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EFFECT OF NUTRIPRIMING WITH ZINC AND BORON ON GROWTH AND YIELD OF LENTIL WITH IRRIGATION REGIMES IN THE LATERITIC BELT OF THE OF SUB-HUMID TROPICAL REGION

Kalipada Pramanik[1], Sananda Mondal[2*], Spurti Mondal[1] and Debasish Panda[2]

[1]Department of Agronomy, PalliSiksha Bhavana, Visva-Bharati, Sriniketan, West Bengal- 731204, India
[2]Department of Crop Physiology, PalliSiksha Bhavana, Visva-Bharati, Sriniketan West Bengal- 731204, India
*Corresponding author E-mail: sananda.mondal@visva-bharati.ac.in

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ABSTRACT

Micronutrient deficiencies resulting from unbalanced use of fertilizer application is a major bottleneck in growth and productivity of pulse crops in the lateritic belt of the subtropical region. Application of zinc and boron through seed priming not only overcome the deficiency problem but also enhance growth and yield of lentil in lateritic soil. Lentil is a moisture sensitive crop; therefore, maintaining appropriate irrigation regimes may further enhance the productivity of lentil.

The experiment was conducted in the year 2014–15 and 2015-16 in lateritic of West Bengal, India. The main plots represented irrigation regimes: irrigation at 75% CPE (I_{75}), irrigation at 100% CPE (I_{100}) and irrigation at 125% CPE (I_{125}); while subplots represented nutripriming with water, zinc sulphate heptahydrate, boric acid along and/ in combinationin a split-plot design with three replications. Dry matter accumulation, Crop Growth Rate, Leaf Area Index, branches per plant,Relative Leaf water Content, root length, root area, root volume, root diameter, Total Chlorophyll Content, Chlorophyll Stability Index, Proline Content, Grain yield, Stalk yield and Harvest Index were evaluated.

All growth parameters and production were influenced by irrigation regimes, and nutripriming with zinc and boron. The present study revealed that the combination of irrigation at 100% CPE (I_{100}) with Zn sulphate heptahydrate + boric acid (2 mM + 4 mM) priming (P_5) performed best results in respect of all parameters, which needs further studies to find climate-smart management techniques in lentil crop.

***Key words*: Boron, Chlorophyll content, Irrigation regimes, Nutriprimimg, Relative leaf water content, Root parameter, Zinc**

Introduction

Since Aceramic Neolithic times, lentils can be a part of the human diet. Lentil (*Lens culinaris*Medik. L.) is considered as one of the oldest cultivated crops; which is diploid and self-pollinated in nature (Bethapalli *et al*., 2021). In India, water-soaked lentils and/ or sprouted lentils are offered to gods in different temples. It is considered to be one of the best pulses among the all because the internal chemical structures are not altered due to cooking (Singh and Singh, 2014). It covers an area of 1.51 million ha with a production of 1.56million tons and productivity of 1032 kg ha^{-1} (Directorate of Economics and Statistics, 2020). According to Venugopalan *et al*., (2021) terminal drought and heat stress results forced maturity of the crop, with low production. According to Reddy (2009) only drought stress may reduce the seed yields of lentil upto 50% in the tropics and it suffers very badly.

In rainfed situation, the growth and yield of lentil is depending upon the precipitation's level. Optimum supply of water is essential during the growing period to achieve highest yield. According to Blum (2005) the maximum yield was obtained when the irrigation was provided in adequate level at the time of flowering and fruiting. For instance, the controlled supplementary irrigation (SI) is one of the best methods to improve and stabilize the productivity of crops. Interestingly, Hosseini *et al*., (2011) depicted that higher biomass containing lentil crop were obtained from irrigated condition in comparison to non-irrigated one. Similar results were also noted in lentil by Bhattacharya (2009), Hosseini *et al*., (2011), Khourgami *et al*., (2012) and Kahraman *et al*., (2016) stated that SI had a positive impact on growth and yield. For instance, plant height, number of branches per plant, biomass yield, harvest index and grain yield of lentil were increased significantly due to SI and irrigation at 100% CPE (I_{100}), except I_{125}. According to Kahraman *et al*., (2016) in dry land condition (I_0) lentil was the poor performer. Similarly, Soltani *et al*., (2015) depicted that during the time of reproductive phase, proper irrigation increased the yield of lentil. Present studies revealed the importance of irrigation during flowering and/ or pod-filling stage of lentil.

Micronutrients having a vital role in plants most commonly acts as a cofactor in several enzyme systems and participate in redox reactions. Moreover, micronutrients are engaged in important physiological processes in plant system i.e., photosynthesis and respiration (Marschner, 2012; Mengel *et al*., 2001) and their deficiency limiting the grain yield by hampering these vital physiological processes. According to Cakmak (2008) Zinc having a crucial role in seed germination as well as seedling establishment; and also involved in detoxification of ROS within the plant cells (Broadley *et al*., 2007; Cakmak, 2000).

Srivastava *et al*., (1997) reported that in acidic soil of some regions boron (B) may be a major causative agent for reduction of yield. The B application is essential when the B concentration in the soil is less than 0.3 mg kg^{-1} (Ahlawat *et al*., 2007). The deficiency of B can substantially reduce the yield of wheat (Rerkasem and Jamjod, 2004), chickpea (Johnson *et al.,* 2005) and lentil (Nema *et al.,* 2022).

To reduce micronutrient malnourishment from the human population, dietary diversification, supplements and fortified foods are the provable way out of individuals choice. Biofortification, improves the levels of limiting specific micronutrients within the edible tissues of plant's by combining with different approaches like crop management, breeding and molecular biology (Olson *et al*., 2021). The most prevalent method of micronutrient applications are soil and foliar applications but it is a costly affair for the farmers. Similar observation was also noted by Johnson *et al*., (2005) that foliar spray of micronutrient has been found more effective in terms of improvement of yields and grain enrichment; but high cost has restricted its adaptability, specifically by the resource-poor farmers.

Seed priming is an innovative, delicate and complex alternative option for the overall improvement of germination physiology and various parameters throughout the plant's life cycle. Seed priming, pre-activate the metabolic processes within the seeds which promotes the germination process by imbibing the seed up to a certain level (Mondal and Bose, 2021). In seed priming, the imbibition must be halted precisely at a right time or we can say it is a restricted hydration process; whereas the timeframe of priming is depending upon the species, genotype, and the types of seed and has to be dried carefully under the fan/forced air until retaining its original weight. It is of different types based on the agents used for seed priming; micronutrient priming is one of them. Priming can induce the seed germination by improving the speed and synchronization of germination; it can also improve the seedling vigor and it requires a very short span or no activation time for germination (Mondal and Bose, 2021). Nutrient seed priming' is a technique where seeds are soaked in a mineral nutrient solution along with subsequent re-drying to its initial moisture content. The ultimate aim is to improve the germination percentage, early seedling establishment and stress resistance ability, with an improved micronutrient status which pre-activates various metabolic pathways, is essential for germination during pre-imbibition time known as priming effect; as reported by Mondal and Bose (2019). In addition, seed priming is an effective as well as promising technology in this modern crop management practices which has a great impact on stress tolerance in various crop plants (Mondal *et al*., 2022).

