PERFORMANCE OF LENTIL VARIETIES AS INFLUENCED BY IRRIGATION LEVELS

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CERTIFICATE

This is to certify that the research work entitled ,**“Performance of Lentil Varieties as Influenced by Irrigation Levels”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University , Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the result of a piece of bonafide research work successfully carried out by **Razib Mohammad Zakaria** bearing **Registration No. 08-3242** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

. . . .

Dated:

Prof. Dr. Md. Shahidul Islam
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Place: Dhaka, Bangladesh

DEDICATED TO
MY
BELOVED PARENTS

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The Author

PERFORMANCE OF LENTIL VARIETIES AS INFLUENCED BY IRRIGATION LEVELS

Abstract

The present study was conducted at the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2010 to February, 2011 to evaluate performance of lentil varieties as influenced by irrigation levels. The treatment variables were three varieties (V_1: BARI mosur 4, V_2: BARI mosur 5 and V_3: BARI mosur 6) and four irrigation levels (I_0: no irrigation, I_v: irrigation at 25 DAS, I_f: irrigation at 50 DAS and I_{vf}: irrigatation at both 25 and 50 DAS). The experiment was laid-out in a randomized complete block design (RCBD) (factional) with three replications. Results of the study were recorded on plant height, branches plant^{-1}, leaves plant^{-1}, pods plant^{-1}, seeds pod^{-1}, plant dry weight, 1000-seed weight, seed yield, stover yield, biological yield and harvest index and were found significantly variable with irrigation levels. Individually, BARI mosur 6 and irrigation at both 25 and 50 DAS, showed the best performance on growth and yield of lentil. Combined effect also showed significant effect on all parameters of the study. BARI mosur 6 along with irrigation at both vegetative and productive stage produced the highest 1000-seed weight (24.33 g), seed yield (1967.17 kg ha^{-1}) and biological yield (4467.13 kg ha^{-1}). From the results it is suggested that BARI mosur 6 with irrigation at both vegetative and reproductive stages may give optimum yield.

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LIST OF ABBREVIATION

ABBREVIATION	FULL MEANING
@	At the rate of
˚C	Degree Celsius
AEZ	Agro-Ecological Zone
Agric	Agriculture
Agril	Agricultural
ANOVA	Analysis of Variance
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
CGR	Crop Growth Rate
cm	Centimeter
CMS	Cell Membrane Stability
CPE	Cumulative Pan Evaporation
CV	Co – efficient Variation
DAS	Days After Sowing
Df	Degree of Freedom
DM	Dry matter
DMRT	Duncan's Multiple Range Test
eg	For example
et al	et alibi (and others)
etc	etcetera (and so on)
FAO	Food and Agricultural organization

LIST OF ABBREVIATION (CONTD.)

FW	Fresh Weight
g	Gram
GAD	Green Area Duration
GEY	Gram-equivalent Yield
GMP	Geometric Mean Productivity
GY	Grain Yield
HI	Harvest Index
ICARDA	International Centre for Agricultural Research in the Dry Areas
i.e.	That is
IW	Irrigation Water
J	Journal
K	Potassium
LA	Leaf Area
LCC	Leaf Chlorophyll Content
LSD	Least Significant Differences
MOP	Muriate of Potash
N	Nitrogen
P	Phosphorus
PEG	Polyethylene glycol
P^H	Concentrate of H^+
RCBD	Randomized Complete Block Design
RDW	Root Dry Weight
RFW	Root Fresh Weight

LIST OF ABBREVIATION (CONTD.)

RGR	Relative Growth Rate
SAU	Sher-e-Bangla Agricultural University
Sci	Science
SD	Standard Deviation
SDW	Seedling Shoot Dry Weight
SFW	Seedling Shoot Fresh Weight
SI	Supplemental Irrigation
SRDW	Seedling Root Dry Weight
SRFW	Seedling Root Fresh Weight
SSDW	Seedling Shoot Dry Weight
SSFW	Seedling Shoot Fresh Weight
STI	Stress Tolerance Index
Ta	Air Temperature
TB	Total Biomass
Tc	Canopy Temperature
TDM	Total Dry Matter
TL	Leaf Temperature
TSP	Triple Super Phosphate
TW	turgid weight
USA	United States of America
viz.	that is say
WP	Water Productivity

CHAPTER I
INTRODUCTION

Lentil (*Lens culinaris*) is one of the most important pulse crops in Bangladesh. In Bangladesh, lentil ranks second in acreage and production but ranks first in market price. Lentil grain contains 59.8% carbohydrates, 25% protein, 10% moisture, 4% minerals and 3% vitamins (Khan, 1981; Kaul, 1982). The green plants can also be used as animal feed and its residues have mineral value. Pulse is an important food crops because they provide a cheap source of high protein, amino acids like isoleucine, leucine, lysine, valine; good flavor and easily digestible components; thus pulses are called poor men's protein. According to, FAO (2008), a minimum intake of pulse should be 80 g per head per day, whereas, it is only 14.19 g in Bangladesh (BBS, 2009) because of the fact that national production of the pulses is not adequate to meet the national demand.

In Bangladesh, yield of lentil is low because of using low yielding varieties by the farmers. Lentil is a rain-fed crop in most countries, grown either during the wet season or on the residual soil moisture in the post rainy season. The present domestic lentil production is 71.100 thousand metric tons under the area of 190.982 thousand acres resulting yield per acre 372 kg (BBS, 2010; www.bbs.gov.bd).

Variety selection is an important factor for more production with good quality of lentil. Bangladesh Agricultural Research Institute developed some new lentil varieties. These varieties are high yielder than previous genotypes. All the high yielding varieties require high inputs, one of which is water. Therefore, these high yielding varieties of lentil may require more water. The management of irrigation water is important one that greatly influences the growth, development and yield of this crop. If sufficient amount of water is applied at critical growth stages, then growth and production will be increased (Michael, 1985). Critical stages of lentil for water use are vegetative stage, pre-flowering stage and pod setting stage. The significant increase of the yield attributes of lentil applying irrigation water, though most of the farmers of Bangladesh do not use irrigation water in pulse crops (Quah and Jafar, 1994). It is considered as a drought resistant crop, capable of drawing water from deeper layers of soil through extensive roots but most varieties respond favorably to added water resulting in higher yields, especially when irrigation is given at the time of water stresses or during short drought periods or at the critical growth stages.

Drought is one of the most environmental problems responsible for greater loss in agricultural productivity throughout the world (Ramagopal, 1993). Water availability is an essential factor influencing agriculture. Growth and photosynthesis are two of the most important processes suppressed, partially or completely, by water stress (Kramer and Boyer, 1995), hence both of them are major causes for limiting crop yield. Damage to plants caused by drought stress is variable depending on the level and duration of the stress and other environmental factors (Glantz, 1994). Drought in plants occur when the rate of transpiration is greater than rate of water absorption (Bray, 1997).

Water is the major factor limiting crop production in many regions of the world. All physiological processes like photosynthesis, cell turgidity, growth of cells and tissue etc., in plant are directly or indirectly affected by water (Reddi and Reddi 1995). Siliquae per plant, seed and oil yield of canola decreased as water stress increased (Rahnema and Bakhshandeh, 2006). Similarly, increase in seed yield with increase in number of irrigations has been reported by Hati *et al*. (2001). Application of irrigation can increase the seed yield of canola from 41.7 to 62.9% (Panda *et al*. 2004). The present study was, therefore, carried out to examine the yield response of lentil to irrigations at different growth stages.

The specific objectives of the study are-

i. to identify suitable lentil variety for maximum yield;
ii. to determine the optimum irrigation level for high yield of lentil; and
iii. to find out the suitable variety and its optimum irrigation level as a combined treatments.

CHAPTER II

REVIEW OF LITERATURE

Variety and irrigation are the most important factors on their relation to maximum the growth; yield and yield contributing attributes of any crops as well as lentil variety. Relevant research information regarding the cultivar of lentil with irrigation, which are pertinent to the present experiment, have been reviewed and presented in this chapter.

2.1. Effect of variety

Variety may have variable effects on growth, yield components and yield of lentil as well as other pulse crops.

BARI (1982) reported that strain 7706 gave significantly higher yield than 7704. BINA (1988) reported that MC-18 (BINA moog 5) produced higher seed yield over BINA mung 2. Field duration of BINA mung 5 was about 78 days and 82 days for BINA mung 2.

Farrag (1995) reported from a field trial with 23 mungbean accessions that seed yield, number of pods plant^{-1}, number of seeds pod^{-1} and 1000-seed weight varied among the tested accessions. He also observed that some cultivars like VC2711 A, KPSI and UTT performed well under late sown condition. Varietal differences in yield do exist under similar field condition. This indicates that all varieties do not perform equally under similar condition.

Among the 32 accessions of mungbean under three sowing dates, Farghali and Hussain (1995) concluded that V6017 had the highest seed yield. They also recorded that the accessions V6017 and UTI had significantly higher plant height, number of seeds pod^{-1}, pod length and number of pods plant^{-1} than that of other accessions.

Haque *et al*. (2002) reported that there was significantly positive correlation between the number of pods plant^{-1} and yield plant^{-1}.

Cultivars played a key role in increasing yield since the response to management practices was mainly decided by the genetic potential. The yields of mungbean cultivars Mubarik, Kanti and Binamoog 1 ranged from 0.8 to 1.0, 1.0 to 1.2 and 0.8 to 1.0 t ha^{-1}, respectively (Farghali and Hussain, 1995).

In an experiment under Bangladesh condition with four varieties of mungbean Duqueand Pessanha (1990) reported the highest number of branches $plant^{-1}$ given by the variety Faridpur-1 followed by Mubarik, BM-7715 and BM-7704. The maximum number of pods plant-1 was produced by Mubarik followed by BM-7704, BM-7715 and Faridpur-1. He identified that pods $plant^{-1}$ were a usefull agronomic character contributing to higher yield in mungbean.

Jain and Kanderar (1988) reported from an experiment with four mungbean varieties that ML 131 produced the highest seed yield as compared with other varieties. In another study Kalita and Shah (1998) studied 19 cultivars of *Vigna radiata* and found that 1000 seed weight was the highest in Gajaral 2 (29 g) and the lowest in ML 131 (24 g). Seed yield was the highest in PIMS-1 (0.89 t ha^{-1}) and the lowest in 11/99 (0.2 t ha^{-1}). Yield variation due to different mungbean varieties were also reported by Masood and Meena (1986 and Pahlwan and Hossain (1983).

Patil *et al*. (2003) studied genetic diversity among 36 genotypes of mungbean, consisting of both released varieties and advance lines are selected for tolerance to different deficit conditions. The genotypes were grown in three distinct environments with recommended dose of fertilizer + plant protection measures, only recommended dose of fertilizer, and fertilizer and pesticide free conditions in Dharwad, Karnataka, India. The simultaneous test for significance for pooled effect of all the characters in all the test environments showed significant differences among the genotypes, indicating the presence of considerable genetic variability for different characters. Among the genotypes, K 851, LM 608 and LM $5^{-1}2$ were the most genetically diverse in all the 3 environments.

Pookpakdi and Pinja (1980) working with five cultivars of mungbean viz. CES 87, CES 14, Pagasa, Hong 1 and local Thai variety with 32 plants per m-^{2} reported that the highest yield of CES 14 was due to highest number of seeds pod^{-1}, and the low yield of local variety resulted from the lowest number of pods plant^{-1}. Among the varieties, Pagasa produced the lowest amount of total dry weight because the variety gave the lowest shoot dry weight.

Rajat and Gowda (1998) found that the highest grain yield was produced by PS 7 followed by PS 16 and PS 10. The higher yield was due to the results of higher number of pods plant^{-1} and 1000-grain weight.

Singh and Singh (1988) observed that four mungbean cultivars sown at a density of 40, 50 or 60 plants m^{-2} gave similar seed yields of 1.3 – 1.5 tha^{-1}. The cultivars UPM 792 and ML 26/10/3 gave the yield of 1.21 and 1.18 tha^{-1} respectively compared to 1.06 - 1.21 tha^{-1} that of the two other cultivars.

The experimental evidence presented above revealed that asynchronous type of lentil and other legume crops continued flowering over a period of several weeks, plants contains mature pods, green pods and flower at the same time and the yield of lentil was also influenced by variety. Any delayed in harvesting of mature pods from the optimum stage of maturity leads to shattering of seeds. Moreover, excessive rainfall at maturity period also reduced the seed quality. Therefore, it was necessary to pick up the pods at maturity period also reduced the seed quality. Therefore, it was necessary to pick up the pods at a suitable time for obtaining better yield and quality of seed with minimum cost. It was thus important to examine the effect of different harvesting time on the yield and yield attributes as well as on seed quality attributes of lentil.

2.2. Effect of irrigation

Irrigation may have variable effects on growth, yield components and yield of lentil. Dastan and Aslam (1986) found that in sandy loam soil of Delhi, lentil responded positively up to 2 irrigation each at 15 and 30 days after sowing.

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

Pannu and Singh (1988) demonstrated that the total dry matter as well as grain yields of mungbean was affected by moisture deficit in lentil.

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

Yadav *et al*. (1992) found that lentil needs relatively better moisture regime than gram. In north east plains (Faizabad) one irrigation at flower initiation (50 DAS) was found most promising; whereas, in Central India (Jabalpur), 2 irrigation, each at branching and flowering were found optimum.

Siowit and Kramer (1997) observed in soybean that, the maximum reduction in yield due to moisture deficit occurred during grain filling stage. Drastic yield reduction was also reported in mungbean due to water deficit (Sadasivam *et al*., 1988; Hamid and Rahih, 1990). The yield loss was primarily caused by the reduction of canopy development, inhibition of photosynthetic rate and lower dry matter production.

Michael (1985) found that the plant height, branches per plant, pods per plant and 1000-grain weight increased significantly with one irrigation; whereas, three irrigations reduced the grain yield, 1000-grain weight, grain protein content and nodulation in lentil.

Pandey *et al*. (1984) reported that mungbean is more susceptible to water deficits compared to other grain legumes. Water deficit affects canopy development and overall growth process but there is varietal difference in tolerance to water deficit.

Talukder (1987) reported that wheat seed yield and harvest index were the most susceptible parameters to water deficit at flowering and pod development stages.

Sadasivam *et al*. (1988) reported that water deficit during vegetative phase reduces grain yield through reducing plant size, limiting root growth and number of pods and harvest index in mungbean. Decreased grain yield due to water deficit was also reported in chickpea (Provakar and Suraf, 1991), soybean (Rajput *et al*. 1991), greengram and blackgram (Tripurari and Yadav, 1990) and fababean (Khade and Varma, 1990).

Lopes *et al*. (1988) reported that moisture deficiency resulted in lower number of leaves, pods per plant, reduced plant height-root length ration in *Phaseolus vulgaris*. Pannu and Singh (1988) demonstrated that the total dry matter as well as grain yields were affected by moisture deficit in lentil.

Hamid and Haque (2003) reported a drastic yield reduction in mungbean due to water deficit. They also explained that the yield loss was primarily caused by the reduction of canopy development, inhibition of photosynthesis and lowering of dry matter production.

