component of lentil. Eur. J. Agron., 15: 185-196.

Singh, A.K., Manibhushan, Bhatt, B.P., Singh, K.M. and Upadhyaya ,A. 2013. An Analysis Of Oilseeds And Pulses Scenario in Eastern India During 2050-51. *J. Agril. Sci.* 5 (1) 241- 249.

Singh, B.P. 2000. Effect of potassium fertilizer rates and application methods on rice-lentil cropping system. Indian J. Agron. 43(4): 588-590.

Singh, J.P. 1998. Effect of levels of potassium and sulphur on growth, yield contributory and yield of lentil. Lens Newsletter. 25 (1/2): 32-35.

Singh, S.K., Varma, S.C. and Singh, R.P.D. 2004. Residual effect of organic and inorganic sources of nutrients in lowland rice on succeeding lentil. *Indian J. Agric. Res.*, 38(2): 121-125.

Singh, S.P., Sahay, N. and Sharma, V.K. 2013. Effect of cobalt and potassium application on growth, yield and nutrient uptake in lentil (L*ens culinaris*. L.), Agricultural Research Communication Centre, *Legume Res.,* 36 (3) : 259 – 262.

Singh, S.S., Singh A.K., and Sundaram P.K., 2014. Agrotechnological options for upscaling agricultural productivity in Eastern Indo Gangetic Plains under impending climate change situations: A review. *J. Agri. Res.* 1 (2): 55-65.

Sinha, R.K.P. and Sinha, B.B.P. 2004. Effect of potash, botanical and fungicides against with disease complex in lentil. Annals Plant Protection Sci. 12 (2): 454-455.

Sinha, R.B., Sakal, R., Singh, A.P. and Bhogal, N.S. 1991. Response of some field crops to boron application in calcareous soils. J. Indian Soc. Soil Sci. 39: 118-122.

Solanki, J.S., Kapoor, A.C. and Singh, U. 2004. Lentil occupy an important place in human nutrition *(Lens culinaris L.),* J. Res. Birsa Agril. Univ. 16 (@): 187-195.

Song. M., A. P. Rodino, PA. Casquero and A. M. D. Ron. 2001. Effect of NPK and organic fertilizer on yield component of lentil. Eur. J. Agron., 15: 185-196.

Srinivasarao, C., Masood, A., Ganeshamurthy, A.N. and Singh, K.K. 2003. Potassium requirements of pulse crops on marginal and sub-marginal lands. Better Crops Int. 17 (1): 8-11.

Singh, B.P. 2004. Correlation and path co-efficient analysis were conducted to find out the characters associated with grain yield and dry matter production and the ways to improve harvest index in lentil. Punjab Agril. University, Lundhiana, India. J. Euphytica. Springer Netherlands Pub. 6(3): 833-839.

Srivastava, S. P., Bhandari, T. M. S., Yadav, C.R., Joshi M. and Erskine, W. 2004. Boron deficiency in lentil, yield loss and geographic distribution in a germplasm collection. J. Plant and Soil. Springer Netherlands Pub. 219 (1-2) : 147-151.

Tanaka, M. and Fujiwar, T. 2008. Physiological roles and transport mechanisms of boron: perspectives from plants. Pflugers Arch. European J. Physiol. 456, 671-677.

Tariq, M. Khaliq, A. and Umar, M. 2001. Effect of phosphorus and potassium application on growth and yield of mungbean (Vigna radiate L.). J. Biol. Sci. 1 (6): 427-428.

Tiwari, K.N. and Nigam, V. 1985. Crop response to potassium fertilizer in soil of Uttar Pradesh. J. Potaasium Res. 1: 62-71.

Togay, Y., Togay, N. and Dogan, Y. 2008. Research on the effect of potassium and molybdenum applications on the yield and yield parameters in lentil *(Lens culinaris Medic)*. African J. Biot. 7 (9): 1258-1260.