Generally, in the developing countries the proper irrigation facility is not available and the crop production schedule is depending on rain fed condition; as a result, water scarcity is a problem at the time of seed germination and seedling establishment. According to Fischer and Turner (1978), high speed and uniform germination of seed under water deficiency is a determinant factor which affect the crop establishment. However, Ashraf and Rauf (2001) stated that during the time of germination phase, if the stress effect is removed, there will be a high chance to attain a good crop establishment.

Keeping these aspects in view and realizing the importance of the problem, an investigation was undertaken to study the "Effect of irrigation regimes and seed nutripriming on growth and yield of lentil (*Lens culinaris* L.) under lateritic belt of West Bengal"

Table 1: Physical properties of initial soil of the experimental site (mean of two years).

Particulars	Value	Methods followed
Soil textural classes	Sandy loam	
Sand	62.0	Hydrometer method
Silt	11.9	Hydrometer method
Clay	26.1	Hydrometer method
Bulk density (g cm^{-3})	1.41	Core method (Dastane, 1972)
Field capacity (% w/w)	18.92	Field method (Dastane, 1972)
Permanent wilting point (% w/w)	9.81	Sunflower method (Dastane, 1972)

Materials and Methods

Experimental design

The experiment was carried out at the Agricultural Farm, Institute of Agriculture ($23^0$39' N latitude, $87^0$42' E longitude), Visva-Bharati, Sriniketan, Birbhum, West Bengal. The Farm is located under the red and lateritic belt (Ultisols) of sub-humid tropical zone of Eastern India.

The soil of the experimental site is sandy loam in texture having bulk density (1.41 g cm^{-3}), field capacity (18.92%), and permanent wilting point (9.81%) were estimated in the laboratory at the commencement of the experiment and presented in Table 1. The soil is acidic in nature (6.18), electrical conductivity (0.21 dSm^{-1}), low in organic carbon (5.2 g kg^{-1} of soil), available nitrogen (139.7 kg ha^{-1}), available P (11.9 kg ha^{-1}), medium in available K (160.8 kg ha^{-1}), available Zn (0.483 mg kg^{-1} of soil), and available B (0.51 mg kg^{-1} of soil) were estimated in the laboratory at the commencement of the experiment and presented in Table 2.

The farm is situated under sub-humid and semi-arid tropic having a little extreme weather condition. The mean maximum and minimum temperatures during the hottest month (May) are about 42-44^{0}C while the mean monthly minimum temperature in the coldest month (January) is as low as 9.2^{0}C. The normal onset period of monsoon is in the third week of June and received an annual rainfall of about 1190 mm, of which about 80% is received during a short span of three month from mid-June to mid-September and the rest between October to May.

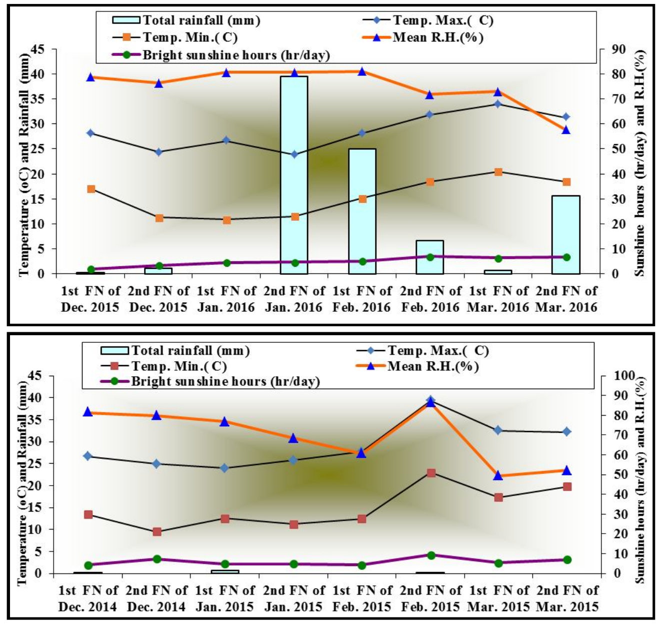

Fig. 1: Fortnightly (FN) weather parameters in both crop seasons during 2014-15 and 2015-16.

The crop received total rainfall of 11.6 mm, and 73.8 mm during the cropping period of 2014-2015, and 2015-2016, respectively. In 2015-16, crops received comparatively less rain during the crop growth period that provided stress due to scarcity soil moisture. The meteorological data of the experimental site related to the weather conditions prevailing during crop seasons (from December 2014 to March 2015 in the first year of experiment), and (from December 2015 to March 2016 in the second year of experiment) with respect to rainfall, relative humidity, sunshine hours, and temperature obtained from the agro-meteorological advisory services (Sriniketan Meteorological Station, Government of India) is presented in Fig. 1.

Experimental treatments

The experiment was carried out for two consecutive years (2014-15 and 2015-16) in rabi season. The research was conducted in a split-plot design consisting of fifteen treatment combinations in 3m × 5m net plot size and replicated thrice. Three irrigation regimes, i.e., "irrigation

Table 2: Initial soil fertility status of the experimental site (mean of two years).

Particulars	Value	Methods followed
pH (1:2.5 soil water suspension	6.18	Blackman's Xeromatic p^H meter method, (Jackson, 1973)
Electrical conductivity(dS m^{-1}) at 25°C	0.21	1:2 soil: water suspension with conductivity meter (Jackson,1973)
Organic carbon (%)	0.52	Walkley and Black's rapid titration method (Piper, 1966)
Available N (kg ha^{-1})	139.7	Alkali permanganate method, (Subbiah and Asijia, 1956)
Available P (kg ha^{-1})	11.9	Bray and Kurtz method (Bray and Kurtz, 1945)
Available K (kg ha^{1})	160.8	0.1 N Ammonium acetate extractable K method (Jackson, 1973)
Available Zn (ppm)	0.483	DTPA extraction (Lindsay and Norvell, 1978)
Available B (ppm)	0.009	

at 75% CPE (I_{75})", "irrigation at 100% CPE (I_{100})", and "irrigation at 125% CPE (I_{125})" were arranged in main plots, and five nutripriming i.e., "control (P_1; without seed priming)", "hydropriming (P_2)", "zinc sulphate heptahydrate (2mM) priming (P_3)", "boric acid (4 mM) priming (P_4)", and "zinc sulphate heptahydrate + boric acid (2 mM + 4 mM) priming (P_5)" were taken as subplot treatments.

Irrigation regimes

Irrigation at 100% CPE (I_{100}): Irrigation at 100 % CPE means quantity of irrigation water to replenish the equivalent amount of evaporated water (measured from USWB Open Pan Class A evaporimeter) from the field and irrigation time decided upon visible symptom of rice plant (initiation of tip rolling of first top leaves) as described by Parthasarathi *et al*., (2012).

Irrigation at 75 % CPE: Irrigation at 75 % CPE means 75 per cent of I_{100}

Irrigation at 125 % CPE: Irrigation at 125 % CPE means 125 per cent of I_{100}

Measurement of irrigation water

The volume of irrigation water in each plot was calculated by multiplying the USWB Open Pan Class A evaporimeter reading and pan co-efficient (0.8) and area of the plot. The irrigation water was measured through 90^0 V-notch weirs set up in the pucca channel of the experimental field. The rate of discharge was calculated as per the formula given below:

$$Q=0.0138 \times H^{5/2}$$

Where,

Q is the rate of discharge (litre per second) and

H is the head of the crest (cm).