Venkateswarlu and Ahlawat (1993) observed significant yield increase due to irrigation; the higher yield was obtained under wet moisture regime (IW/CPE = 0.6) as compared to dry moisture regime (IW/CPE =0.35) under Delhi conditions on sandy loam soils.

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

Majumdar and Roy (1992) reported that the higher grain yield and positive effect on yield components due to irrigation application in summer sesame. Similar result was found in soybean (Rajput *et al*., 1991), in edible pea (Rahman, 2001), in greengram (Pal and Jana, 1991).

Denmead *et al*. (1990) in their studies with corn stated that plant growth, grain yield and dry matter production were reduced by water deficit at all the growth stages. They further reported that when the deficit was removed the growth rate did not immediately return to normal but required several days to recover.

Salter and Goode (1997) stated that the extent of yield reduction from water deficits depends not only on the magnitude of the deficit but also on the stage of growth of bushbean. Yield and dry matter production were reduced at all the growth stages by water deficit. They further reported that when the deficit was removed the growth rate did not immediately return to normal but required several days to recover.

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

Vitkov (1972) found that soil wetting up to 60 cm depth by sprinkler irrigation increased seed yield up 950 kg per hectare in Frenchbean. It was also reported that fieldpea were most sensitive to water deficit during flowering and early pod filling stage (Lewis *et al*., 1994). They also reported that sorghum grain yield was reduced to 17.34% and 10% over control when water deficit occurred at late vegetative and booting stage, respectively.

Turk *et al*. (1980) studied the response of cowpea to water deficit at different growth stages and reported that yield was not reduced by water deficit imposed at vegetative stage; while at flowering stage, yield reduction was substantial. Variation in yields resulted from difference in number of pods per m^2 and seed size.

Cselotel (1980) reported that a regular water supply particularly during flowering and pod formation is necessary for high yield and good quality of snapbeans. Higher number of dry pods per plant, increased seed weight and seed yield per hectare was found when irrigation water was supplied weekly. Haque (1998) and Sankar (1992) reported similar results in peas and greengram, respectively.

Lawlor *et al*. (1981) observed that yields, total dry matter production and harvest index of barley were decreased by water deficit. The grain growth in un-irrigated crop was decreased. They explained the results as probability of insufficient supply of current assimilates towards the grain due to poor photosynthates under water deficit condition.

Irrigation increased pigeonpea yield by 97%, while water deficit during the reproduction phase was the major yield-limiting factor (Masood and Meena, 1986). Duque and Pessanha (1990) found that the deleterious effects of drought deficit imposed at flowering reduced number of filled spikelets per panicle and reduced photosynthetic leaf area that affected directly the grain yield of chickpea. Petersen (1989) reported that water deficit reduced pods per plant and mean seed weight in *Phaseolus vulgaris* and pods per plant and seeds per pod in *Phaseolus acutifolius*. Similar results were reported by Lopes *et al*. (1988).

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

Viera and Banik (1991) reported a yield reduction of 35 to 40% when drought deficit was imposed seed filling but found no effect on germination or vigour in soybean seeds.

Karim and Banik (1993) stated that soil and atmospheric water deficit controls plant growth directly of soybean.

Grain yield and net returns were higher with 3 irrigations that with 1 and 2 irrigations in French bean (Provakar and Suraf, 1991) and blackgram (Tripurari and Yadav, 1990).

Biswas (2001) reported that irrigation frequency exerted a remarkable impact on yield of fieldbean. Application of 3 irrigations increased vegetable pod and 100-seed weight.

In order to study of limit water stress effect on yield of 18 selected lentil genotypes, irrigation stop was applied in all plots with first flower appearance and then irrigation interrupted till harvest stage (Rad *et al*., 2010). With study of drought indices stress tolerance index (STI) and geometric mean productivity (GMP) had positive and significant correlation in %1 level with yield in drought and normal condition and on basis of both indices Naeen and Shiraz7 genotypes showed the highest tolerance than other genotypes.

Azam *et al*. (2002) conducted an experiment to investigate the effect of sowing date (7 November, 6 December), irrigation (nil, full irrigation, irrigation at podding) and population density (100,150, 200 plant m^{-2}) on lentil seed yield and its components at the Crop Production and Water Management Research Area, University of Agriculture. Faisalabad. Sowing in November significantly enhanced seed yield by 113.2% in 1993-94 and 102.1 % in 1994-95 compared to sowing in December. Similarly fully irrigated treatments also increased seed yield over control or crop irrigated at podding only. A population density of 150 plant m^{-2} outyielded in seed yield over 100 or 200 plant m^{-2} in both the years. This positive response to early sowing, higher density or fully irrigated crop was the direct consequence of improvement in all the yield components.

Response of lentil to plant population depends upon the growing conditions and genotypes. The availability of soil moisture affects the crop response to plant population. Generally, seed yield increased linearly with increasing population from 160 to 400 plants m^{-2} for irrigated lentil whereas optimum population level of unirrigated crops was 334 plants (Tosun and Eser, 1979; Shoaib, 1992). Silirn *et al.* (1990) reported that the relationship between seed or TOM yields and density was best described by a quadratic curve.

Bstawi *et al*. (2011) were studied two consecutive winter seasons (2008/09-2009/10) at the Demonstrated Farm, Sudan University of Science and Technology, Shambat, Sudan to study the effect of skipping one irrigation during different developmental stages on growth, yield, yield components and water use efficiency of wheat (*Triticum aestivum* L.). Condor cultivar was grown under six irrigation treatments at developmental growth stage, in which one-irrigation was skipped at some of growth stages (seedling W_1, tillering W_2, booting W_3, dough W_4 and repining stage W_5) and irrigation without skipping with intervals of 10 days as control W_S. The results showed there were highly significant differences in all tested parameters due to skipping irrigation except plant/m^2 in both seasons, and plant height and dry matter accumulation in 45 days reading (booting stage) in the second seasons. Irrigation every 10 days throughout (control) gave higher values (few different with seedling and repining stages) than the other sensitive stages. Although, the result showed highly significant effect on the studied parameters biomass, straw and grain yield, harvest index, water use efficiency and protein content. In general irrigation every 10 days with slightly different at skipping on seedling and repining stages gave the highest protein content, grain and straw yield and field water use efficiency. Skipping irrigation during tillering and booting stage must be avoided.

McKenzie and Hill (1990) conducted an experiment that combined two lentil cultivars (Olympic and Titore) and two irrigation treatments. In 1985-86, Titore was sown on two dates, with four irrigation treatments. The 1985-86 season was wetter than average and seed yields were lower, ranging from 0·6 to 1·5 t ha^{-1}. Under rain shelters, seed yield ranged from the equivalent of 0·32 to 2·5 t ha^{-1}. Same times un-irrigated plots from the May sowing yielded 1·5 t ha^{-1}, whereas all other plots yielded 0·8 t ha^{-1}. There was little positive response to irrigation in both seasons. Fully irrigated plants produced 1·27 g DM and 0·72 g seed/m^2 per mm of water received. Under the rain shelters, there was a strong relationship between yield and actual evapotranspiration (ET). Water-use efficiency (WUE) ranged from 2·81 g DM/m^2 per mm ET in unirrigated plots to 0·69 g seed/m^2 per mm ET.

Turay (1993) was observed that the additional nitrogen (N), irrigation and sowing date on early growth, N nutrition, leaf growth and yield of *Lens culinaris* (lentil) were examined under glasshouse and field conditions. Leaf appearance rates were linear. Rate of appearance was increased by full irrigation and 150 kg N ha^{-1} when compared to 1/4 irrigation and 0 N. With full irrigation and 150 N, leaves appeared at the rate of one every 3.8 days compared to one every 5.8 days with 1/4 irrigation and 0 N. The field experiment was autumn and spring sown and used cv. Olympic only. There was no effect of irrigation on all parameters measured due to the unseasonally high rainfall recorded during November and December, 1991.

Oweis *et al*. (2004) found that lentil often experiences considerable drought stress during reproductive development, which reduces yields. Limited supplemental irrigation (SI) can boost and stabilize productivity.

Paramjit and Roy (2001) were observed that the field experiment was conducted during rabi season of 1998-99 at Agronomy Research Area, CCS Haryana Agricultural University, Hisar. The experiment comprised four levels of irrigation i. e. I0 (no irrigation), I1 (one irrigation at tillering stage), I2 (one irrigation at flag leaf stage) and I3 (two irrigations first at tillering and second at flag leaf stage) and four levels of nitrogen (0, 30, 60 and 90 kg N ha^{-1}). The application of two irrigations (I3) significantly increased the nitrogen content and uptake in grain and straw, and protein content in grain as compared to other treatments of irrigation. The malt yield decreased with the increasing frequency of irrigation. The increasing levels of nitrogen up-to 90 kg N ha^{-1} significantly increased the nitrogen concentration and uptake by grain and straw and protein content in grain. The malt yield decreased significantly with the increasing levels of nitrogen upto 90 kg N ha^{-1}.

Bajehbaj (2010) conducted an experiment to evaluation water deficit stress and potassium rates effects on some morpho-physiological attributes of sunflower, in Islamic Azad University, Tabriz Branch research field in 2008. Four sunflower cultivars as Airfloure, Alestar, Armawirski and Ismailli, along with three rates of potassium application as control, 75 and 150 kg/ha were arranged in subplots and three rates of water application after 70, 140 and 210 mm evaporation from Class A pan were arranged in main plots. The results showed that the application of water deficit stress decreased significantly plant height, seed number per head, seed hollowness percent, leaf water potential, leaf area index, leaf relative water content, stomatal resistance and harvest index. In water application after 70 mm evaporation from Class A pan Airfloure and Alestar cultivars had the highest seed number per head and the least hollowness percent, while maximum harvest index was obtained in Airfloure cultivar in consumption of 75 kg/ha potassium sulphate and water application after 210 mm evaporation from Class A pan. Increasing irrigation level decreased leaf water potential as 31.71% and increased stomata resistance as 45.61%, consequently leading to 49.17% decrease in head fresh weight.

Bhatti (2004) were investigate on different irrigation treatments which were I_1 = No irrigation, I_2 = One irrigation (at 30 days of sowing), I_3 = Two irrigation (One each at 30 days of sowing and at 75% flowering) and I_4 = Three irrigation (One each at 30 days of sowing 75% flowering and pod filling). Application of three or two irrigation proved effective and gave higher seed yield (1623.00 and 1568.00 kg per ha). Lentil crop irrigated at 30 days of sowing and flowering or at complete pod filling stages produced similar seed yields. Similarly, yield components such as branches plant^{-1}, pods plant^{-1}, seed pod^{-1}, seed weight plant^{-1}, and seed index were also superior under three and two irrigation. These results demonstrated that for getting better seed yield, crop may be irrigated twice at 30 days of sowing and at flowering, while further increase in irrigation increased yield but was not superior than two irrigation.

Parihar and Tripathi (1989) were studied at Kharagpur in Eastern India. Irrigation scheduling was based on the ratio between irrigation water applied and cumulative pan evaporation (ID/CPE), and had little effect on dry matter accumulation. Increasing the frequency and amount of irrigation reduced the number and dry weight of nodules per plant, which increased to a maximum 70 days after sowing and then declined. Irrigation significantly reduced grain yield as a result of excessive vegetative growth at the expense of pod formation.

Anwar *et al*. (2003) were observed that the canopy development, radiation absorption and its utilization for biomass production in response to irrigation at different growth stages of three Kabuli chickpea (*Cicer arietinum* L.) cultivars was studied on a Wakanui silt loam soil in Canterbury, New Zealand (43°38S, 172°30E). Green area duration (GAD), intercepted radiation (F_i), radiation use efficiency (U) and total intercepted PAR were significantly ($P<0{\cdot}001$) increased by irrigation. Fully irrigated November-sown crops had a final U of 1·46 g DM/MJ PAR. Full irrigation from emergence to physiological maturity always gave the highest seed yield (>4·7 t/ha), and there was no indication of a critical period of sensitivity to water stress.

Chauhun and Asthana (1981) conducted an experiment to determine the effect of concentration of boron in irrigation water on tissue Ca/B ratio and yield of lentil, barley and oats is described and the results discussed. Tissue Ca/B ratio is a better index for detecting B toxicity in plants. The grain and straw yield of lentil and barley decreased on and beyond 3 and 6, and 6 and 8 mg B/1 in irrigation water, respectively, but there was no effect on green fodder yield of oats.

Rowe and Neilsen (2010) studied on the effects of applying irrigation to spring sown forage turnips, *Brassica rapa* var. *rapa* cv. *Barkant*, during four stages of vegetative growth on yields, yield components and growth rates, were investigated in two field experiments in north-west Tasmania during the 1999–2000 and 2000–01 spring–summer seasons as a basis for developing irrigation strategies for turnip that could improve their efficiency of water use. Increases in dry matter yield in response to irrigating during the four consecutive periods of vegetative growth were additive for all treatment periods and harvest times: the yield increases to irrigation during any period were independent of prior or subsequent levels of irrigation. The results also show that moisture deficits that restrict yields in a previous treatment period do not restrict yield response to irrigation in later periods.

Cheth (2011) establish the ‘best-bet’ management options for mungbean and peanut cropping after rice in the rainfed lowland environment of Cambodia. The frequency of irrigation had a significant effect on the final grain yield of peanut but not for mungbean. The GY and total dry matter (TDM) of peanut was reduced by 37 and 25 %, respectively, when the irrigation frequency was reduced from every 4, 8 or 12 days, to every 16 days. The results of the first field experiment in the 2009 -10 dry-season indicated that for mungbean the use of drip irrigation three times per week gave the lowest GY (212 kg/ha), while hand-watering every three days produced the highest GY (575 kg/ha). There was no difference between GY for the furrow irrigation treatments every week (449 kg/ha) or every two weeks

(453 kg/ha). For peanut, both drip irrigation and furrow irrigation at an interval of once every two weeks resulted in significant reductions in final grain yield of 25-47 % and 26 %, respectively, when compared with frequent irrigation regimes.

Malhotra *et al*. (1997) reported that an experiment was conducted to investigate the response of chickpea to irrigation, the field at Tel Hadya, Syria, from 1985 to 1988 using 24 improved chickpea genotypes sown in winter. Irrigation increased seed yield by 916 kg ha^{-1} (44.0%) over the 3-year period. Irrigation requirement for chickpea coincided with flowering and seed development period. Their mean seed yields ranged from 3877 to 3208 kg ha^{-1}. These results indicate that it may be possible to breed chickpea for improved response to irrigation, and irrigation can enhance the yields of winter-sown chickpea grown in the lowland Mediterranean dry lands.

Balasio *et al*. (2002) carried out in farmer's field in Selaim basin for two consecutive seasons (2000-01 and 2001-02) to study the response of fababean to differential irrigation. Three watering regimes (14, 21and 28-day intervals) were interchanged in all possible combinations during the two phases of plant growth (vegetative and reproductive). In both seasons treatment C1 (28 days-vegetative and 14 days-reproductive) gave the highest grain yield (3545 kg ha^{-1} and 2631 kg ha^{-1}) in the first and the second seasons, respectively. Treatment (C1) received only six irrigations with a total quantity of irrigation water of about 4464 m3 ha^{-1} compared to irrigating 14 days throughout the growing season, which consumed about 7429 m3 ha^{-1} in eight irrigations.