Turk, M.A. and Tawaha, A.M. 2002. Lentil (*Lens culinaris* Medik) Response to frequencies of hand weeding. Indian J. Agril. Res. 36(2): 137-14

Uddin, J., Sarker, A., Podder, R., Afzal, A., Rashid H. and Siddique, K. H.M. 2006. Lentil cultivation and production in Bangladesh. Development pilot proj. of ICARDA and Pulse Res. Center, BARI, Gazipur-1701. Pub. No. 18-64 PP.

VijayLaxmi. 2003. Dry matter distribution pattern and seed yield of different genotypes of lentil. J. Farm Sci. 12(2): 110-112.

Vinay, M., Skukla, S. K., Gupta, H. S. and Khati, P. 2006. Yield improvement in small and bold-seeded lentil *(Lens culinaris* Medik) in mid-altitude of Northwestern Himalayas. Crop Improv. 33 (2): 181-184.

Vitosh, M.L., Wameke, D.D. and Lucas, R.E. 1997. Boron. Mishigan State University Extension Soil and Management Fertilizer. Available on the http://www.Msue.msu.EDV.

Wang, N., Hatcher, D.W. Toews, R. and Gawalko, E.J. 2009. Influence of cooking and dulling on nutritional composition of several varieties of lentils (Lens culinaris). Food Sci. Technol. 42: 842-848.

Wasiq, I. 2006. Effect of plant density andcultivar on the performance of lentil. M.S. Thesis, Dept. Agron. Bangladesh Agril. Uni. Mymensingh. pp. 39-41.

World Production Statistics for Lentils 2013. Food and Agricultural Organization of the United Nations, Statistics Division. 2015. Retrieved 24 March 2015.

Yadav, S. S., Phogat, D. S., Solanki, I. S. and Tomer, Y. S. 2005. Character association and path coefficient analysis under two environments in lentil. Indian J. Pulse Res. 18 (2): 147-149.

Yadav, D. S., Kumar, A. and singh, V. K. 1993. Response different crops to potassium on 'cultivator's fields in Uttar Pradesh under irrigated and rainfed conditions. J. Potassium Res. 9: 253-261.

Yamur, M., Kyadan, D. and Arvas, O. 2005. Effect of sewage bio-solid application on seed protein rations, seed NK contents, some morphological and yield characters in lentil. Dept. of Field crop, Faculty of Agril., Van-Turkey. Res. J. Agril. Biol. Sci. 1 (4): 308-314.

Zahan, S. A., Alim, M. A., Hasan, M.M., Kabira, U.K. and Hossain, M.B. 2009. Effect of potassium levels on the growth, yield and yield attributes of lentil. Int. J. Sustain. Crop Prod. 4(6):1-6.

Zahran, F. A., Negm, A. Y., Bassiem, M. M. and Ismail, K. M. 1998. Foliar fertilization of lentil and lupine in sandy soils with the supernatant of super phosphate and potassium sulphate. Egyptian J. Agril. Res. 76 (1): 19-31.

APPENDICES

Appendix I. Morphological characteristics of soil

Constituent	Characteristics
1. Location	Agronomy Field laboratory western side of the Department of Agronomy and Agriculture Extension, Rajshahi university
2. Land type	Medium High land
3. General soil type	Non calcareous dark grey soil
4. Agro-ecological zone (AEZ)	AEZ-11: High ganges River flood
5.Topography	Fairly level
6. Soil color	Dark grey
7. Drainage	Well drainage
8. Soil series	Gopalpur series

Appendix II. Physical characteristics of the initial soil (0-15 cm depth)

Constituent	Results*
Particle size analysis	
Sand (%) (0.0-0.2 mm)	60
Silt (%) (0.02-0.002 mm)	25
Clay (%) 9<0.002 mm)	15
Soil texture class	Sandy loam

*= result obtained from the mechanical analysis of the initial soil sample was done in the Soil Resource Development institute, Regional Research Station, shampur, Rajshahi.