The time of irrigation for every plot was computed by using given depth of irrigation, area of the plot and discharge rate. It was calculated by the formula given below:

$$T = A \times \frac{D}{Q}$$

Where,

Q is the rate of discharge (litre per second),

A is the area of the plot (m^2),

D is the CPE value (mm) and

T is the time of irrigation (sec or min).

Nutripriming

Healthy and bold lentil seeds (cv. HUL 57) were surface sterilized by keeping them in 0.1% $HgCl_2$ (Mercuric chloride) solution for 5 minutes and then thoroughly washed with distilled water for 5-6 times. For nutripriming, seed weight to solution volume ratio was 1:1.5 (w/v). At first seeds were soaked in respective solutions or water for 12 h at a temperature of 25±2°C. Thereafter, the seeds were taken out of the beaker and washed once with distilled water. Afterwards, primed seeds were allowed to dry back to their original moisture content under the shade for one day and in the sun for two days.

Control (P_1; without seed priming), Hydropriming (P_2), Zinc sulphate heptahydrate (2mM) priming (P_3), Boric acid (4 mM) priming (P_4),Zinc sulphate heptahydrate + boric acid (2 mM + 4 mM) priming (P_5).

Procedures of experiment

The experiment was conducted on medium upland immediately after the harvest of the previous crop soybean. The land was ploughed thoroughly with soil turning plough. The layout of the experiment was made immediately after final land preparation to minimize the loss of moisture from the surface soil before sowing. Primed seeds were treated with Thiram 75% WP @ 2 g kg^{-1} of seed to prevent fungal diseases. Seeds were also inoculated properly with the culture of *Rhizobium leguminosarium*. For seed inoculation ten per cent cold sugar solution was prepared by boiling and then cooled. The inoculated seed was air-dried in shade and then used for sowing. The variety HUL 57 of lentil crop was sown on 3 December 2014 and 1 December 2015. The sowing was performed by the drilling method with spacing of 20 cm × 10 cm.

Measurements and analytical procedures

Growth attributes

Leaving the first row from the border of each side of an experimental plot, destructive samples were taken from the second row to record biometric observations, such as dry matter accumulation, crop growth rate, and leaf area index (LAI). Ten plants were selected randomly from the area marked for the purpose of dry matter estimation. Plants were cut from the collar root at 30, 60, 90 and 120 days after sowing. Samples were sun-dried for two days and finally oven-dried at 70°C for 48 hours for estimation of dry matter accumulation in different growing stage (Perry and Compton, 1977). Crop growth rate (CGR) during the period of 30-60, 60-90, and 90-120 DAS were determined by the method was suggested by Watson (1956) with the following equation (1).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{p} \text{ (g m}^{-2}\text{ day}^{-1}) \quad ...(1)$$

Where,

(g/m^{-2}/day); W_1 and W_2 are whole plant dry weight at time t_1 and t_2 respectively. p is the ground area on which W_1 and W_2 were recorded.

For leaf area determination, the representative green leaves were taken randomly from destructive samples, and their areas were recorded by leaf area meter. The destructive samples were dried in a hot air oven at 80^0C for 10 h until constant weights were obtained as per the standard procedure. The recorded dry weights of green leaves were used to calculate leaf area index. The ratio of the recorded leaf area and dry weight of these green leaves was used to measure the leaf area indices, since LAI is the area of leaf surface per unit of the land surface.

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}} \qquad ...(2)$$

The ten plants selected for recording height were used for counting the number of branches. The branches were counted and average number of branches plant^{-1} of each plot was recorded.

Study of root parameters

The PVC tubes of 10 cm-wide and 30-cm-long were filled with soil and placed in the holes made in each plot (Plate 1). Lentil plants were gown in each PVC tube. The PVC tubes with plant and soil were dig out from each plot at flower initiation stage and kept for soaking in water for 24 hours. Root washing protocol was followed in which roots were separated from soil by flotation based on the “Goetingen method”. A root scanner and image analysis program (WinRhizo, Regent Instruments, Quebec, Canada) was used for determining root length, root volume, root surface area and root diameter.

Physiological parameters

Dry matter accumulation (g plant^{-1})

Five plants were cut at ground level from each plot kept for destructive sampling at 30, 60, 90 and 120 DAS and used to determine the dry matter accumulation. The green leaves, stem and pods were separated from these plants of each plot and kept in labeled paper packets for drying in a hot air oven at 80^0C for 48 hours till constant weight were obtained. The dry weighs of leaves, stems, and pods were recorded with the help of an electric balance and used for determination of dry matter accumulation.

Plate 1: PVC pipe in the field for root study.

Relative leaf water content (RLWC)

For estimation of relative leaf water content, fresh and greenish leaves were collected from the mid-section of branches, to minimize age effects. Individual leaves were collected, and to recut the leaf base by a sharp razor blade. Immediately weight was taken and each sample was above the minimum 0.5 g (Clausen and Kozlowski, 1965) in an analytical scale, with precision of 0.0001 g. To obtain the turgid weight, leaves were kept in distilled water inside a closed petri dish for 4 hours. The weights of turgid leaf materials were taken after carefully removing water from leaf surface with tissue paper. Subsequently these leaf materials were kept in butter paper bags and pre-heated oven (Catsky, 1974a; Turner, 1981), at 80^oC, for 48 hours, to obtain the dry weight. The relative leaf water content (RLWC) was estimated using the formula given by Turner (1986).

$$\text{RLWC} = \frac{FW - DW}{TW - DW} \times 100$$

Where,

FW is leaf fresh weight,

DW is leaf dry weight and

TW is leaf turgid weight

Chlorophyll estimation

The total chlorophyll content was measured adopting the method of Hiscox and Israelstam (1979), by using dimethyl sulfoxide (DMSO). The absorbance of the solution was read at 663nm for chlorophyll a and 645nm for chlorophyll b using spectrophotometer against the DMSO blank. Total chlorophyll content was determined by using the formula given by Arnon (1949) and expressed as mg g^{-1} of fresh leaf.

$$\text{Chlorophyll a} = [12.7(D_{663})\text{-}2.69(D_{645})] \times \frac{V}{(1000 \times w)}$$

$$\text{Chlorophyll b} = [22.9(D_{645})\text{-}4.68(D_{663})] \times \frac{V}{(1000 \times w)}$$

$$\text{Total Chlorophyll II} = [20.2(D_{645}) + 8.02(D_{663})] \times \frac{V}{(1000 \times w)}$$

Where,

Table 3: Effect of irrigation regime and nutripriming on dry matter accumulation of lentil at different growth stages.