Manjunath *et al*. (2010) found that irrigating lentil at flowering stage increased the grain yield significantly over no irrigation to the tune of 9.01 and 10.73% during 2005–06 and 2006–07, respectively. This may be due to more number of pods/plant, grains/plant and 1000-grain weight recorded under irrigated treatment.

McKenzie (1987) reported a research programme to study the growth, development and water use of lentils was initiated in 1984 and continued in 1985. The unirrigated May sowing yielded 1.5 t seed ha^{-1}, with the August sowing yielding about 0.8 t ha^{-1}. In 1985-86, a wet growing season, irrigation in the field experiment caused significant yield losses. In the May sowing, unirrigated plots yielded 1.5 t seed ha^{-1} while the fully irrigated plots yielded only 0.7 t seed ha^{-1}. There was no difference in yield between the irrigated treatments in the August sowings. Under the rain shelters, however, there was a large positive response to irrigation. The fully irrigated plants produced the equivalent of 2.4 t seed ha^{-1} , while the unirrigated plants produced only 0.32 t seed ha^{-1}.

Krouma (2010) conducted an experiment on chickpea (*Cicer arietinum* L.) in a greenhouse to assess the effects of drought stress on plant growth, photosynthesis, and water relations. A close relationship between plant growth, and photosynthesis and leaf water status was observed. In comparison to Chetoui and Kesseb, Amdoun exhibited the greatest plant growth and photosynthetic activity, the lowest drought intensity index, and important osmotic adjustment under drought stress. Water use efficiency clearly differentiated the studied genotypes.

A two growing seasons (2006-2008) field experiment was conducted at the Experimental Research Center, Shiraz University to study the effects of water stress at different growth stages [Normal irrigation at all growth stages (control), water stress at flowering, at pod development and at seed filling stages] and nitrogen (N) levels (0, 75, 150 and 225 kg ha^{-1}) on yield and yield components of rapeseed (*Telayeh cultivar*). Full irrigation and the highest N level had the highest plant height, number of branches per plant, pods per plant, seed and oil yields. Flowering was the most sensitive stage for water stress damage resulting a drastic reduction in seed and oil yields by 29.5% and 31.7%, respectively. Pods per plants was the most sensitive yield components to water stress during reproductive growth in both year and it had the highest significant positive correlation with seed and biological yields. Overall, supplying sufficient water to rapeseed crop, particularly at flowering and pod formation, in comparison with 225 kg ha of N fertilizer are important to produce higher yields (Ahmadi and Bahrani (2009).

A field experiments were conducted during the 2007/2008 dry season farming in Maiduguri, Borno state; in the northern Sahel savanna agro-ecological zone of Nigeria to evaluate the effect of imposing a 50% irrigation water deficit at different stages of growth of cow pea (*Vigna unguiculata* L*)* on growth and yield of the crop (Dibal *et al*., 2010). The results indicated that the reduction in 50% of irrigation water requirement had affected the both the growth and yield of the crop. It also showed that water savings are possible without significant effect on the growth and yield of the crop at stages 1, 2, 4 and 1&4. Applying the same water stress at two or more stages of growth of the crop has a detrimental consequence.

The effect of four irrigation regimes (I_1-Irrigation after 70 mm, I_2-Irrigation after 100 mm, I_3-Irrigation after 130 mm and I_4-Irrigation after 160 mm evaporation from class A pan) and two dates of sowing (August 30 and January 27) were studied during growing season of 2009-2010 at I.A. University of Takestan, Iran. Among the irrigation treatments, irrigation after 70 mm evaporation from class a pan, gave significantly highest plant height, seed siliqua^{-1}, siliqua plant^{-1}, thousand seed weight and seed yield (Rafiei *et al*., 2011).

Ashraf *et al*. (2011) were studied that the effect of various irrigation frequencies on pea seed yield and seed quality was investigated under field conditions at the Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan during the years of 2005-06 and 2006-07. Two promising pea cultivars i.e. Meteor and Climax were tested along with four irrigation levels i.e. 8 irrigations upto flowering (I_1): 10 irrigations upto pod filling (I_2): 12 irrigations upto seed filling (I_3) and 13 irrigations upto seed maturity (I_4) were applied. The results indicated that cultivar Meteor produced significantly higher seed yield (2.5 t ha^{-1}) in treatment I_3 while Climax gave maximum yield (2.2 t ha^{-1}) in I_4.

Upadhyay *et al*. (2002) were investigate on Indian mustard *(Brasslca napus* L.) plants grown under field conditions. Maximum leaf area, growth parameters including crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate were observed under zinc sulphate 20 kg/ha with three irrigation levels while biochemical constituents of leaves especially chlorophyll was higher under zinc sulphate 40 kg/ha with three irrigation. The maximum seed yield was recorded In zinc sulphate 40 kg/ha with three irrigation.

Al-Barrak (2006) conducted a field experiment to determine the effect of irrigation intervals and nitrogen levels on canola "cv. Fido" on a sandy loam soil during 2000-2001 and 2001-2002 seasons. Irrigation intervals had significant effects on growth characters as well as seed and oil yields. In general, it can be concluded that irrigation canola plants at the regular interval of 14 days with 650 m3 water irrigation ha^{-1} and adding nitrogen fertilizer with the rate of 120^{-1}80 kg N ha^{-1} produced the highest seed and oil yield and increase the water use efficiency under the environmental condition of Al-Hassa region.

Sims *et al*. (1993) reported that canola yields in Montana increased greatly with increased availability of water, but higher water content lowered mean oil content.

Leilah *et al*. (2002) stated that irrigation canola plants every 14 days associated with the highest values of water use efficiency (WUE) in the two seasons of study.

Al-Habeeb and Al-Hamdan (2002) found that the optimum seasonal irrigation volume as 3000 m3 per hectare.

The interaction between irrigation treatments and nitrogeen rates had significant effects on seed and oil yields ha^{-1} (Leilah *et al*., 2003).

Taylor *et al*. (1991) reported that despite seasonal differences, shoot dry matter significantly increased as more irrigation water was applied. Marked differences in total dry weight yield among different interval irrigation period application, especially between shorter and longer period, were probably caused by differences in plant height, stem diameter and number branches

Ahlawat *et al*. (2005) conducted a field experiment during 2000-2002 at the Indian Agricultural Research Institute, New Delhi, to find out the optimum irrigation schedule for gram (*Cicer arietimum* L.) + Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] intercropping system. Irrigation at 0.2 irrigation water : cumulative pan evaporation (IW : CPE) ratio in sole gram and 0.4 IW : CPE ratio in Indian mustard was optimum for seed yield. Irrigation in gram at 0.4IW : CPE ratio caused 31.6% reduction in seed yield compared with 0.2 IW : CPE ratio. The water-use efficiency (kg/ha-mm) was the highest in sole Indian mustard (12.66) and unirrigated crops (11.7)

To evaluate the yield and yield components of lentil genotypes under drought stress conditions, an experiment was conducted in Ardabil Agricultural Research Station during 2005. The results showed that irrigation water deficit during lentil flowering led to the decrease in pod number, grain number per plant, grain weight, grain yield and harvest index.

Ali *et al*. (2003) were observed that the influence of four nitrogen levels (0, 60, 90 and 120 kg N ha') and three irrigation regimes (2, 3 and 4) on the seed yield and oil quality of hybrid canola (cv. Hyola 401) in a field trial at University of Agriculture, Faisalabad during 1999-2000. Seed oil content were decreased but protein content were increased with the increase of irrigation frequencies and nitrogen rates.

Piril *et al*. (2011) had studied on the effect of irrigation intervals and sulphur fertilizer on growth analyses and yield of Indian mustard (*B. juncea* var. Pusa Jagannath), in a field experiment at Indian Agricultural Research Institute, New Delhi during crop season of 2007-2008 and 2008-2009. The results showed that in both years of experimentation application of two irrigations significantly increased plant height and number of primary branches per plant over one irrigation, which resulted in significantly higher straw yield. Also application of two irrigations, being on par with one irrigation, significantly increased RGR and NAR over no irrigation at all the stages of plant growth in both the years of investigation.

Malik *et al*. (2006) conducted an experiment to evaluate the interactive effects of irrigation and phosphorus on green gram (*Vigna radiata* L). Irrigation treatments exhibited positive effects on yield and yield components. Less than two and more than two irrigations were not economically beneficial. Interactive effects of two irrigations and 40 kg P2O5 ha^{-1} were most effective.

Tahir *et al*. (2007) conducted a field experiment was carried out to examine the effect of different irrigation levels on growth and yield of canola in 2005-06. The results showed that maximum crop growth rate, net assimilation rate, number of seeds per siliqua, 1000-seed weight and seed yield were attained with three irrigations at early vegetative, flowering and seed formation (21, 56 & 93 DAS). The oil and protein contents of the seed were not affected significantly by varying irrigation levels.

CHAPTER III
MATERIALS AND METHODS

The materials and methods of this research work were described in this chapter as well as on experimental materials, site, climate and weather, land preparation, experimental design, lay out, sowing of seeds, intercultural operations, crop sampling, data collection, harvest index etc. within a period. Overall discussion about planting materials on water relations and yield of lentil varieties as influenced by different irrigation levels on some morpho-physiological and yield contributing characters of lentil under the following headings:

3.1. Experimental site

The present research work was conducted at the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2009 to February, 2010. The experimental area is located at 23.41^{0} N and 90.22^{0} E latitude and at an altitude of 8.6 m from the sea level.

3.2. Climate and soil

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature recorded by the National Meteorological Research Centre, Dhaka during the period of study have been presented in Appendix I. The experimental plot was also high land, fertile, well drained and having p^{H} 5.8. The physicochemical property and nutrient status of soil of the experimental plots are given in Appendix II.

3.3. Planting materials

Three varieties of lentil (BARI masur 4, BARI masur 5 and BARI masur 6) which were released by Bangladesh Agricultural Research Institute (BARI) were used as experimental materials for the study. The mature seeds of these varieties were also collected from the Pulse Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur- 1701.

3.4. Experimental treatments

The experiment was consisted of two treatment factors as follows:

Factor A: Variety -3

V_1 : BARI Masur- 4

V_2 : BARI Masur- 5 and

V_3 : BARI Masur- 6

Factor B: Irrigation level- 4

I_0 : No irrigation

I_v : Irrigation at vegetative stage (25 days after sowing- DAS)

I_f : Irrigation at flowering stage (at 50 DAS)

I_{vf} : Irrigation at both vegetative and flowering stage (at 25 DAS & 50 DAS)

3.5. Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (factorial) (RCBD) with three replications. The size of unit plot was 3.5 × 2.5 m where block to block and plot to plot distances were 1.0 and 0.75 m, respectively. Row to row and plant to plant distances were also 30 and 10 cm, respectively, in each plot.

3.6. Land preparation

Power tiller was used for the preparation of the experimental field. Then it was exposed to the sunshine for 5/6 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed and deep ploughing was due to obtained good tilth, which was necessary to get better yield of this crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The plots were spaded one day before planting and the whole amount of fertilizers were incorporated thoroughly before planting according to fertilizer recommendation guide (BARC, 1997). The soil was treated with insecticides at the time of final ploughing. Insecticides Furadan 5G was used @ 8 kg ha^{-1} to protect young plants from the attack of mole cricket, ants, and cutworms.

3.7. Manures and fertilizers

The calculated entire amount of all manures and fertilizers were applied during final plot preparation. The applied manures were mixed properly with the soil in the plot using a spade.

Manure and fertilizers	**Dose ha^{-1}**
Cow dung	10 ton
Urea (Nitrogen)	50 kg
TSP	85 kg
MoP	35 kg
Gypsum	45 kg

Source: *BARC, 1997 (Fertilizer Recommended Guide)*

3.8. Seed sowing

Seeds of BARI masur varieties were hand sown in the experimental plot. Seeds were sown on 26 November 2009. The row to row and plant to plant distances were 30 and 10 cm, respectively. Seeds were placed at about 3 to 4 cm depth from the soil surface.

3.9. Intercultural operations

3.9.1. Thinning

Emergence of seedling was completed within 10 days after sowing. Over crowded seedlings were thinned out two times. First thinning was done after 15 days of sowing which is done to remove unhealthy and lineless seedlings. The second thinning was done 10 days after first thinning.

3.9.2. Weeding

First weeding was done at 20 DAS and then once a week to keep the plots free from weeds and to keep the soil loose and aerated.

3.9.3. Irrigation

The irrigation was done at four times as per treatment with watering can as substitute of sprinkler system. Water application was continued till soil saturation.

3.9.4. Disease and pest management

The research field looked nice with normal green plants. The field was observed time to time to detect visual difference among the treatments and any kind of infestation. The experimental crop was not infected with any disease and no fungicide was used. Hairy caterpillars attacked the young plants and accumulated on the lower surface of leaves where they usually sucked juice of green leaves. Borers also attacked the pods. They attacked at the early growing stages of seedlings. To control these pests, the infected leaves were removed from the stem and destroyed together with insects by hand picking. Beside, spraying pyriphos controlled these insects. The insecticide was sprayed three times at seven days interval.

3.10. Harvesting and threshing

Harvesting of the crop was done after 120 days of sowing for data collection when about 80% of the pods attained maturity. The morphological, growth and yield attributes crop sampling was done at harvest stage. Data were recorded on $1m^2$

area of the middle portion of each plot for average results. The harvested plants of each treatment were brought to the cleaned threshing floor and separated pods from pants by hand and allowed them for drying well under bright sunlight.

3.11. Crop sampling and data collection

The data of the different parameters of lentil were collected from randomly selected ten plant samples which collected from the middle portion of the plot ($1m^2$). The harvested plants were kept for yield. The sample plants were uprooted carefully from the soil with khurp so that no seeds were dropped into the soil and then cleaned, dried on floor and separated pods from pants by hand and allowed them for drying well under bright sunlight. Finally, grain weights were taken on individual plot basis at moisture content of 12% and converted into kg ha^{-1}. The yield of dry stover was also taken. The data on growth and yield parameters were recorded from at harvest stage. The leaf area of each sample was measured by LICOR automatic leaf area meter (LICOR- 3000, UK) before drying. At final harvest, data on some morpho-physiological, yield components and yield were also collected. A brief outline of the data recording on morpho-physiological and yield contributing characters are given below.

3.11.1. Plant height (cm)

Plant height was measured in centimetre by a meter scale at harvest period from the ground surface to the top of the main shoot and the mean height was expressed in cm.

3.11.2. Leaflets plant^{-1} (No.)

Number of leaflets per plant was counted at the time of harvest and then the randomly selected first simple leaf and the subsequent compound leaves were counted and recorded.

3.11.3. Branches plant^{-1} (No.)

Number of branches per plant data was also recorded at harvest time where all the primary and secondary branches were developed in each plant.