Appendix III. Chemical characteristics of initial soil (0- 15 cm depth)

SI. No	Soil characteristics	Analytical data
1	PH	8.4
2	Total Nitrogen (%)	0.04
3	Organic Matter (%)	0.46
4	Available phosphorus (ppm)	11.33
5	Available Sulphur (ppm)	3.10
6	Exchangeable Potassium (ppm)	0.19
7	Zinc (ppm)	0.78

Source : Soil Resource Development Institute (SRDI), Regional Centre , Rajshahi

Appendix IV. Monthly temperature, relative humidity and rainfall during the study period (October 2010 to March 2011) at Rajshahi University Campus, Rajshahi

Year	Month	Average air temperature (°C)			Total Rainfall (mm)	Total Humidity (%)
		Maxi.	Mini.	Average		
2010	October	31.5	23.6	27.55	125.5	86
2010	November	29.4	18.6	23.2	3.1	81
2010	December	24.6	12.3	17.4	38.4	79
2011	January	22.0	9.0	14.8	6.2	81
2011	February	27.5	12.9	19.5	-	74
2011	March	33.1	19.1	25.6	11.0	65

Appendix V. Monthly temperature, relative humidity and rainfall during the study period (October 2011 to March 2012) at Rajshahi University Campus, Rajshahi

Month	Year	** Air temperature (°C)			** Humidity (%)	Rainfall (mm)	** Sunshine (hrs)
		Maximum	Minimum	Average			
October	2011	33.0	22.4	27.7	82	24.1	7.38
November	2011	29.2	17.1	23.1	79	1	6.82
December	2011	24.2	12.8	18.5	84	Nil	4.50
January	2012	23.3	11.6	17.4	80	5.5	4.25
February	2012	28.3	12.2	20.2	66	0.6	7.94
March	2012	33.7	17.3	25.5	60	6.6	8.28

Source: Regional Meteorological Station, Shaympur, Rajshahi

* = Monthly total

* * = Monthly average

Appendix VI. Analysis of Variance (ANOVA) for total dry matter (g plant^{-1}) production at different DAS

Source of variation	Degrees of freedom	Mean Square						
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
Replication	2	0.000	0.000	0.000	0.000	0.003	0.034	0.011
Factor A (variety)	3	0.000^{NS}	0.000^{NS}	0.001**	0.043**	0.105**	0.175**	0.412**
Factor B (K level)	4	0.000^{NS}	0.000**	0.006**	0.013**	0.114**	0.148**	0.161**
A × B	12	0.000^{NS}	0.000*	0.000NS	0.002**	0.006**	0.016^{NS}	0.007^{NS}
Error	38	0.000	0.000	0.000	0.000	0.002	0.010	0.010

* Significant at 5% level of probability

** Significant at 1% level of probability

NS = Non- significant

Appendix VII. Analysis of Variance (ANOVA) for crop growth rate (g m^{-2} day^{-1}) at different DAS

Source of variation	Degrees of freedom	Mean Square					
		15 - 30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS
Replication	2	0.002	0.005	0.025	0.132	0.932	2.912
Factor A (variety)	3	0.001^{NS}	0.039**	1.432**	0.649**	1.604^{NS}	2.392^{NS}
Factor B (K level)	4	0.016**	0.170**	0.164**	2.652**	0.495^{NS}	0.895^{NS}
A × B	12	0.002**	0.014^{NS}	0.119**	0.410**	0.516^{NS}	0.922^{NS}
Error	38	0.001	0.006	0.021	0.089	0.560	0.803

** Significant at 1% level of probability

NS = Non- significant

Appendix VIII. Analysis of Variance (ANOVA) for leaf production rate at different DAS

Source of variation	**Degrees of freedom**	**Mean Square**					
		15 - 30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS
Replication	2	0.000	0.000	0.003	0.001	0.003	0.000
Factor A (variety)	3	0.029**	0.006**	0.000^{NS}	0.001^{NS}	0.002^{NS}	0.001^{NS}
Factor B (K level)	4	0.006**	0.001^{NS}	0.004^{NS}	0.000^{NS}	0.014**	0.004**
A × B	12	0.001**	0.000^{NS}	0.001^{NS}	0.001^{NS}	0.001^{NS}	0.001^{NS}
Error	38	0.000	0.001	0.001	0.001	0.001	0.001