Treatments	Dry Matter Accumulation (g m^{-2})							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2014-2015	2015-2016	2014-2015	2015-2016	2014-2015	2015-2016	2014-2015	2015-2016
Irrigation Regimes								
I_{75}	18.1	19.9	112.9	124.1	213.4	221.8	228.5	246.7
I_{100}	20.1	21.2	116.6	128.0	252.3	252.9	272.0	285.4
I_{125}	17.8	19.6	112.9	126.6	194.0	211.9	213.6	233.9
SEm(±)	0.61	0.56	2.45	2.72	5.09	4.57	5.16	4.64
CD at 5%	NS	NS	NS	NS	20.0	17.9	20.2	18.2
CV (%)	10.1	8.9	8.3	8.3	9.0	7.7	8.4	7.0
Nutripriming								
P_1	15.8	17.8	100.1	102.8	140.9	150.1	157.8	181.7
P_2	16.3	18.1	108.0	122.0	204.5	219.3	224.2	243.6
P_3	18.5	21.1	119.5	132.1	241.6	235.8	256.6	268.8
P_4	18.1	20.2	114.8	129.4	233.2	247.9	244.4	272.6
P_5	24.4	24.1	126.9	145.0	279.4	291.3	307.1	309.9
SEm(±)	0.57	0.45	2.70	3.38	4.70	4.49	4.83	5.00
CD at 5%	1.67	1.32	7.8	9.87	13.7	13.1	14.1	14.6
CV (%)	9.2	6.7	7.1	8.0	6.4	5.9	6.1	5.9

I = Irrigation level; I_1=75% of CPE; I_2=100% of CPE; I_3= 125% of CPE; P = Nutripriming; P_1=No priming; P_2=Hydropriming; P_3=Zinc sulphate heptahyrate; P_4= Boric acid; P_5=Zinc sulphate heptahyrate + Boric acid

D = Absorbance,

V = Final volume of DMSO (ml) and

W = Weight of fresh leaf (g)

Chlorophyll Stability Index (CSI)

In Chlorophyll stability index, two series of leaf samples (250 mg each) were put in two testtube series containing 10 mL of distilled water. One of the test tubes was placed in a water bath and heated at 65°C for 30 minutes while the other was kept in room temperature, as a control. Then, total chlorophyll content was estimated using a spectrophotometer at 652 nm (Koleyoreas, 1958). CSI was calculated using the following formula:

$$\text{CSI (\%)} = \frac{Total\ chlorophyll\ content\ (heated)}{Total\ chlorophyll\ content\ (control)} \times 100$$

Proline Content

Proline content was estimated in dry leaves sample (100 mg from each treatment) by using the method of Bates *et al.*, (1973).

Yield

The grain yield obtained from each treatment in the net plot area was sundried, threshed, winnowed, and cleaned. After that, the weight of the grains per net plot was recorded at 14% moisture with the help of electronic balance. Each treatment's grain yield per hectare was calculated from the net plot yield and expressed in kg ha^{-1}.

The net plots (leaving two border rows on each side and 50 cm from each side of the length) were harvested at the time of maturity, and sun-dried for four days in the ûeld and then the total biomass yield (stalk yield) was recorded. Harvest index was calculated as per the formula given by Donald (1962) and expressed in percentage.

Calculations and statistical analysis

The experimental data obtained from lentil crop for two consecutive years of study were analyzed statistically by using the F-test (Gomez and Gomez, 1984). The standard error of means (SEm±) and the critical difference at a 5% probability level of significance (CD, $p < 0.05$). Excel software (Microsoft Office Home and Student version 2019-en-us, Microsoft Inc., Redmond, Washington, DC, (USA) was used for statistical analysis and drawing graphs and figures.

Results

Growth Parameters

Dry Matter Accumulation (gm^{-2})

The data on dry matter accumulation of shoot recorded 30, 60, 90 and 120 days after sowing (DAS), were analysed statistically and presented in the Table 3. Dry matter accumulation increased gradually towards maturity of the crop irrespective of irrigation regimes and nutripriming treatments during 2014-2015 and 2015-2016. The dry matter accumulation at the above growth stages i.e., 90 and 120 DAS was recorded maximum at irrigation regime of 100% CPE (I_{100}) (252.3 & 252.9 at 90 DAS and 272.0 & 285.4 at 120DAS in 2014-15 and 2015-16)

Table 4: Effect of irrigation regime and nutripriming on Crop Growth Rate of lentil at different growth stages.

Treatments	Crop Growth Rate (g/m²/day)					
	30-60 DAS		60-90 DAS		90-120 DAS	
	14-15	15-16	14-15	15-16	14-15	15-16
Irrigation Regimes						
I_{75}	3.16	3.47	3.35	3.25	0.50	0.83
I_{100}	3.22	3.56	4.53	4.16	0.65	1.08
I_{125}	3.17	3.57	2.70	2.84	0.65	0.73
SEm(±)	0.07	0.08	0.13	0.12	0.05	0.06
CD at 5%	NS	NS	0.52	0.47	0.19	0.22
CV (%)	8.7	9.3	14.5	13.7	30.6	24.3
Nutripriming						
P_1	2.85	2.83	1.32	1.58	0.56	1.05
P_2	3.06	3.46	3.21	3.24	0.66	0.81
P_3	3.36	3.70	4.07	3.46	0.50	1.10
P_4	3.22	3.64	3.95	3.95	0.38	0.82
P_5	3.42	4.03	5.08	4.88	0.92	0.62
SEm(±)	0.09	0.11	0.19	0.15	0.12	0.19
CD at 5%	0.27	0.32	0.56	0.44	0.36	0.55
CV (%)	8.7	9.4	16.3	13.1	60.9	63.5

I = Irrigation level; I_1=75% of CPE; I_2=100% of CPE; I_3= 125% of CPE; P = Nutripriming; P_1=No priming; P_2=Hydropriming; P_3=Zinc sulphate heptahyrate; P_4= Boric acid; P_5=Zinc sulphate heptahyrate + Boric acid

and it showed statistically significant value over the other treatments. However, the dry matter accumulation at early growth stages (30 and 60 DAS) of lentil did not differ significantly among the different irrigation regimes in either of the two years of study.The combined application of zinc sulphate + boric acid as priming agent (P_5) exhibited maximum dry matter accumulation among different nutripriming treatments i.e., 279.4 & 291.3 at 90 DAS and 307.1 & 309.9 at 120 DAS in 2014-15 and 2015-16 respectively. However, zinc sulphate (P_3) and boric acid (P_4) priming individually recorded significantly higher dry matter accumulation over that of hydro priming (P_2) and control (P_1) treatments in both the study years.

Crop growth rate (CGR) ($gm^{-2}day^{-1}$)

The data revealed in Table 4 observed that the irrigation regimes significantly influenced the CGR (g m^{-2} d^{-1}) in lentil variety "HUL 57" in both the consecutive years at 60-90 DAS. The treatment 100% CPE (I_{100}) recorded a significantly greater CGR (4.53 & 4.16 at 60-70 DAS in 2014-15 and 2015-16 respectively) than 75% CPE (I_{75}), and 125% CPE (I_{125}) irrigation regimes at 60-90 DAS. Among the nutripriming treatments, P_5 resulted significantly highest CGR over other treatments at 60-90 DAS and the values were 5.08 & 4.88 in 2014-15 and 2015-16 respectively followed by P3 & P4 in the same time span. In this regards control (P_1) showed poor performance.

Leaf Area Index (LAI)

Year-wise data on leaf area index (LAI) are presented in Table 5 which indicate that irrigation regimes and nutripriming significantly influenced leaf area index

Table 5: Effect of irrigation regime and nutripriming on Leaf Area Index (LAI) of lentil at different growth stages and branches plant^{-1} at 120 DAS.