3.11.4. Plant dry weight (g)

The plant dry matter weight was taken by over dry method. Ten plants samples randomly collected from unit plots at the harvest period were gently washed to remove sand and dust particles adhere to the plants. Then the water adhere to the plants were soaked with paper towel. After then the samples were kept in an oven at 70^{o}C for 72 hours to attain constant weight. When the plant samples were attained at constant weight, the dry weights were recorded.

3.11.5. Pods plant^{-1} (No.)

The pods from all the branches of the pre-selected ten plants were counted and the number of pods per plant was calculated from their mean values.

3.11.6. Seeds pod^{-1} (No.)

Number of seeds per pod was recorded after harvesting of the crop from the ten randomly selected pods from ten pre-selected plants was counted. The seed per pod was calculated from their mean values.

3.11.7. 1000- seeds weight (g)

The weight of 1000 randomly selected oven dried (temperature 80^{O}C for 48 hours) seeds was measured in gram by an electric balance.

3.11.8. Seed yield (kg ha^{-1})

The seed yield per plot was measured by threshing and separating grain from the central 1m^{2} areas of unit plot and then seed yield was expressed in kg per ha.

3.11.9. Stover yield (kg ha^{-1})

The stover weight was taken from the remaining plant parts after threshing and separating grain from the plants collected from the central 1m^2 areas of unit plot by threshing and then stover yield was expressed in kg per ha.

3.11.10. Biological yield (kg ha^{-1})

The summation of economic yield (grain yield) and biomass yield (stover yield) was considered as biological yield. Biological yield was calculated by using the following formula:

Biological yield= Grain yield + stover yield (dry weight basis)

3.11.11. Harvest index

It is the ratio of economic yield (grain yield) to biological yield and was calculated with the following formula:

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

3.12. Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed in MSTAT-C computer program by Completely Randomized Block Design (RCBD) (Russel, 1986). The mean values for all the parameters were calculate and the analysis of variance for the characters was accomplished by Least Significant Differences (LSD) test at 5 % levels of probability (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

The experimental results as obtained due to the application of different irrigation levels with three BARI genotypes of lentil which output results are discussed in this chapter. All the data were recorded at harvest and after harvest on different characteristics of morphy-physiological, yield contributing characters viz. plant height, number of leaves per plant, number of branch per plant, number of pods per plant, number of seeds per pod, pod weight, plant dry weight, 1000- seeds weight (g), seed yield (t ha^{-1}), stover yield, biological yield and harvest index. Those results are presented in different Tables and Figures, and possible interpretations were made as required.

4.1. Effect on plant height

4.1.1. Effect of different varieties

Plant height varied significantly due to the effect of three BARI released varieties at harvest (Appendix VI and Fig. 5). The variety BARI masur 6 showed the tallest (23.414 cm) plant. The variety BARI masur 5 gave the shortest (22.00 cm) plant which was statistically identical to that of BARI masur 4. Similar results were also found by Agarawal (1998) in mungbean who reported that the variation in plant height was significantly influenced by variety.

4.1.2. Effect of different irrigation levels

Plant height was significantly influenced by irrigation levels (Appendix VI and Fig. 6). Among the irrigation levels, the tallest (23.667 cm) plant was found in I_{vf} (irrigation at both vegetative and reproductive stage) followed by I_v (irrigation at vegetative stage) and I_f (irrigation at first flowering stage), where the results were identical in I_v & I_f. The treatment I_0 (no irrigation) produced the shortest plant. These results were similar to that of Firiappa (1998) and Yadav *et al.* (1992).

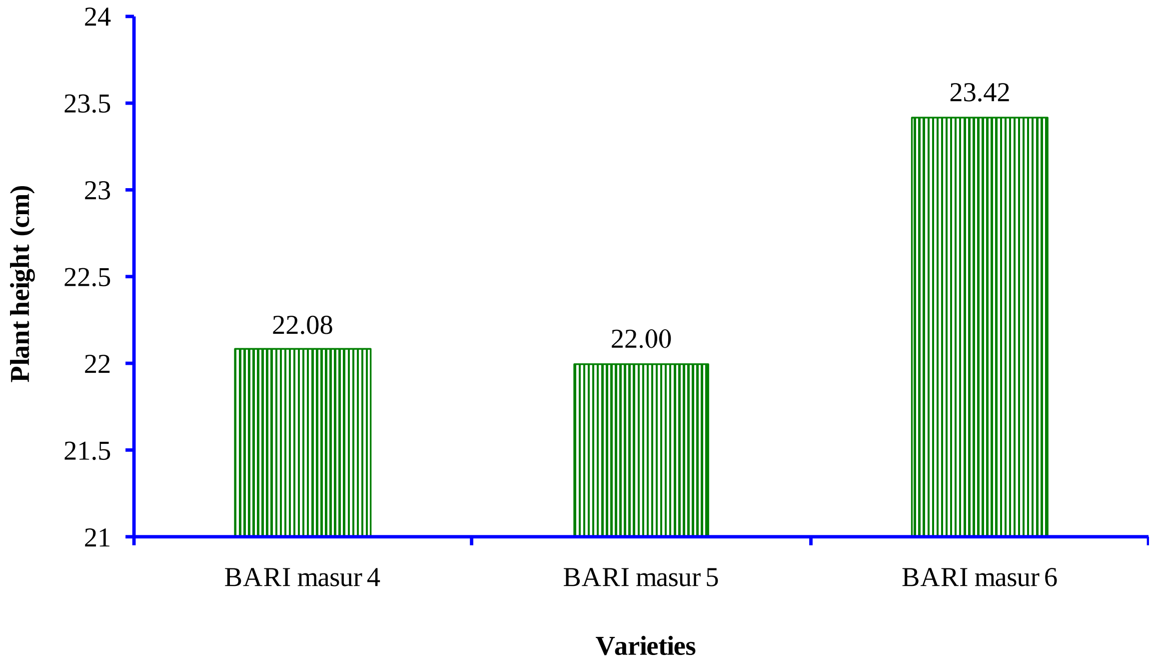

Fig. 1: Effect of variety on plant height of lentil ($LSD_{0.05}$= 0.2323)

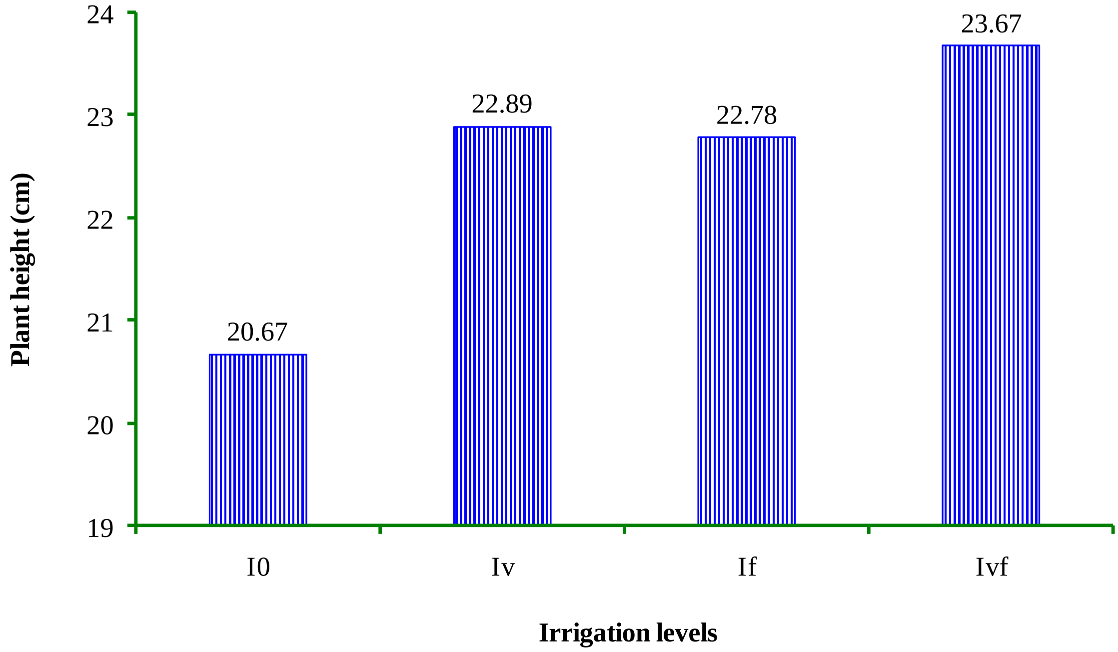

Fig. 2: Effect of irrigation levels on plant height of lentil ($LSD_{0.05}$= 0.2323)

I_0= no irrigation; I_v= irrigation at vegetative stage i.e. 25 days after sowing; I_f= irrigation at reproductive stage i.e. 50 days after sowing and I_{vf}= irrigation at both vegetative and reproductive stage

4.1.3. Combined effect of different varieties and irrigation levels

The combined effect of different variety and irrigation on plant height at harvest was found significant (Appendix VI and Table 4). The tallest plant (24.33 cm) was observed with the combined effect of BARI masur 6 and irrigation at both vegetative and reproduction stage (V_3I_{vf}). The shortest plant (19.67 cm) was found controlled irrigation treatment from BARI masur 5 (I_0V_2).

4.2. Effect on branches plant^{-1}

4.2.1. Effect of different varieties

A significant variation ($p \geq 0.01$) was observed among the varieties with regards to their number of branches per plant harvest (Appendix V and Table 2). It was found that the maximum (7.58) number of branches was found in BARI masur 6 and was statistically identical to that of BARI masur 4 (7.17). BARI masur 5 showed the lowest number of branches (6.25) per plant (Table 2).

4.2.2. Effect of different irrigation levels

Due to the effect of different irrigation levels, number of branches per plant showed significant variation (Appendix V and Table 5) where the maximum number of branches (7.78) was found in I_{vf} treatment (irrigation at vegetative and reproductive stage) and was followed by that of I_v (7.22), I_f (6.89) and I_0 (6.11), where I_v and I_f produced statistically identical number of branches per plant (Table 3)

This may be due to more uptakes of nutrients and production of photosynthates and its translocation towards the axial buds in BARI masur 6 compared to other two varieties. Similar results were also reported by Yusuf (1973), Singh and Srivastava (1986) and Jadhav (1988).

4.2.3. Combined effect of different varieties and irrigation levels

The combined effects of variety and irrigation level were significant on number of branches per plant (Appendix VI and Table 4). Among the combined effects, the maximum (8.67) number of branches per plant was found in the combined effect of V_3Iv_f (BARI masur 6 × irrigation at both vegetative and reproductive stage) followed (8.00) by BARI masur 4 at the same irrigation treatment. The lowest (5.66) number of branches was recorded under no irrigation treatment (Io) from the variety BARI masur 5 (V_2I_o) (Table 4).

4.3. Effect on leaflets plant^{-1}

4.3.1. Effect of different varieties

Significantly the maximum (574.50) number of leaflets per plant was found in BARI masur 4, which was statistically identical to BARI masur 6 (543.33) and significantly different from that of BARI masur 5 (512.08) (Table 4).

4.3.2. Effect of different irrigation levels

The effect of irrigation levels on number of leaflets per plant was significant ($p \leq 0.05$) (Appendix VI and Table 3). Among the irrigation treatments, two irrigations significantly increased number of leaves per plant over no irrigation and also one irrigation. This may be due to more uptakes of nutrients and photosynthates due to more availability of moisture from higher amount of irrigation water. So, the maximum (600.56) number of leaflets per plant was recorded in irrigation at both vegetative and reproductive stage (Iv_f) where the minimum (468.89) number of leaves per plant was found under controlled irrigation treatment (Io) (Table 3).

From the above results, it was clear that number of leaflets increased by the increase of irrigation levels. Similar types of results were also reported by Yusuf (1973), Singh and Srivastava (1986), and Jadhav (1988).

4.3.3. Combined effect of different varieties and irrigation levels

The combined effect of different variety and irrigation levels on number of leaflets per plant was significant (Appendix VI and Table 4).

The significantly maximum number of leaflets (623.33) were found in BARI masur 6 with irrigation both vegetative and reproductive stage (I_{vf}) (610.00) followed by the treatment combination of V_1Iv_f (genotype BARI masur 4 under irrigation at both vegetative and reproductive stage). The minimum (460.00) number of leaflets were recorded in BARI masur 5 under controlled irrigation treatment (Io)(Table 4).

The increase in number of leaflets per plant with the increase in irrigation level was due to improved photosynthesis and allocation of photosynthates towards the lateral buds, and also for the higher activation enzymes involving photosynthesis process.

Table 1: Effect of different variety on branches plant^{-1} and leaflets plant^{-1}

Variety	Branches plant^{-1} (No.)	Leaflets plant^{-1} (No.)
BARI masur 4	7.17	547.50
BARI masur 5	6.25	512.08
BARI masur 6	7.58	543.33
LSD(0.05)	**0.73**	**9.59**
Level of significance	**	**
CV (%)	**6.87**	**5.17**

**= Significant at 1% level of significance

Table 2: Effect of different irrigation levels on branches plant^{-1} and leaflets plant^{-1}

Irrigation level	Branches plant^{-1} (No.)	Leaflets plant^{-1} (No.)
I_0	6.11	468.89
Iv	7.22	538.89
I_f	6.89	528.89
Iv_f	7.78	600.56
LSD(0.05)	**0.48**	**27.36**
Level of significance	**	**
CV (%)	**6.87**	**5.17**

**= Significant at 1% level of significance

Table 3: Combined effect of different variety and irrigation levels on plant height, branches plant^{-1} and leaflets plant^{-1}

Varieties	Irrigation levels	Plant height (cm)	Branches plant^{-1} (No.)	Leaflets plant^{-1} (No.)
BARI masur 4	I_0	20.33	6.33	486.67
	Iv	22.67	7.33	556.67
	I_f	22.00	7.00	536.67
	Iv_f	23.33	8.00	610.00
BARI masur 5	I_0	19.67	5.67	460.00
	Iv	22.33	6.67	510.00
	I_f	22.67	6.00	510.00
	Iv_f	23.33	6.67	568.33
BARI masur 6	I_0	22.00	6.33	460.00
	Iv	23.67	7.67	550.00
	I_f	23.67	7.67	540.00
	Iv_f	24.33	8.67	623.33
LSD(0.05)		**0.73**	**0.82**	**47.39**
Level of significance		**	*	**
CV (%)		**1.91**	**6.87**	**5.17**

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

4.4. Effect on plant dry weight

4.4.1. Effect of different varieties

Plant dry matter was significantly influenced in case of the variety effect at harvest period (Appendix VIII). BARI masur 6 showed the significantly highest (3.71 g) plant dry weight compared to other two genotypes. Significantly the lowest (3.26 g) plant dry weight was produced by the variety BARI masur 5, where the variety BARI masur 4 showed 3.53 g plant dry weight (Fig. 7).

Different variety had differentiation on diverse characters which effect was also on plant dry weight. Similar variation in plant dry weight due to the varieties was also reported by Farghali and Hossain (1995) in mungbean.

4.4.2. Effect of different irrigation levels

The main effect of different irrigation levels on plant dry weight was significant. (Appendix VIII). After the harvest, the highest (4.55 g) plant dry weight was recorded from the treatment having irrigation at both vegetative and reproductive stage (I_{Vf}) followed by irrigation at first flowering stage (3.90 g). The lowest (1.87 g) plant dry weight was produced by the treatment $I_{o.}$ (Fig.8).