** Significant at 1% level of probability

NS = Non- significant

Appendix IX. Analysis of Variance (ANOVA) for branch production rate at different DAS

Source of variation	Degrees of freedom	Mean Square					
		15 - 30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS
Replication	2	0.001	0.204	0.385	0.305	0.084	0.034
Factor A (variety)	3	0.277**	0.582**	0.475**	0.014^{NS}	0.152^{NS}	0.027^{NS}
Factor B (K level)	4	0.198**	0.400**	0.503**	0.040^{NS}	0.041^{NS}	0.149^{NS}
A × B	12	0.019^{NS}	0.078**	0.136**	0.058^{NS}	0.077^{NS}	0.077^{NS}
Error	38	0.010	0.023	0.050	0.099	0.106	0.065

** Significant at 1% level of probability

NS = Non- significant

Appendix X. Analysis of Variance (ANOVA) for rate of flowering at different DAS, days to 50% flowering and days to maturity

Source of variation	Degrees of freedom	Mean Square			
		FR at different DAS		Days to 50% flowering	Days to maturity
		60-75	75-90		
Replication	2	0.108	0.026	2.817	3.617
Factor A (variety)	3	0.143**	0.487**	79.133**	43.600**
Factor B (K level)	4	1.286**	1.397**	14.225**	0.267^{NS}
A × B	12	0.038^{NS}	0.082^{NS}	0.314^{NS}	0.156^{NS}
Error	38	0.026	0.085	0.396	0.178

** Significant at 1% level of probability

NS = Non- significant

Appendix XI: Analysis of variance (ANOVA) for yield and yield contributing characters of lentil

Sources of variation	**Degrees of freedom**	**Mean square value**										
		Plant Height (cm)	**Number of branches plant^{-1}**	**Number of effective pods plant^{-1}**	**Number of non effective pods plant-1**	**Number of seeds pod^{-1}**	**Length of the pod (mm)**	**1000 seed weight (g)**	**Grain yield (t ha^{-1})**	**Stover yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**
Replication	2	13.508	0.008	8.074	0.458	0.007	0.009	0.283	0.007	0.044	0.000	5.548
Factor A (variety)	3	5.115^{NS}	71.208**	1364.954**	4.743**	0.004^{NS}	0.044**	52.829**	0.642**	1.275**	3.860**	0.619^{NS}
Factor B (K level)	4	17.483**	18.244**	822.883**	7.605**	0.476**	0.139**	8.528**	0.703**	1.023**	2.965**	22.017**
A × B	12	4.009^{NS}	1.686^{NS}	24.612^{NS}	1.136**	0.005^{NS}	0.037**	1.029^{NS}	0.017^{NS}	0.015^{NS}	0.053^{NS}	1.677**
Error	38	3.071	0.998	17.218	0.091	0.008	0.006	2.117	0.016	0.041	0.073	0.568

** Significant at 1% level of probability

NS = Non- significant

Appendix XII. Analysis of Variance (ANOVA) for total dry matter (g plant^{-1}) production at different DAS

Source of variation	Degrees of freedom	Mean Square						
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
Replication	2	0.000	0.000	0.000	0.000	0.004	0.006	0.005
Factor A (variety)	3	0.000^{NS}	0.000**	0.001**	0.016**	0.021**	0.065**	0.092**
Factor B (B level)	4	0.000^{NS}	0.001**	0.007**	0.025**	0.066**	0.116**	0.063**
A × B	12	0.000^{NS}	0.000**	0.000**	0.000^{NS}	0.001^{NS}	0.001^{NS}	0.002^{NS}
Error	38	0.000	0.000	0.000	0.000	0.001	0.005	0.007

** Significant at 1% level of probability

NS = Non- significant

Appendix XIII. Analysis of Variance (ANOVA) for crop growth rate (g m^{-2} day^{-1}) at different DAS