Treatments	Dry Matter Accumulation (g m^{-2})								Branches plant^{-1}	
	45 DAS		60 DAS		75 DAS		90 DAS		120 DAS	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Irrigation Regimes										
I_{75}	0.28	0.38	0.81	0.92	1.04	1.10	0.65	0.72	5.3	7.0
I_{100}	0.32	0.40	0.83	0.91	1.17	1.25	0.78	1.05	6.4	7.6
I_{125}	0.30	0.38	0.82	0.90	0.99	1.03	0.62	0.82	4.9	6.9
SEm(±)	0.012	0.014	0.020	0.022	0.022	0.022	0.013	0.030	0.2	0.1
CD at 5%	NS	NS	NS	NS	0.08	0.08	0.05	0.12	0.9	0.5
CV (%)	15.9	14.2	9.5	9.2	7.9	7.4	7.2	13.5	15.3	6.4
Nutripriming										
P_1	0.24	0.34	0.66	0.76	0.83	0.89	0.40	0.58	5.0	5.7
P_2	0.29	0.38	0.80	0.90	1.07	1.13	0.71	0.88	5.5	6.4
P_3	0.30	0.39	0.86	0.93	1.09	1.15	0.74	0.90	5.8	7.8
P_4	0.30	0.38	0.84	0.93	1.10	1.16	0.73	0.90	5.4	7.1
P_5	0.36	0.43	0.94	1.04	1.22	1.28	0.86	1.05	6.1	8.9
SEm(±)	0.011	0.011	0.022	0.022	0.024	0.024	0.023	0.024	0.20	0.1
CD at 5%	0.03	0.03	0.06	0.06	0.07	0.07	0.07	0.07	0.6	0.4
CV (%)	10.6	8.6	8.0	7.2	6.9	6.5	9.9	8.2	10.9	5.3

I = Irrigation level; I_1=75% of CPE; I_2=100% of CPE; I_3= 125% of CPE; P = Nutripriming; P_1=No priming; P_2=Hydropriming; P_3=Zinc sulphate heptahyrate; P_4= Boric acid; P_5=Zinc sulphate heptahyrate + Boric acid

Table 6: Effect of irrigation regime and nutripriming on Relative Leaf Water Content of lentil at different growth stages.

Treatments	Relative Leaf Water Content					
	45 DAS		65 DAS		90 DAS	
	14-15	15-16	14-15	15-16	14-15	15-16
Irrigation Regimes						
I_{75}	78.7	78.2	69.2	67.4	52.8	49.8
I_{100}	83.7	82.0	72.8	71.8	57.0	54.1
I_{125}	85.7	83.7	73.8	73.2	58.8	57.9
SEm(±)	0.75	0.78	0.60	0.93	1.01	0.92
CD at 5%	2.95	3.06	2.36	3.64	3.97	3.60
CV (%)	3.5	3.7	3.2	5.1	7.0	6.6
Nutripriming						
P_1	79.6	76.0	64.3	63.2	49.0	47.6
P_2	81.1	79.7	70.5	68.2	53.0	51.4
P_3	84.4	84.6	75.1	73.2	59.4	56.2
P_4	81.9	80.2	71.2	71.4	55.3	52.3
P_5	86.7	86.2	78.6	77.9	64.2	62.2
SEm(±)	0.88	0.96	1.19	1.09	1.13	0.84
CD at 5%	2.57	2.81	3.47	3.19	3.28	2.45
CV (%)	3.2	3.5	5.0	4.6	6.0	4.7

I = Irrigation level; I_1=75% of CPE; I_2=100% of CPE; I_3= 125% of CPE; P = Nutripriming; P_1=No priming; P_2=Hydropriming; P_3=Zinc sulphate heptahyrate; P_4= Boric acid; P_5=Zinc sulphate heptahyrate + Boric acid

of "HUL 57" lentil crop. In Table 5, among the different irrigation regimes, 100% CPE (I_{100}) showed significant results over other two irrigation regimes in leaf area index at 75, and 90 DAS 1.17 & 1.25 at 75 DAS and 0.78 & 1,05 at 90 DAS in both the study years respectively; but all the irrigation regime's treatments showed statistically at par values at 45, and 60 DAS in both the years. In nutripriming, a similar trend was noted in both the years as represented in Table 5. Treatment P_5noted higher values of LAI (0.36 & 0.43 at 45 DAS, 0.94 & 1.04 at 60 DAS, 1.22 & 1.28 at 75 DAS and 0.86 & 1.05 at 90 DAS respectively) over other treatments but they are statistically at par and exhibited a significantly higher LAI over control one (P_1) at every durationin both the years.

Number of branches plant^{-1}

The data presented in Table 5, the number of primary branches plant^{-1} revealed that the treatment 100% CPE (I_{100}) produced maximum number of branches i.e., 6.4 & 7.6 at 120 DAS than 75% (I_{75}), and 125% (I_{125}) CPE of irrigation regimes in both years.

In case of nutripriming, control (P_1) showed significantly lower number of branches over other treatments under study. Whereas, treatment P_5(6.1 & 8.9 at 120 DAS) reported maximum number branches plant^{-1} than that of all other nutripriming treatments. Moreover, zinc sulphate (P_3) primed seed revealed higher number of branches over boric acid (P_4) and hydro priming (P_2) in both years which is statistically significant.

Relative leaf water content

The observations on relative leaf water content (RLWC) recorded at 45, 65 and 90 DAS were analysed statistically and presented in the Table 6. The table depicted that gradual decrease of RLWC was observed due to advancement of age of the crop.

Table 7: Effect of irrigation regimes and nutripriming on root parameters of lentil.

Treatments	Root Length (cm) plant^{-1}		Diameter (cm)		Area(cm^2) plant^{-1}		Volume (cm^3) plant^{-1}	
	2014-2015	2015-2016	2014-2015	2015-2016	2014-2015	2015-2016	2014-2015	2015-2016
Irrigation Regimes								
I_{75}	597.7	658.5	0.47	0.47	99.0	111.7	1.21	1.35
I_{100}	608.6	668.3	0.46	0.46	114.6	124.8	1.35	1.49
I_{125}	593.7	651.0	0.47	0.47	111.4	122.2	1.31	1.45
SEm(±)	26.3	18.1	0.01	0.01	3.8	3.3	0.04	0.04
CD at 5%	NS	NS	NS	NS	14.9	12.8	NS	NS
CV (%)	17.0	10.7	11.23	10.91	13.5	10.6	13.32	11.65
Nutripriming								
P_1	555.9	611.5	0.45	0.46	97.1	106.3	1.16	1.28
P_2	585.1	641.4	0.47	0.47	100.1	110.1	1.20	1.33
P_3	620.9	674.6	0.49	0.48	115.7	129.0	1.38	1.52
P_4	595.1	656.2	0.46	0.47	102.9	113.8	1.24	1.37
P_5	643.0	712.5	0.45	0.46	125.9	138.8	1.48	1.65
SEm(±)	19.3	17.8	0.01	0.01	4.2	3.2	0.05	0.05
CD at 5%	56.5	51.8	0.04	0.04	12.2	9.4	0.13	0.14
CV (%)	9.7	8.1	8.17	8.36	11.6	8.1	10.62	10.19

I = Irrigation level; I_1=75% of CPE; I_2=100% of CPE; I_3= 125% of CPE; P = Nutripriming; P_1=No priming; P_2=Hydropriming; P_3=Zinc sulphate heptahyrate; P_4= Boric acid; P_5=Zinc sulphate heptahyrate + Boric acid

Table 8: Effect of irrigation regimes and nutripriming on Total Chlorophyll Content in lentil leaf at different growth stages.