It may be due to the increase in irrigation level increased soil moisture availability to plant and thereby facilitated photosynthesis of which ultimate effect was the increase in plant dry matter. This result was also supported by the findings of Girriappa (1988).

4.4.3. Combined effect of different varieties and irrigation levels

A significant variation was found due to the combined effect of different variety and four irrigation levels on plant dry weight (Appendix VIII and Table 8). Among the treatment combination of variety and irrigation levels, the maximum (4.80 g) plant dry weight was recorded in combination of V_3I_{Vf} (BARI masur 6 and irrigation at both vegetative and reproductive stage) followed (4.53 g) by the same irrigation levels from the variety BARI masur 4 (V_1I_{Vf}). It was also observed that increase in irrigation levels increased plant height in all the varieties studied.

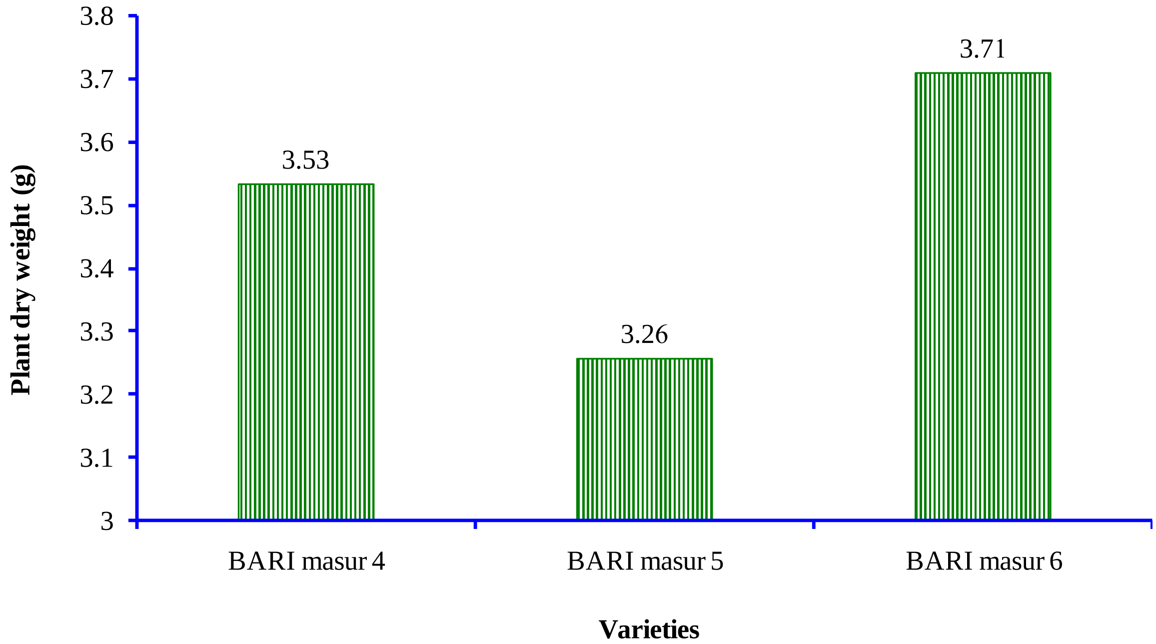

Fig. 3: Effect of variety on plant dry weight of lentil ($LSD_{0.05}$= 0.1075)

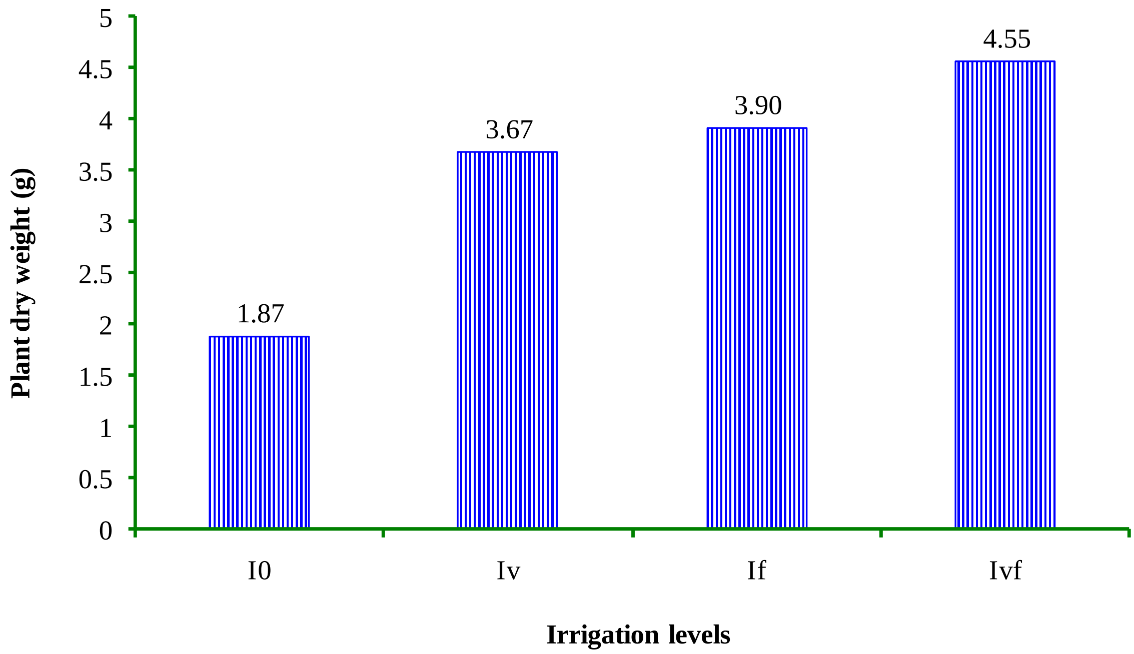

Fig. 4: Effect of irrigation levels on plant dry weight of lentil ($LSD_{0.05}$= 0.08858)

I_0= no irrigation; I_v= irrigation at vegetative stage i.e. 25 days after sowing; I_f= irrigation at reproductive stage i.e. 50 days after sowing and I_{vf}= irrigation at both vegetative and reproductive stage

4.5. Effect on pods plant^{-1}

4.5.1. Effect of different varieties

The main effect of variety on total number of pods per plant was significant (Appendix VII and Table 5). The highest number of pods per plant (55.00) was recorded from the variety BARI masur 6 followed by BARI masur 4 (53.33) which was statistically identical. The minimum number of pods per plant (48.33) was produced from the variety BARI masur 5 and was significantly different from other two varieties (Table 5).

This result was supported by Farghali and Hussain (1995) and Islam *et al*. (2010) in mungbean genotypes.

4.5.2. Effect of different irrigation levels

A significant variation was found in total number of pods per plant due to irrigation level treatments (Appendix VII and Table 6). Among the irrigation treatments, the maximum number of pods per plant (55.33) was found in irrigation at both vegetative and reproductive stage (Iv_f) followed by the treatment of I_v (52.67). On the other hand, the minimum number of pods per plant (49.00) was also produced when it was observed in no irrigation treatment. Similar result was found by Bhan (1977).

4.5.3. Combined effect of different varieties and irrigation levels

Number of pods per plant varied significantly due to the combined effect of varieties and irrigation levels (Appendix VII and Table 7). The maximum number of pods per plant (58.00) was recorded from the combination of V_1Iv_f (BARI masur 4 under irrigation at both vegetative and reproductive stage) followed (57.67) by the same irrigation treatment in BARI masur 6. The minimum number of pods per plant (45.67) was recorded from the variety BARI masur 5 under no irrigation treatment (V_2Io). The similar results were also reported by Ashraf *et al.* (2011) and Milbourn and Hardwick (1968).

4.6. Effect on seeds pod^{-1}

4.6.1. Effect of different varieties

A non-significantly effect was shown on the number of seeds per pod due to the effect of varieties. Because, each variety produced same (2.00) number of seeds per pod (Table 5).

4.6.2. Effect of different irrigation levels

A non-significant effect was shown on the number of seeds per pod due to the effect of different levels of irrigation (Table 6).

4.6.3. Combined effect of different varieties and irrigation levels

In the combined effect of different variety and irrigation levels on number of seeds per pod showed no significant effect for its same results (Table 7).

Table 4: Effect of different variety on pods plant^{-1} and seeds pod^{-1}

Varieties	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)
BARI masur 4	53.33	2.00
BARI masur 5	48.83	2.00
BARI masur 6	55.00	2.00
LSD(0.05)	**2.23**	**2.146**
Level of significance	**	**ns**
CV (%)	**3.13**	**58.93**

**= Significant at 1% level of probability and ns= non significant

Table 5: Effect of different irrigation levels on pods plant^{-1} and seeds pod^{-1}

Irrigation level	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)
I_0	49.00	2.00
Iv	52.67	2.00
I_f	52.56	2.00
Iv_f	55.33	2.00
LSD(0.05)	**1.63**	**1.17**
Level of significance	**	**ns**
CV (%)	**3.13**	**58.93**

**= Significant at 1% level of probability and ns= non significant

Table 6: Combined effect of different variety and irrigation levels on pods plant^{-1} and seeds pod^{-1}

Varieties	Irrigation levels	Pods plant^{-1} (No.)	Seeds pod^{-1}
BARI masur 4	I_0	50.33	2.00
	Iv	53.33	2.00
	I_f	51.67	2.00
	Iv_f	58.00	2.00
BARI masur 5	I_0	45.67	2.00
	Iv	49.33	2.00
	I_f	50.00	2.00
	Iv_f	50.33	2.00
BARI masur 6	I_0	51.00	2.00
	Iv	55.33	2.00
	I_f	56.00	2.00
	Iv_f	57.67	2.00
LSD(0.05)		**2.82**	**2.02**
Level of significance		**	**ns**
CV (%)		**3.13**	**58.93**

**= Significant at 1% level of probability and ns= non significant

4.7. Effect on 1000-seed weight

4.7.1. Effect of different varieties

Variety had a significant influence on 1000-seed weight (Appendiz VIII and Fig.9). The maximum 1000-seed weight (22.00 g) was found from the variety BARI masur 6 (V_3) followed (20.99 g) by the genotype BARI masur 4 (V_1). Significantly lowest (20.44 g) 1000-seed weight was found in BARI masur 5 (Fig. 9). Varietal differentiation in 1000-seed weight also found by Rajat and Gowda (1998).

4.7.2. Effect of different irrigation levels

Irrigation levels had significant influence on 1000-seed weight (Appendix VIII and Fig. 10). The maximum 1000-seed weight was found in Iv_f (irrigations at both vegetative and reproductive stage) followed (22.20 g) in irrigation treatment of I_v (irrigation at vegetative stage i.e. 25 days after sowing). Significantly the lowest (16.50 g) 1000-seed weight was found in controlled irrigation treatment.

Seed weight depends on growth rate and length of filling period, which is supplied by two sources of current photosynthesis and remobilization of stored material in the plant. In their experiments, Gunasekera *et al*. (2006) and Iqubal *et al*. (2008) individually noted that by increase in moisture stress intensity, 1000-seed weight decreases. Increased water use efficiency with increasing water stress has also been observed in lentils by Mckenzie and Hill (1990) reflecting the lower soil evaporation component of water use without irrigation.

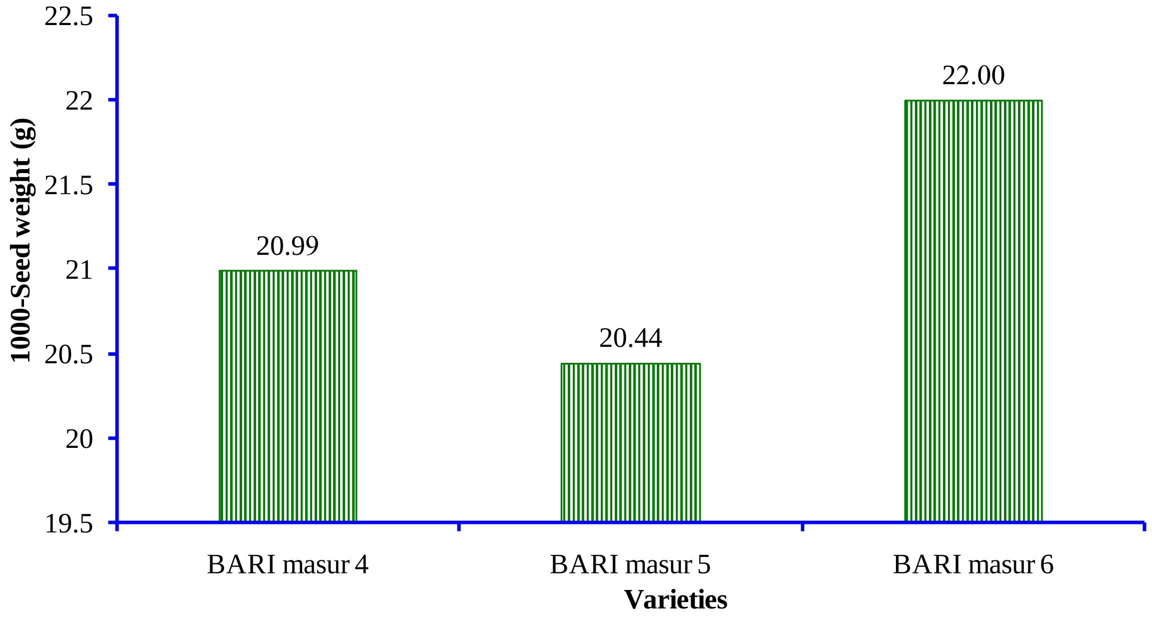

Fig. 5: Effect of variety on 1000-seed weight of lentil ($LSD_{0.05}$ = 0.2238)

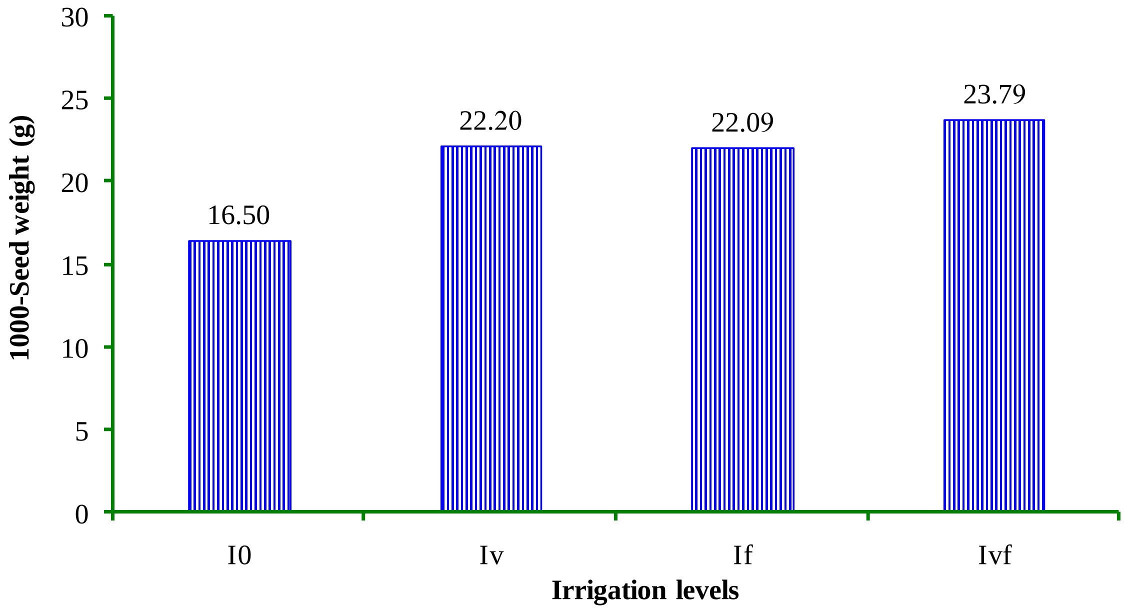

Fig. 6: Effect of irrigation levels on 1000-seed weight of lentil ($LSD_{0.05}$ = 0.1687)

I_0= no irrigation; I_v= irrigation at vegetative stage i.e. 25 days after sowing; I_f= irrigation at reproductive stage i.e. 50 days after sowing and I_{vf}= irrigation at both vegetative and reproductive stage

4.7.3. Combined effect of different varieties and irrigation levels

The combined effect of variety and irrigation levels on 1000-seed weight was significant (Appendix VIII and Table 8). Significantly the highest (24.33 g) 1000-seed weight was recorded from the variety V_3 (BARI masur 6) under the irrigation at both vegetative and reproductive stage (I_{Vf}). From the same irrigation levels with the variety BARI masur 4 showed the second maximum (23.87 g) to compare with another all treatments which was more or less similar. Significantly the lowest (16.20 g) 1000-seed weight was found in the treatment combination of V_1I_0 (BARI masur 4) under the controlled irrigation treatment.