Source of variation	Degrees of freedom	Mean Square					
		15 - 30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS
Replication	2	0.001	0.001	0.004	0.176	0.621	0.455
Factor A (variety)	3	0.020**	0.032**	0.473**	0.036^{NS}	0.712^{NS}	0.243^{NS}
Factor B (B level)	4	0.023**	0.166**	0.260**	0.443**	0.567^{NS}	0.479^{NS}
A × B	12	0.001^{NS}	0.026**	0.058**	0.063^{NS}	0.046^{NS}	0.084^{NS}
Error	38	0.000	0.004	0.010	0.040	0.274	0.242

** Significant at 1% level of probability

NS = Non- significant

Appendix XIV. Analysis of Variance (ANOVA) for leaf production rate at different DAS

Source of variation	Degrees of freedom	Mean Square					
		15 - 30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS
Replication	2	0.022	0.005	0.018	0.008	0.120	0.267
Factor A (variety)	3	0.095**	0.006^{NS}	0.042^{NS}	0.318**	0.052^{NS}	0.061^{NS}
Factor B (B level)	4	0.099**	0.117**	0.195**	1.964**	0.134^{NS}	0.055^{NS}
A × B	12	0.003^{NS}	0.003^{NS}	0.015^{NS}	0.112^{NS}	0.092^{NS}	0.056^{NS}
Error	38	0.006	0.012	0.035	0.061	0.064	0.095

** Significant at 1% level of probability

NS = Non- significant

Appendix XV. Analysis of Variance (ANOVA) for branch production rate at different DAS

Source of variation	**Degrees of freedom**	**Mean Square**					
		15 - 30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS
Replication	2	0.000	0.000	0.001	0.001	0.001	0.000
Factor A (variety)	3	0.003**	0.001**	0.001^{NS}	0.005^{NS}	0.006^{NS}	0.001^{NS}
Factor B (B level)	4	0.002**	0.001**	0.014**	0.002^{NS}	0.010*	0.001^{NS}
A × B	12	0.000^{NS}	0.000^{NS}	0.001^{NS}	0.001^{NS}	0.001^{NS}	0.000^{NS}
Error	38	0.000	0.000	0.001	0.002	0.003	0.001

* Significant at 5% level of probability

** Significant at 1% level of probability

NS = Non- significant

Appendix XVI. Analysis of Variance (ANOVA) for rate of flowering at different DAS, days to 50% flowering and days to maturity

Source of variation	Degrees of freedom	Mean Square			
		FR at different DAS		Days to 50% flowering	Days to maturity
		60-75	75-90		
Replication	2	0.027	0.000	0.200	2.067
Factor A (variety)	3	0.141**	0.513**	79.000**	39.244**
Factor B (B level)	4	1.273**	1.448**	10.042**	0.525**
A × B	12	0.042**	0.102**	0.375**	0.258*
Error	38	0.003	0.011	0.130	0.102

* Significant at 5% level of probability

** Significant at 1% level of probability

NS = Non- significant

Appendix XVII: Analysis of variance (ANOVA) for yield and yield contributing characters of lentil

Sources of variation	Degrees of freedom	Mean square value										
		Plant Height (cm)	**Number of branches plant^{-1}**	**Number of effective pods plant^{-1}**	**Number of non effective pods plant-1**	**Number of seeds pod^{-1}**	**Length of the pod (mm)**	**1000 seed weight (g)**	**Grain yield (t ha^{-1})**	**Stover yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**
Replication	2	1.324	0.002	1.733	0.110	0.001	0.002	0.003	0.001	0.006	0.000	0.575
Factor A (variety)	3	5.575**	67.011**	1359.694**	4.875**	0.011**	0.042**	55.383**	0.631**	1.247**	3.752**	0.890**
Factor B (B level)	4	19.047^{NS}	18.235**	850.236**	8.133**	0.486**	0.140**	9.522**	0.734**	1.020**	3.127**	22.873**
A × B	12	4.019^{NS}	1.815**	30.092**	1.134**	0.010**	0.037**	1.127^{NS}	0.019**	0.014^{NS}	0.060**	1.917**
Error	38	0.398	0.156	2.269	0.006	0.000	0.001	0.487	0.003	0.009	0.016	0.081

** Significant at 1% level of probability

NS = Non-significant