Treatments	Total Chlorophyll content (mg g^{-1})					
	45 DAS		65 DAS		90 DAS	
	14-15	15-16	14-15	15-16	14-15	15-16
Irrigation Regimes						
I_{75}	2.72	2.97	4.09	4.28	1.63	1.77
I_{100}	2.79	3.07	4.36	4.51	1.92	2.18
I_{125}	2.75	2.93	4.19	4.49	1.41	1.47
SEm(±)	0.09	0.09	0.17	0.11	0.06	0.05
CD at 5%	NS	NS	NS	NS	0.22	0.21
CV (%)	12.8	11.4	15.7	10.0	13.0	11.6
Nutripriming						
P_1	2.59	2.73	2.78	3.02	1.19	1.34
P_2	2.69	2.86	3.70	3.97	1.49	1.64
P_3	2.86	3.10	4.63	4.73	1.68	1.82
P_4	2.68	2.88	4.53	4.80	1.71	1.86
P_5	2.95	3.37	5.41	5.60	2.20	2.36
SEm(±)	0.05	0.07	0.13	0.12	0.05	0.06
CD at 5%	0.15	0.20	0.37	0.35	0.16	0.17
CV (%)	5.7	6.9	8.9	8.1	9.8	9.9

I = Irrigation level; I_1=75% of CPE; I_2=100% of CPE; I_3= 125% of CPE; P = Nutripriming; P_1=No priming; P_2=Hydropriming; P_3=Zinc sulphate heptahyrate; P_4= Boric acid; P_5=Zinc sulphate heptahyrate + Boric acid

Table 9: Effect of irrigation regime and nutripriming on Chlorophyll Stability Index and Proline Content in lentil 90 days after sowing.

Treatments	Chlorophyll stability index (%)		Proline Content (mg g^{-1} of fresh leaf)	
	2014-15	2015-16	2014-15	2015-16
Irrigation Regimes				
I_{75}	39.5	40.0	0.423	0.410
I_{100}	51.9	53.0	0.193	0.203
I_{125}	34.8	35.6	0.320	0.303
SEm(±)	1.26	0.94	0.004	0.005
CD at 5%	4.96	3.69	0.014	0.019
CV (%)	11.64	8.49	4.53	6.05
Nutri priming				
P_1	35.7	37.2	0.133	0.140
P_2	38.2	38.9	0.213	0.233
P_3	45.3	45.9	0.350	0.347
P_4	42.9	43.3	0.353	0.347
P_5	48.3	49.1	0.511	0.460
SEm(±)	0.95	0.96	0.005	0.006
CD at 5%	2.78	2.81	0.013	0.018
CV (%)	6.80	6.75	4.35	6.01

I = Irrigation level; I_1=75% of CPE; I_2=100% of CPE; I_3= 125% of CPE; P = Nutripriming; P_1=No priming; P_2=Hydropriming; P_3=Zinc sulphate heptahyrate; P_4= Boric acid; P_5=Zinc sulphate heptahyrate + Boric acid

Crop receiving irrigation at 125% CPE (I_{125}) recorded the maximum RLWC, which was closely followed by the crop having irrigation at 100% CPE (I_{100}) at all the growth stages during the two years. The above two treatments showed statistically at par results at any of the growth stages during the two years but both the treatments recorded significantly higher RLWC than that of irrigation at 75% CPE (I_{75}) under the study.

The RLWC varied significantly due to nutripriming lentil seeds under the study. The maximum RLWC was recorded in crop with zinc sulphate + boric acid priming (P_5) treatment (86.7 & 86.2 at 45 DAS, 78.6 & 77.9 at 65 DAS, 64.2 & 62.2 DAS respectively) and it was significantly higher than that of all other nutripriming treatments at all the stages during both the years except at 45 DAS stage, when thedifference in RLWC betweenzinc sulphate + boric acid priming (P_5) and only zinc sulphate priming (P_3) was not significant in either of the two years (Table 6). The control (P_1) recorded the lowest values of RLWC at all the growth stages under the study.

Root length and root diameter

The scrutiny of two-year data for root length and root diameter in lentil demonstrated that irrigation regime did not cause much effect on total root length and root diameter of lentil in either of the two years of study. However, irrigation at 100% CPE (I_{100}) had a tendency of increasing total root length under the study. The maximum root length was observed in treatment P_5, and the minimum was observed in control P_1 (Table 7).

Root area and root volume

The results depicted that maximum root area plant^{-1} of lentil was observed at 100% CPE (I_{100}) (114.6 & 124.8 cm^2 plant^{-1}) at 90 DAS, but showed statistically at par value with 125% (I_{125}) CPE during both the years. Whereas, the root volume showed statistically at par value for all the irrigation regimes including the control one. The maximum root areaand root volume plant^{-1} were obtained from the treatment zinc sulphate + boric acid priming (P_5) and it was closely followed by zinc sulphate priming (P_3) and both treatments significantly increased the root area plant^{-1} and root volume plant^{-1} over boric acid (P_4), hydropriming (P_2), and control (P_1) during two years of study (Table 7).

Chlorophyll content

The two yearsdata concerning the total chlorophyll content (mg g^{-1}) in the fresh leaf of lentil with irrigation regimes and nutripriming were presented in Table 8. Among the different irrigation regimes, maximum total chlorophyll content was found in treatment 100% CPE

Table 10: Effect of irrigation regimes and nutripriming on Grain and Stalk Yield and Harvest Index of lentil.

Treatments	Grain yield (kg ha^{-1})			Stalk yield (kg ha^{-1})			Harvest Index (%)		
	2014-2015	2015-2016	Pooled	2014-2015	2015-2016	Pooled	2014-2015	2015-2016	Pooled
Irrigation Regimes									
I_{75}	831.2	905.1	868.1	1550	1775	1662	34.8	34.0	34.4
I_{100}	960.2	1059.5	1009.8	1757	1993	1875	35.2	34.8	35.0
I_{125}	701.0	830.0	765.3	1347	1763	1555	34.2	31.9	32.9
SEm(±)	14.70	19.34	11.9	23.3	53.3	27.6	0.4	0.62	0.40
CD at 5%	57.72	75.92	37.6	91.5	209.1	86.8	1.6	2.43	1.27
CV (%)	6.9	8.0	7.4	5.8	11.2	8.9	4.6	7.2	6.5
Nutripriming									
P_1	657.2	778.3	717.8	1255	1484	1369	34.3	34.3	34.3
P_2	730.2	850.7	790.4	1389	1702	1545	34.5	33.2	33.8
P_3	954.4	1012.2	982.9	1711	1974	1843	35.8	33.8	33.7
P_4	818.8	941.1	880.0	1640	2000	1820	33.3	32.1	33.6
P_5	993.4	1075.4	1034.4	1763	2058	1910	35.8	34.3	35.0
SEm(±)	17.51	23.02	14.5	28.0	52.3	29.6	0.2	0.85	0.43
CD at 5%	51.12	67.19	41.1	81.6	152.5	84.2	0.6	2.48	1.23
CV (%)	6.3	7.4	7.0	5.4	8.5	7.4	1.9	7.6	5.4

I = Irrigation level; I_1=75% of CPE; I_2=100% of CPE; I_3= 125% of CPE; P = Nutripriming; P_1=No priming; P_2=Hydropriming; P_3=Zinc sulphate heptahyrate; P_4= Boric acid; P_5=Zinc sulphate heptahyrate + Boric acid

(I_{100}) which was statistically significant with the treatments 75% CPE (I_{75}), and 125% CPE (I_{125}) at 90 DAS (1.92 & 2.18 mgg^{-1}) only in both the years followed by other treatments.