From the above result, it was observed that the increasing irrigation levels gradually increase the 1000-seed weight in all lentil variety studied because of more water supply increased the seed size as well as weight of seed. Similar result was also found by Siowit and Kramer (1997).

4.8. Effect on seed yield

4.8.1. Effect of different varieties

The variety had a significant influence on seed yield of lentil (Appendix VIII). Significantly the highest (1638.78 kg ha^{-1}) seed yield was found in BARI masur 6. Significantly the lowest (1029.23 kg ha^{-1}) seed yield was also found in BARI masur 5 (Fig. 11).

4.8.2. Effect of different irrigation levels

Irrigation level significantly influenced on seed yield (Appendix VIII and Fig. 12). The maximum seed yield (115.97 kg/ha) was found in irrigation treatment I_{Vf} (irrigation at both vegetative and reproductive stage) followed (1422.90 kg ha^{-1}) by I_f (irrigation at flowering stage). The lowest seed yield (733.98 kg ha^{-1}) was recorded in control irrigation treatment (Fig. 12). From this examination, it was found that increasing irrigation level from vegetative stage to harvest stage produced more seed as well as more yield (Fig. 12).

The similar results were also found by Michael (1985) and Pannu and Singh (1988). The increase in number of irrigation resulted in significant increase in seed yield, which may be attributed from the higher number of pods per plant, number of seeds per pod and 1000-seed weight. Increase in seed yield with increase in number of irrigations has been reported by Hati *et al*. (2001) and Panda *et al*. (2004).

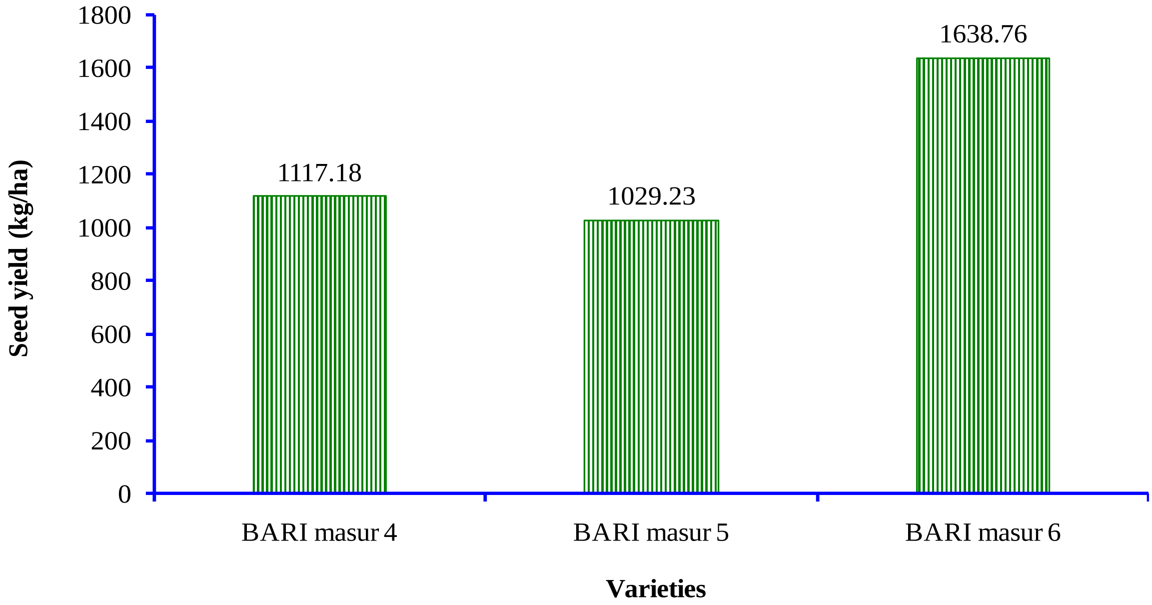

Fig. 7: Effect of variety on seed yield of lentil ($LSD_{0.05}$ = 32.41)

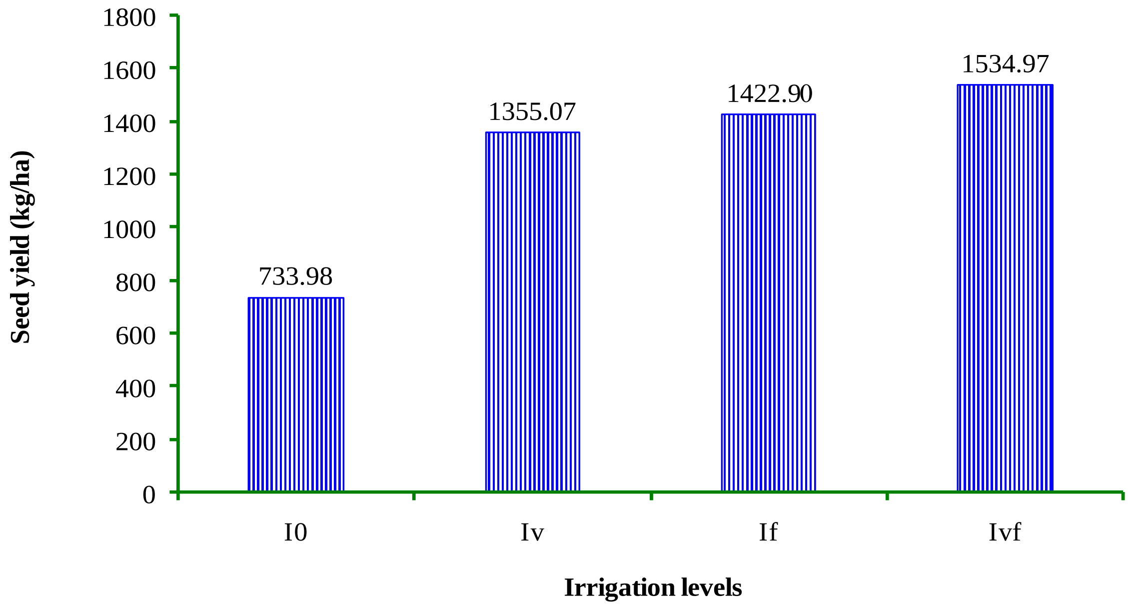

Fig. 8: Effect of irrigation levels on seed yield of lentil ($LSD_{0.05}$ = 24.87)

I_0= no irrigation; I_v= irrigation at vegetative stage i.e. 25 days after sowing; I_f= irrigation at reproductive stage i.e. 50 days after sowing and I_{vf}= irrigation at both vegetative and reproductive stage

4.8.3. Combined effect of different varieties and irrigation levels

Interaction between lentil genotypes and different irrigation levels, had significant influence on seed yield (Appendix VIII and Table 8). BARI masur 6 produced seed yield (1967.17 kg ha^{-1}) under the irrigation at both vegetative and reproductive stages (V_3T_{Vf}) followed by the (1842.27 kg ha^{-1}) combination of V_3I_f (BARI masur 6 and irrigation at flowering stage). The lowest seed yield (575.47 kg ha^{-1}) was recorded from the genotype BARI masur 5 under the control irrigation treatment.

Irrigation at flowering and again at pod filling represented the traditional irrigation recommendation for dry peas grown on heavier soils (Stoker, 1979). The lower yields were associated with lower number of pods, branches per stem and pods per branches and a slower increase in pod weight (Milbourn and Hardwick, 1968). In these experiments, irrigation at any growth stage increased yield but the highest yield for cultivars were achieved where water stress was completely eliminated by irrigating up to seed filling stage where yield was significantly higher than those achieved by other irrigation treatments.

Table 7: Combined effect of different variety and irrigation levels on plant dry weight, 1000-seed weight and seed yield

Varieties	Irrigation levels	Plant dry weight (g)	1000-seed weight (g)	Seed yield (kg ha^{-1})
BARI masur 4	I_0	1.93	16.20	717.33
	Iv	3.60	20.60	1211.13
	I_f	4.07	21.11	1222.93
	Iv_f	4.53	23.87	1320.40
BARI masur 5	I_0	1.58	16.23	575.47
	Iv	3.51	22.30	1017.53
	I_f	3.60	22.25	1203.50
	Iv_f	4.33	23.17	1317.33
BARI masur 6	I_0	2.11	17.07	909.13
	Iv	3.89	23.36	1836.53
	I_f	4.04	23.23	1842.27
	Iv_f	4.80	24.33	1967.17
LSD(0.05)		**0.15**	**0.29**	**43.08**
Level of significance		*	**	**
CV (%)		**2.60**	**0.81**	**1.99**

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

4.9. Effect on stover yield

4.9.1. Effect of different varieties

Stover yield was significantly influenced by lentil varieties viz. BARI masur 4, BARI masur 5 and BARI masur 6 (Appendix IX). Among the varieties, the highest stover yield (2137.93 kg ha^{-1}) was produced by variety BARI masur 6 and the lowest stover yield (1406.83 kg ha^{-1}) was found from the variety BARI masur 4. So, the variety BARI masur 6 produced the better production of stover than that of other variety as well as the tallest or highly branched was found in that variety in this research (Fig. 13).

4.9.2. Effect of different irrigation levels

Stover yield showed significant variation due to the effect of different levels of irrigation (Appendix IX). The maximum (2362.11 kg ha^{-1}) stover yield was recorded in irrigation at both vegetative and reproductive stage (I_{Vf}) followed by (1697.84 kg ha^{-1}) the irrigation treatment of I_f (irrigation at flowering stage). The minimum yield (1062.24 kg per plot) was also recorded in I_o (no irrigation treatment) (Fig. 14).

Application of two irrigations recorded significantly higher straw yield than one irrigation which in turn gave significantly higher straw yield than no irrigation in all genotypes of the experiment. This variation results indicated that the increasing irrigation levels was more effective on soil moisture and favourable soil for more to more increase plant height as well as stover yield. The results showed that stover yield directly proportional to the application of irrigation water. It might be due to the morpho-physiological growth performance of plants that depends on optimum level of irrigation, which enhanced dry matter accumulation and finally increased overall yield performance. Similar result was reported by Pandey *et al.* (1984).

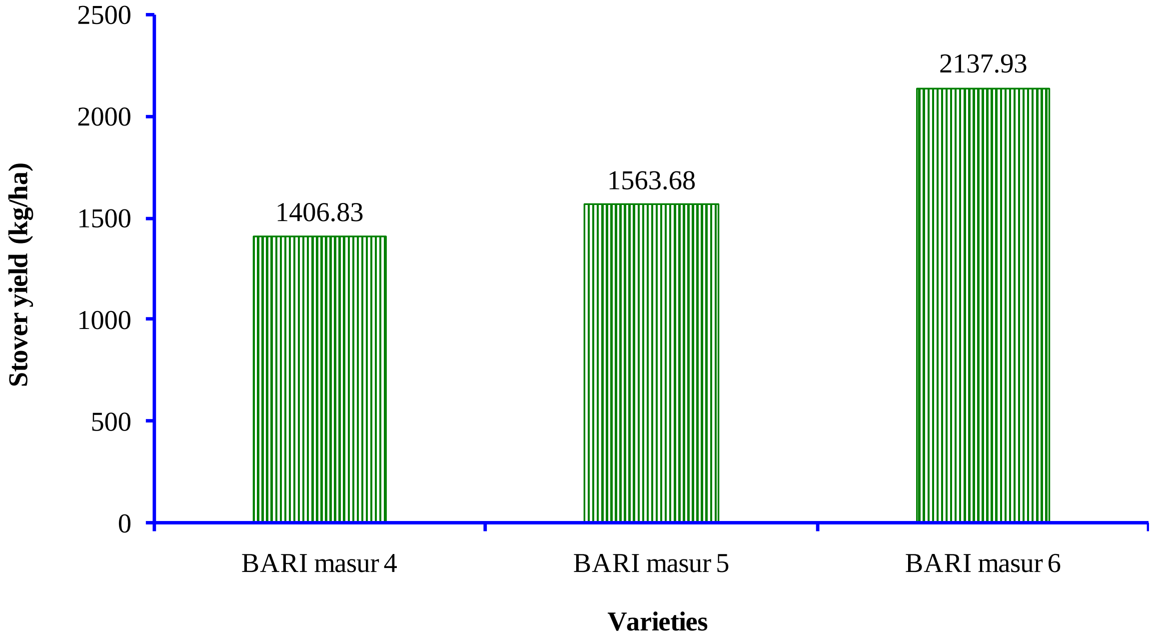

Fig. 9: Effect of variety on stover yield of lentil ($LSD_{0.05}$ = 10.17)

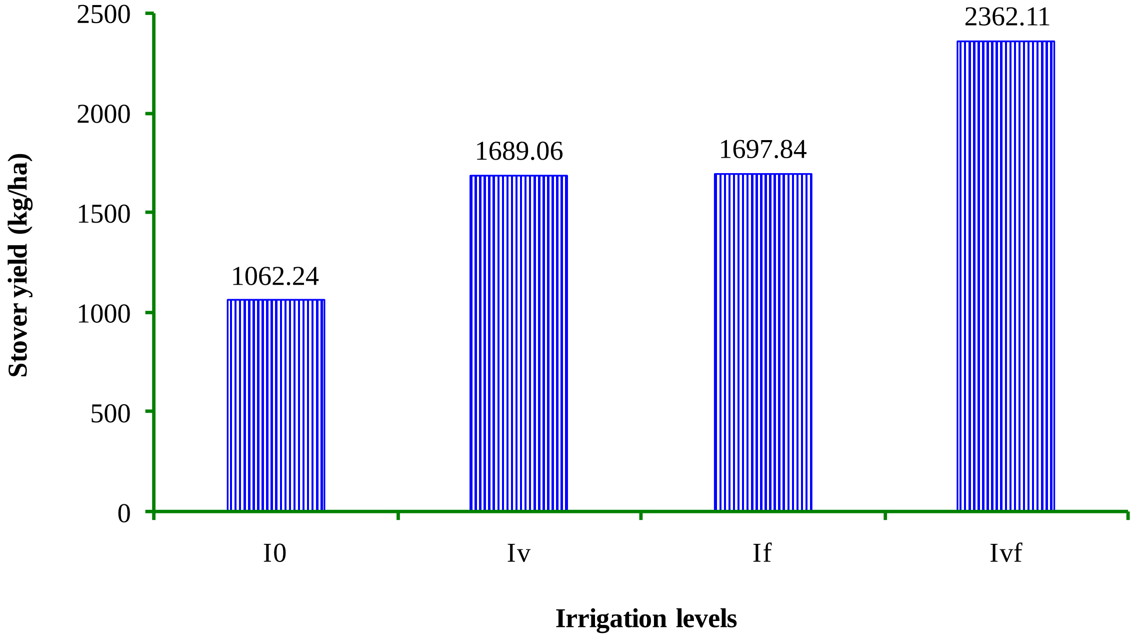

Fig. 10: Effect of irrigation levels on stover yield of lentil ($LSD_{0.05}$ = 8.832)

I_0= no irrigation; I_v= irrigation at vegetative stage i.e. 25 days after sowing; I_f= irrigation at reproductive stage i.e. 50 days after sowing and I_{vf}= irrigation at both vegetative and reproductive stage.