The nutripriming results demonstrated that the treatment P_5(2.95 & 3.37 at 45 DAS, 5.41 & 5.60 at 65 DAS, 2.20 & 2.36 at 90 DAS respectively), significantly enhanced the total chlorophyll content in lentil over the zinc sulphate (P_3), boric acid (P_4), hydro-priming (P_2), and control (P_1)based onthe data of both the years. Thus, nutripriming of zinc sulphate + boric acid (P_5) was most effective to enhance the chlorophyll content in lentil.

Chlorophyll stability index (CSI)

Table 9, noted that among the different irrigation regimes 100% CPE (I_{100}) showed significantly higher value of CSI (51.9 & 53.0%) at 90 DAS than irrigation regimes 75% CPE (I_{75}) and125% CPE (I_{125}) during 2014-15 and 2015-16. Even 75% CPE (I_{75}) exhibited significantly higher CSI over that of irrigation at 125% CPE (I_{125}) at 90 DAS during both the years.

The nutripriming treatment, P_5 showed significantly higher value (48.3 & 49.1%) of CSI than other treatments at 90 DAS during both the years. Priming of seeds with zinc sulphate (P_3) and boric acid (P_4) combinedly recorded significantly higher CSI over that of hydro priming (P_2) and control (P_1) in both the years.

Proline content

Year-wise proline content data were presented in Table 9, indicated that irrigation regimes and nutripriming significantly influenced proline content (mg g^{-1} of fresh leaf) of lentil crop. In different irrigation regimes, 75% CPE (I_{75}) (0.423 and 0.410 mg g^{-1} in both the years respectively) was statistically significant followed by125% CPE (I_{125}), which showed significantly higher values of proline concentration at 90 DAS than 100% CPE (I_{100}).In nutripriming, the treatment P_5(0.511 and 0.460 mg g^{-1} in both the years respectively) showed higher proline content which was statistically significant in lentil crop followed by other treatments. The minimum proline content in leaf was noted in control one (P_1) during both the years.

Grain yield (kg ha^{-1})

The Table 10, represented yield data which was influenced by irrigation regimes and nutripriming. The irrigation regime 100% CPE (I_{100}) depicted significantly higher grain yield (960.2 & 1059.5 Kgha^{-1}) than the 75% (I_{75}) and 125% (I_{125}) CPE in both the years. The percentage increase in grain yield of 100% CPE (I_{100}) over 75% CPE (I_{75}), and 125% CPE (I_{125}) was 16.2% and 31.9%, respectively.

In combination of zinc and boron priming, treatment P_5revealed a significantly higher grain yield (993.4, 1075.4 & 1034.4 Kgha^{-1}) followed by other treatments, like P_4, P_3, P_2 and P_1 in both the years (Table 10) and the values were 44.01, 27.44, 30.50, and 10.03% over control respectively in terms of percentage.

Stalk yield (kg ha^{-1})

Data obtained from 2014-15 showed that 100% CPE (I_{100}) produced significantly higher stalk yield (1757 &

1993 Kgha^{-1}) than other two irrigation regimes, namely, 75% (I_{75}), and 125% (I_{125}) CPE. But in 2015-16, 100% CPE (I_{100}) being statistically at par with 75% (I_{75}), and 125% (I_{125}) CPE (Table 10).

Among nutripriming, treatments P_5 obtained maximum straw yield (1763, 2058 & 1910 Kgha^{-1}) which showed statistically at par results with P_3 in the year 2014-15 followed by other treatments. Whereas, the data obtained from 2015-16 revealed that zinc sulphate + boric acid priming (P_5) being statistically at par with zinc sulphate (P_3), and boric acid priming (P_4), had significantly more stalk yield than other treatments.

Harvest index (%)

Table 10, exhibited the results that irrigation regime had no significant effect on harvest index during both the years. Nutripriming of lentil seeds showed significant effect on harvest index (HI) of the crop during 2014-15 (35.8%); but in 2015-16 year, all nutripriming treatments were showing statistically at par results.

Discussion

Growth and physiological parameters

Effect of Irrigation regime

In present experiment, dry matter accumulation, Crop Growth Rate (CGR), and Leaf Area Index (LAI) were markedly influenced by irrigation regime and nutripriming. According to Arnon (1972), the production of total dry matter per unit area and finally the way dry matter is partitionedandaccumulatedthroughout the plant's body is the pre requisite for higher economic yield. In present study, higher amount of dry matter production at irrigation 100% of CPE indicates that the availability of soil moisture and nutrients at critical growth stages of the crop. These findings lead support those of Chandrasekhar and Saraf (2005); Mansur *et al.*, (2010); Flewury (2023). Moreover, according to Oweis *et al.*, (2004), as lentil is a major winter-sown legume crop so often faces considerable drought stress; but supplementary irrigation enhances the productivity. However, Swetha (2014) noted lowest amount of dry matter production with restricted rainfed condition. It might be due to reduction in cell division, cell volume, cell elongation, photosynthesis and biomass production which occurs under higher moisture stress conditions. Crop growth rate determines at what rate the crop is growing i.e. whether crop is growing at faster rate or slower rate. In the present case, irrigation at I_{100} recorded higher crop growth rate than I_{75} and $I_{125.}$ The increase in crop growth rate with increase in amount of irrigation water upto I_{100}, might be due to effective uptake of water and nutrients resulting in increased dry matter accumulation, a greater number of leaf and higher leaf area coupled with a greater number of branches. The result is in conformity with the finding of (Duary, 2017).

In the present case, it was noted that irrigation at I_{75} and I_{125} significantly reduced total chlorophyll content and this result was resembled with some previous studywhich indicated that water scarcity and excess water increase the plant electrolyte leakage and thus reduce chlorophyll content in leaves (Petrov, 2012; Kazem Ghassemi-Golezani *et al*., 2014). In case of proline content, at I_{75} and I_{125} significantly increased in comparison to I_{100} as less and excess water creates stress for the reason proline content increases in both the cases Similar results was observed by Sood *et al*., (2017); Nazran *et al*., (2019).

Roots are essential for plant survival and play a critical role in determining the yield of crops. Irrigation at I_{100} recorded higher values of root parameters like root length, root volume and root diameter. Whereas, the growth of roots is inhibited during water deficit (I_{75}) or excess water (I_{125}). The results showed that both limited irrigation (I_{75}) and over irrigation (I_{125}) did not benefit the crop in increasing the number of branches plant^{-1} in either of the two years under the study. Higher number of branches plant^{-1}was observed in treatment I_{100} which may be the resultant effect of moisture availability and maintenance of water potential; in addition, with that the net assimilation rate was transformed into vegetative growth. These data of the present study were resembled with the studies of Chandrasekhar and Saraf (2005); Mansur *et al*., (2010) and Swetha (2014).