4.9.3. Combined effect of different varieties and irrigation levels

The combined effect of different irrigation levels and lentil varieties on stover was found significant (P<1%) (Appendix IX and Table 9). Among the treatment combinations, the variety BARI masur 4 produced the maximum stover yield (2521.83 kg ha^{-1}) under the irrigation at both vegetative and reproductive stage (V_1I_{Vf}) followed by (2500.00 kg ha^{-1}) the treatment combinations of V_3I_{Vf} (BARI masur 6 and irrigation at both vegetative and reproductive stage). Significantly the lowest stover yield (888.33 kg ha^{-1}) was observed at no irrigation treatment in BARI masur 5 (V_2I_o) (Table 9).

The increase in strover yield also may be attributed to higher plant height than more number of total branches. Similar result was also reported by Sharma (1994), Prasad (1995) and Malavia *et al*. (1988).

4.10. Effect on biological yield

4.10.1. Effect of different varieties

A significant variation was found on biological yield due to the effect of lentil genotypes (Appendix IX). The highest biological yield (3776.93 kg ha^{-1}) was observed from the variety BARI masur 6 and the lowest biological yield (2444.38 kg ha^{-1}) was recorded from the variety BARI masur 4. Variety BARI masur 6 showed the best performance on biological yield due to the tallest and highly branched plant (Fig. 15). This variation in biological yield was similar to Patil *et al.* (2003).

4.10.2. Effect of different irrigation levels

The irrigation level had a significant influence on biological yield (Appendix IX). Significantly the highest (3893.54 kg ha^{-1}) biological yield was found in irrigation at both vegetative and reproductive stage (I_{Vf}) followed by (3121.74 kg ha^{-1}) the irrigation treatment of I_f (irrigation at flowering stage. On the other hand, the lowest (1806.78 kg ha^{-1}) biological yield was found in controlled irrigation treatment (I_o). From the above results it was found that biological yield increased with the increase of irrigation level whereas no irrigation (control) showed overall average result (Fig. 16).

4.10.3. Combined effect of different varieties and irrigation levels

Biological yield of lentil was significantly influenced by the combination of variety and irrigation level (Appendix IX). The biological yield was recorded maximum (4467.13 kg ha^{-1}) from the variety BARI masur 6 under the irrigation at both vegetative and reproductive stage whereas the minimum (1497.13 kg ha^{-1}) biological yield was found in controlled irrigation treatment BARI masur 5 (V_2I_o). The second maximum (4198.30 kg ha^{-1}) biological yield was recorded from the variety BARI masur 6 under the irrigation at flowering stage (V_3I_f) (Table 9). Kumar *et al*. (2005) also reported similar results.

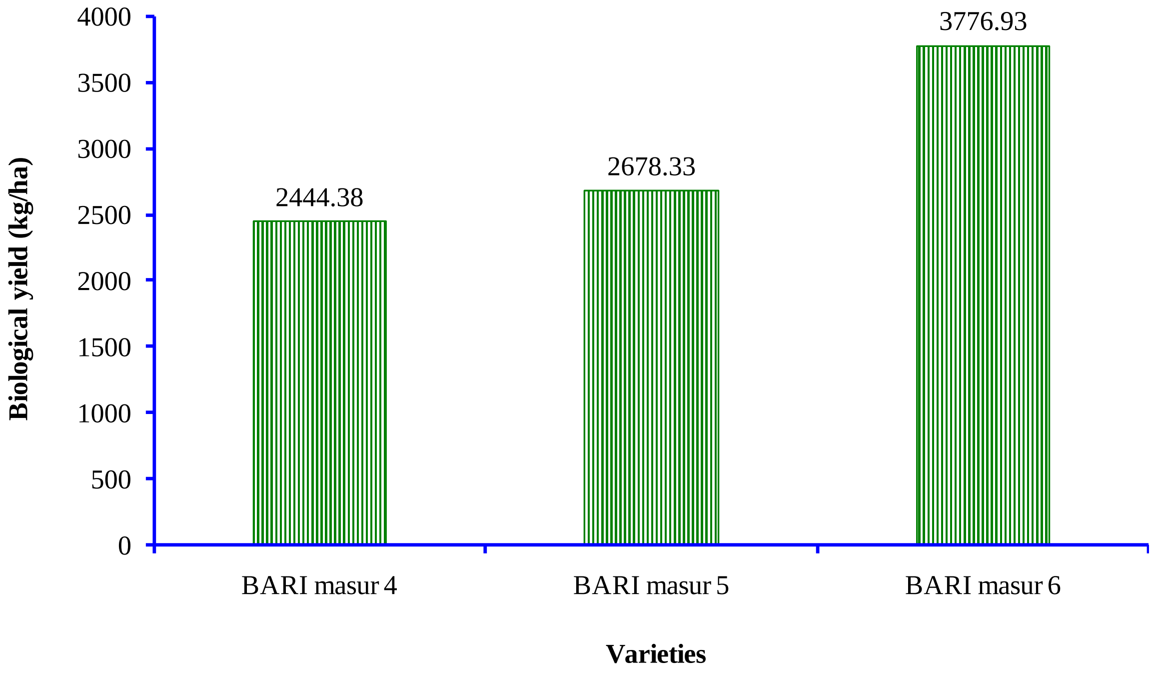

Fig. 11: Effect of variety on biological yield of lentil ($LSD_{0.05}$ = 17.62)

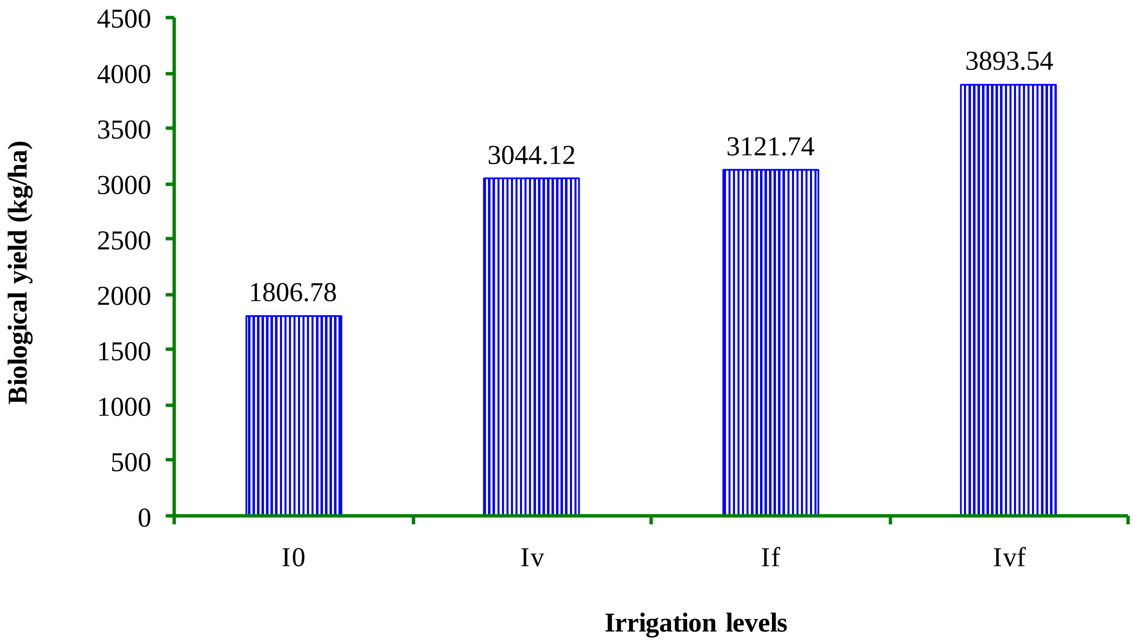

Fig. 12: Effect of irrigation levels on biological yield of lentil ($LSD_{0.05}$ = 22.18)

I_0= no irrigation; I_v= irrigation at vegetative stage i.e. 25 days after sowing; I_f= irrigation at reproductive stage i.e. 50 days after sowing and I_{vf}= irrigation at both vegetative and reproductive stage

4.11. Effect on harvest index

4.11.1. Effect of different varieties

Variety had a significant influence on harvest index (Appendix IX). Maximum harvest index (42.93%) was recorded in case of BARI masur 6 and was statistically identical to that of BARI masur 5 (42.93%) The minimum harvest index (42.56%) was recorded in BARI masur 4, which different from BARI masur 6 (Fig. 17).

4.11.2. Effect of different irrigation levels

Harvest index was significantly influenced by different irrigation level (Appendix IX and Fig.18). The highest harvest index (45.95%) was found in irrigation reproductive stage followed by (44.48%) the irrigation treatment of I_v (irrigation at vegetative stage) and it differed statistically from rest of all the treatments under the study. The lowest harvest index (39.14%) was found in treatment having irrigation at both vegetative and reproductive stage. Similar result are also obtained by Nandan (1998).

4.11.3. Combined effect of different varieties and irrigation levels

The combined effect of lentil variety and different irrigation levels showed significant variation on harvest index (Appendix IX and Table 9). Significantly the maximum harvest index (47.90%) was recorded with the variety BARI masur 5 under the irrigation at reproductive stage followed by (46.37%) the treatment combinations of V_3I_v (BARI masur 6 under irrigation at vegetative stage). In the same contrast, BARI masur 4 and BARI masur 6 showed the lowest harvest index (34.40%) under irrigation at both vegetative and reproductive stage.

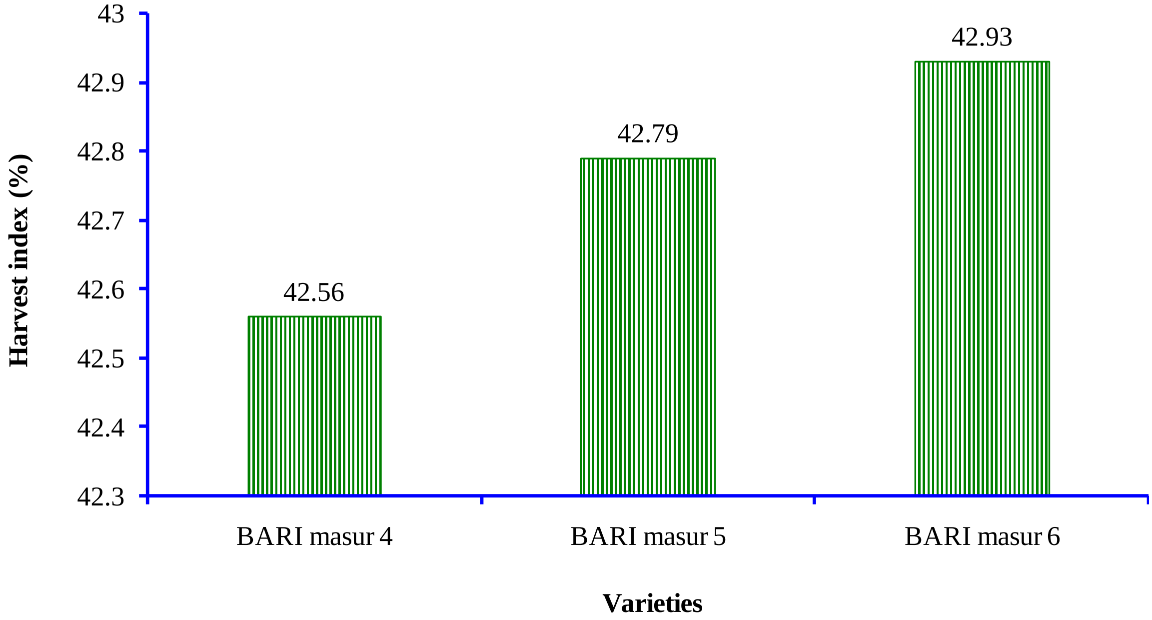

Fig. 13: Effect of variety on harvest index of lentil ($LSD_{0.05}$ = 0.3584)

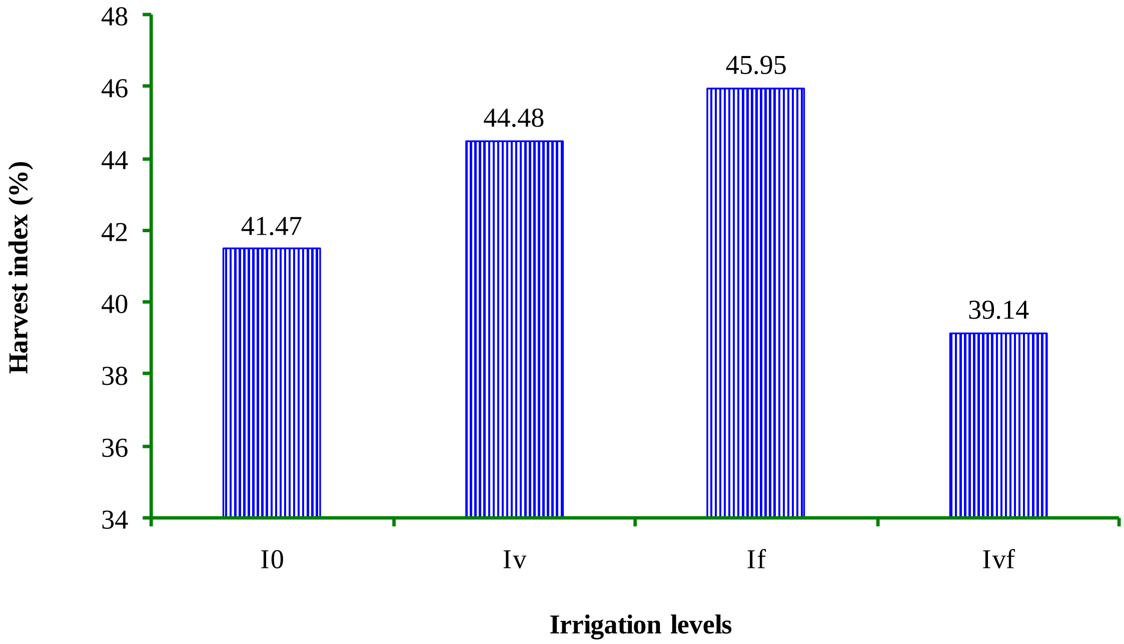

Fig. 14: Effect of irrigation levels on harvest index of lentil ($LSD_{0.05}$ = 0.3770)

I_0= no irrigation; I_v= irrigation at vegetative stage i.e. 25 days after sowing; I_f= irrigation at reproductive stage i.e. 50 days after sowing and I_{vf}= irrigation at both vegetative and reproductive stage

Table 8: Combined effect of different variety and irrigation levels on stover yield, biological yield and harvest index of

Varieties	Irrigation levels	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
BARI masur 4	I_0	900.47	1617.80	44.32
	Iv	1400.53	2611.67	46.36
	I_f	1431.90	2654.83	46.06
	Iv_f	2521.83	3829.00	34.40
BARI masur 5	I_0	888.33	1497.13	39.43
	Iv	1366.27	2383.80	42.67
	I_f	1308.60	2512.10	47.90
	Iv_f	2064.10	3384.50	39.01
BARI masur 6	I_0	1397.93	2305.40	44.32
	Iv	2300.37	4136.90	46.37
	I_f	2353.03	4198.30	46.06
	Iv_f	2500.40	4467.13	34.40
LSD(0.05)		**15.30**	**38.42**	**0.65**
Level of significance		**	**	**
CV (%)		**0.52**	**0.79**	**0.93**

**= Significant at 1% level of significance and

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment conducted at the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2010 to February, 2011 to study the growth and yield performance of lentil varieties under different levels of irrigation. The experiment was laid out in a completely randomized block design (RCBD) in two factors with three replications comprising 36 plots. There are three genotypes of BARI lentil viz. BARI masur 4, BARI masur 5 and BARI masur 6 were used as a Factor A and another Factor B was different irrigation level viz. I_0= no irrigation, I_V= irrigation at vegetative stage i.e. 25 days after sowing, I_f= irrigation at reproductive stage i.e. 50 days after irrigation and I_{Vf}= irrigation at both vegetative and reproductive stage. The study was aimed at finding out the most advantageous variety of lentil under different irrigation levels.

The main effect of variety, BARI masur 6 produced the advanced results on the whole characteristics of the study except number of leaves. BARI masur 6 produced significantly maximum plant height (23.42 cm), maximum number of branches (7.58), highest plant dry weight (3.71 g), 1000-seed yield (22.00 g), seed yield (1638.78 kg ha^{-1}), highest stover yield (2137.93 kg ha^{-1}) and highest biological yield (3776.93 kg ha^{-1}). But BARI masur 4 produced the significantly maximum number of leaflets (547.50) and highest number of pods per plant (55.00). BARI masur 5 produced non-significant effect on harvest index. BARI masur 4 produced the lowest stover yield, Biological yield and harvest index (1406.83, 2444.38 kg ha^{-1} and 42.56%), respectively.

Among the irrigation treatment levels, irrigation at both vegetative and reproductive stage i.e. 75 days after sowing perform the best on whole parameter in the present study except harvest index where non significant effect was found number of seeds per pod. The best results of plant height (23.67 cm), branches plant $^{-1}$ (7.78), leaflets plant^{-1} (600.56) , pods plant^{-1} (55.33), plant dry weight (4.55 g), 1000-seed weight (23.79 g), stover yield (2500.40 kg ha^{-1}) seed yield (1967.17 Kg ha^{-1}), and biological yield (4467.13 Kg ha^{-1}) produced by irrigation at both vegetative and reproductive stages whereas maximum harvest index (45.95%) was recorded in irrigation at flowering stage. Lowest result (20.67 cm; 6.11, 468.89, 49.00; 1.87g, 16.50 g; 733.98 kg ha^{-1}, 1062.24 kg ha^{-1}, 1806.78 kg plot^{-1}, respectively) were also found with no irrigation on plant height, number of branches, number of leaves, number of pods, plant dry weight, 1000-seed weight, seed yield, stover yield and biological yield, respectively whereas irrigation at both vegetative and reproductive stage significantly at harvest index (39.14%).

However, at harvest stage, application of four irrigations significantly enhanced with applied three BARI masur genotypes. Harvest index also showed significant variation. The greater results (24.33 cm; 8.67, 623.33, 57.67; 4.80, 24.33 g; 1967.17, 2500.40 and 4467.13 kg ha^{-1}) were observed from the cultivar BARI masur 6 under the irrigation at both vegetative and reproductive stage on plant height, number of branches, number of leaves, number of pods, plant dry weight, 1000-seed weight, seed yield, stover yield and biological yield, respectively and BARI masur 4 produced the highest (47.90%) harvest index under the irrigation at flowering stage. In contrast, the lowest results were also observed by the variety BARI masur 5 with no irrigation on morphological characters viz. plant height (19.67 cm), number of branches (5.67), number of leaflets (460.00) number of pods (45.67) seed yield (575.47 kg ha^{-1}) and biological yield (1497.13 kg plot^{-1}), and lower yield performance was observed the similar irrigation treatment with BARI masur 4 on plant dry weight (1.93 g), 1000-seed weight (16.20 g) and stover yield (888.33 kg ha^{-1}) and, respectively. BARI masur 4 and BARI masur 6 under irrigation at vegetative and flowering stage produced lowest result (34.40) on harvest index.

From the overall observation of the results of morphological and yield characters with three BARI masur genotypes under four types of irrigation levels, BARI masur 6 and irrigation at both vegetative and reproductive stage produced the greater performance to compare with another genotypes and applied treatments of irrigation. So, the BARI developed lentil variety BARI masur 6 was more effective on growth and yield of lentil under irrigation at vegetative and reproductive stage which produced better growth and maximum yield than other genotypes. Irrigation at vegetative and reproductive stage was optimum for superior perform on growth and yield. Their interaction also best combined effect for its growing and yield of lentil.

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APPENDICES

Appendix I. Average monthly rainfall, air temperature, relative humidity during the experimental period from November 2009 to February 2010 at experimental site. SAU, Dhaka

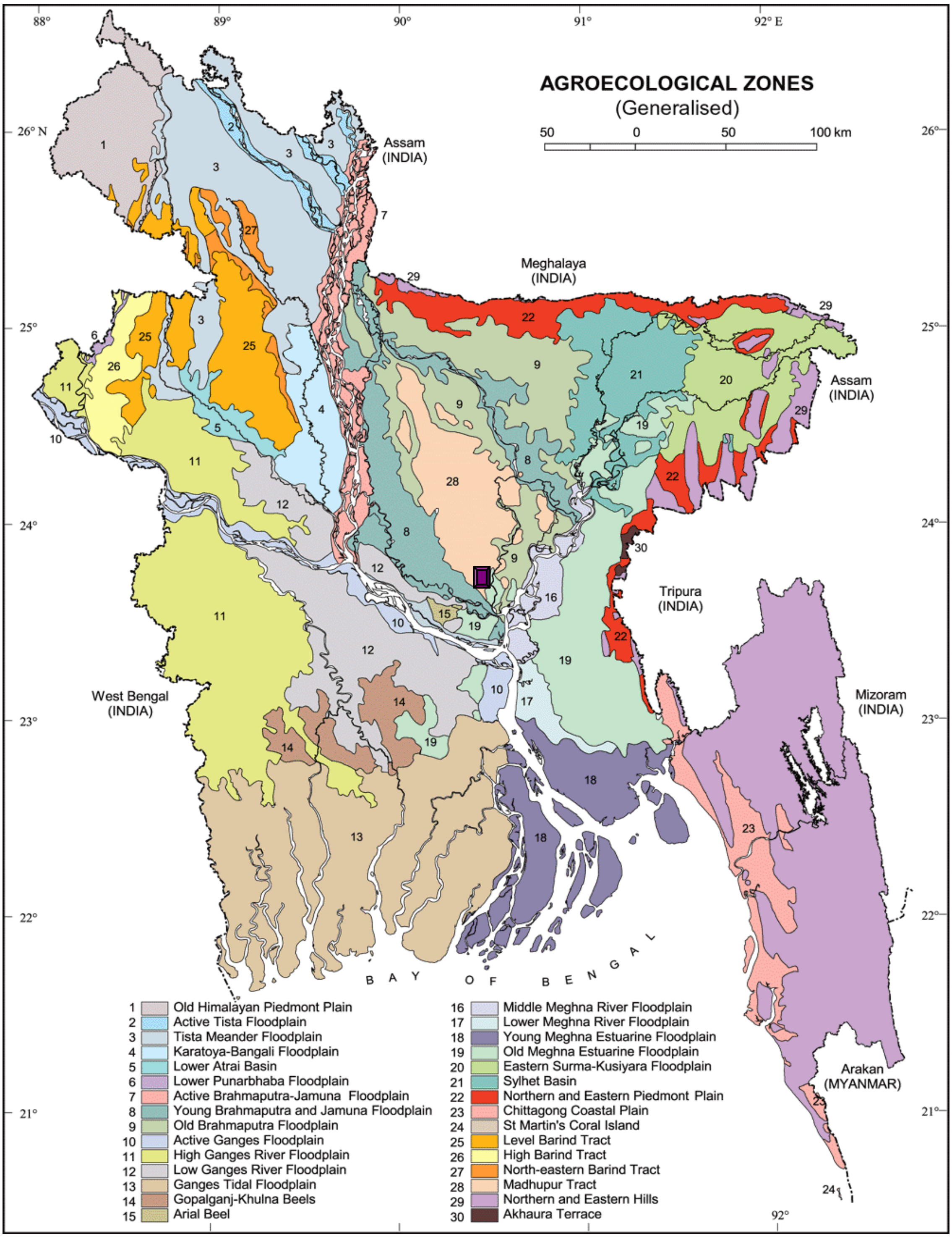
Month	Monthly average air temperature (^0C)			Average rainfall (mm)	Average relative humidity (%)
	Maximum	Minimum	Average		
November	27.00	14.81	20.91	00	72.00
December	28.50	16.40	22.45	92.2	76.75
January	30.56	22.14	26.35	96.6	78.57
February	32.80	23.34	28.05	266	82.50

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

Appendix II. Nutrient status of soil of the experimental site

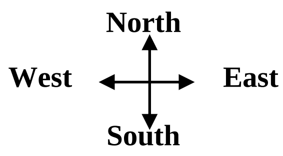
Soil properties	Content
Soil pH	5.8
Organic Carbon (OC)	1.25%
Organic matter (OM)	2.16%
Total nitrogen (N)	0.11%
Available phosphorus (P)	36.50 ppm
Available sulphur (S)	18.10 ppm

Appendix III. Map showing the experimental site under study



Appendix IV. Lay out of the experiment

$V_1I_0R_1$	$V_1I_0R_2$	$V_1I_0R_3$
$V_1I_vR_1$	$V_1I_v R_2$	$V_1I_vR_3$
$V_1I_fR_1$	$V_1I_fR_2$	$V_1I_fR_3$
$V_1I_{vf}R_1$	$V_1I_{vf}R_2$	$V_1I_{vf}R_3$
$V_2I_0R_1$	$V_2I_0R_2$	$V_2I_0R_3$
$V_2I_vR_1$	$V_2I_vR_2$	$V_2I_vR_3$
$V_2I_fR_1$	$V_2I_fR_2$	$V_2I_vR_3$
$V_2I_{vf}R_1$	$V_2I_{vf}R_2$	$V_2I_{vf}R_3$
$V_3I_0R_1$	$V_3I_0R_2$	$V_3I_0R_3$
$V_3I_vR_1$	$V_3I_vR_2$	$V_3I_vR_3$
$V_3I_fR_1$	$V_3I_fR_2$	$V_3I_fR_3$
$V_3I_{vf}R_1$	$V_3I_{vf}R_2$	$V_3I_{vf}R_3$



Legend:
Genotypes: 2 (Two); **Replication:** 3 (Three); **Length of plot:** 2.5 m and **Width of a plot:** 1.5 m
Row to row distance: 20 cm and **plant to plant distances:** 10 cm

Appendix V: Analysis of variance data (ANOVA) on plant height, branches plant^{-1} and leaves plant^{-1} of lentil

Source	Degrees of freedom	Mean square of		
		Plant height	Branches plant^{-1}	Leaflets plant^{-1}
Rep	2	2.583	0.083	1279.861
Factor A	2	7.583**	5.58399*	4496.528**
Error	4	0.042	0.417	71.528
Factor B	3	14.852**	4.37099	26156.250**
AB	6	0.435**	0.287*	468.750**
Error	18	0.185	0.231	763.194

Factor A= Variety, Factor B= Different Irrigation levels, *= Significant at 5% level of probability, **= Significant at 1% level of probability and ns= non significant

Appendix VI: Analysis of variance data (ANOVA) on pods plant^{-1} and seeds pod^{-1} of lentil

Source	Degrees of freedom	Mean square of	
		Pods plant^{-1}	Seeds pod^{-1}
Rep	2	3.694	0.333
Factor A	2	122.111**	0.000
Error	4	3.861	3.583
Factor B	3	60.778**	0.000
AB	6	5.444**	0.000
Error	18	2.694	1.389

Appendix VII: Analysis of variance data (ANOVA) on plant dry weight, 1000-seedweight and seed yield of lentil

Source	Degrees of freedom	Mean square of		
		Plant dry weight	1000-seed weight	Seed yield
Rep	2	0.005	0.104	2742.510
Factor A	2	0.622**	7.448**	1302691.526*
Error	4	0.009	0.039	817.491
Factor B	3	11.835**	91.622**	1163604.553*
AB	6	0.026*	1.163**	49134.197*
Error	18	0.008	0.029	630.655

Factor A= Variety, Factor B= Different Irrigation levels, *= Significant at 5% level of probability, **= Significant at 1% level of probability and ns= non significant

Appendix VIII: Analysis of variance data (ANOVA) on stover yield, biological yield and harvest index of lentil

Source	Degrees of freedom	Mean square of		
		Stover yield	Biological yield	Harvest index
Rep	2	90.212	2870.755	0.925
Factor A	2	1777773.958**	6074716.918**	0.414*
Error	4	80.453	241.702	0.100
Factor B	3	2535648.021**	6703479.183**	83.543**
AB	6	165008.155**	244276.156**	37.003**
Error	18	79.519	550.053	0.159

Factor A= Variety, Factor B= Different Irrigation levels and **= Significant at 1% level of probability