Effect of seed priming

The present study report showed that plant height, dry matter production, leaf area index, and crop growth rate were markedly influenced by seed priming over control seed case. This fact was supported by the study of Mondal and Bose (2021), it was noted that under optimal and adverse environmental conditions, the primed seeds of diversified species lead to an enhanced germination performance with increased vigor index which indicates a good establishment of seedlings in the field and improved the performance of crops. By application of Zn increase in plant height might be attributed to internodal distance as reported by Kaya and Higgs (2002), Arif *et al.*, (2005) and Ali *et al.*, (2007). Mondal and Bose (2019) indicated that seed priming had a significant effect on radicle length, seedling height and dry weight and leaf number of plants, plant height, number of branches, CGR, LAI, relative leaf water content, total chlorophyll content, proline content derived from primed seeds were higher compared with non-primed seeds. The physiological parameters like leaf area index (LAI) and crop growth rate (CGR) were also increased by seed priming with zinc sulphate. Leaf area index (LAI) is the main physiological determinant of crop yield. Greater leaf area index values may attribute to significant increase in leaf expansion due to good germination and dry matter production of plants as affected by priming. Increased leaf area might be due to pre-activation of metaboliteswithin the embryo as a result of seed priming (Wahid *et al.,* 2008, Mondal and Bose, 2021). Moreover, Ullah *et al*., (2019) revealed that combined application of zinc sulphate + boric acid recorded higher growth parameters like plant height, dry matter accumulation, LAI and crop growth over zinc sulphate and boric acid alone.

The seed priming with zinc sulphate + boric acid was recorded greater relative leaf water content in comparison to control. The higher relative leaf water content was noted with zinc sulphate primed seeds. Under primed condition, this parameter can help the crop to fight against drought and by utilizing the solar radiation produce good yield (Pour *et al.,* 2012 and Mahato *et al.,* 2017). The seed priming with zinc sulphate + boric acid showed greater total chlorophyll content, proline content in leaf as compared to the crop grown from non-primed seed. The results agree with Basra *et al.,* (2011), Mondal and Bose (2019) and Ullah *et al*., (2019).

In addition, Kazem Ghassemi-Golezani *et al*., (2014) depicted that priming effects can improve field emergence, seedling vigour and crop stand establishment of lentil crops under different irrigation treatments. According to Marschner (2012) zinc, iron and boron can also regulate the biosynthesis of chlorophyll, improve the rate of photosynthesis which alleviate the effect of stress on various crops. For instance, Venugopalan *et al*., (2021) observed that micronutrient foliar spray will have a positive impact on CGR, biomass, LAI, growth and better yield.

Yield and harvest index

Effect of Irrigation regime

The present study depicted that higher grain yield of lentil might be associated with increase in growth parameters like plant height, LAI, dry matter production and number of branches plant^{-1} under the irrigation regime at I_{100}. Data suggested that, iffavorable situation arise in terms of efficient water supply and uptake of nutrients then it boosts the growth and yield attributes bysupplying more photosynthates towards the reproductive sink (Mustafa *et al*., 2008;Panahyan *et al*., 2009; Singh *et al.,* 2017 and Swetha and Hussain, 2017). Reduction of grain yield and stalk yield under irrigation regime at 75% of CPE could be due to the significant reduction in photo synthetic rate resulting in reduced production of assimilates for growth of pods and filling of grains; ultimately lentil yield was drastically decreased. Irrigation at I_{125} recorded lowest grain yield which might have exposed the crop to relatively more water and pulled down the pods per plant and 1000 grain weight as lentil is a moisture sensitive crop. This result was resembling with the finding of Singh *et al.*, (2017) and Swetha and Hussain (2017).

Meager water supply or excessive irrigation can result in unavailability or leaching of a major part of nutrients resulting in insufficiency of nutrient and low yields. Proper water management will hold these losses to a bare minimum. Likewise, the amount and movement of water in soil influence the availability of nutrients to plant roots. Uptake of the ions from the growth media was closely related to plant water content, transpiration, and/or water ûow as reported by Swetha and Hussain (2017).

Effect of seed priming

Lentil seed priming with zinc sulphate + boric acid recorded maximum number of pods and seeds plant^{-1}. The result of present study was supported by the finding of Dey *et al.,* (2014), Mahato *et al*., (2017) and Ullah *et al*., (2019). The report of Ullah *et al*., (2019) noted that nutripriming help to improve uptake of available nutrientsalong with water to the emerging plant obtained from primed seeds with magnesium, zinc, and boron which effectively improving the germination, growth and development, early flowering, early maturity, grain filling rate, and yield of several field crops. However, Mondal and Bose, (2021) noted that seed priming is effective in the development of reproductive parts, which having the potential to increase the number of grain ovule in the early developmental phases; leads to higher productivity. Similarly, Khurana and Chatterjee, (2001) depicted that without spraying of Zn solution, higher number of less filled grains was observed in control plot which represents a crucial role of zinc for the development of anthers and pollen.

The higher grain yield of lentil with zinc sulphate + boric acid primed lentil seed might be due to increase in growth attributes which enhanced number of pods, filled seeds and test weight. Similar kind of findings was recorded by Dey *et al.*, (2014) and Ullah *et al.*, (2019). The effect of seed priming on grain yield and its components is evidenced in the better and faster seedling establishment, earlier maturity that allow some escape mechanism from terminal drought and heat stress (Musa *et al.,* 2001 and Zulfiqar *et al*., 2020). In support of the present experiment's data, increased in the biological yield might be attributed to better nutrition and early seedling establishmentof the Zn and boric acid primed seed plant, in addition with that increased in dry matter productionof chickpea (Mahato, 2017; Ullah *et al*., 2019).

Conclusions

In a nutshell, irrigation regime 100% CPE (I_{100}) and Zn sulphate heptahydrate + boric acid (2 mM + 4 mM) priming (P_5) showed best results on growth and yield parameters of lentil on both the studied years. In this regard, very few literatures were available in lentil. As lentil is a moisture sensitive crop, this kind of climate smart-technology i.e., micronutrient priming with irrigation management for improvement of better seedling establishment, growth and productivity is a future for the farmers. Moreover, further detailed study will be essential for validation.

Conflict of Interest: The authors declare that they have no conflicts of interest.

References

Ahlawat, I.P.S., Gangaiah B. and Ashrafzadid M. (2007). Nutrient management in chickpea. In: Chickpea breeding and management [Yadav SS, Redden R, ChenW, Sharma B (eds)]. *CAB International*, Wallingford, Oxon, United Kingdom, 213-232.

Ali, S., Arif M., Gul R., Khan A., Shah S.S. and Ali I. (2007). Improving maize seed emergence and early seedling growth through water soaking. *Scientific Khyber*. **19**, 173-177.

Arif, M., Ali S., Shah A., Javed N. and Rashid A. (2005). Seed priming maize for improving emergence and seedling growth. *Sarhad Journal of Agriculture*. **21**, 539- 543.

Arnon, D.I. (1949). Copper enzyme in isolated chloroplasts polyphenol oxidase in Beta vulgaris. *Plant physiology*. 24, 1-15.

Arnon, D.I. (1972). Crop production in dry region. In: Background and Principles. Volume 1 [PolwinN (eds)]. International Text Book Company Limited, 158 Backing ham Palace Road, London, 284.

Ashraf, M. and Rauf H. (2001). Inducing salt tolerance in maize (*Zea mays* L.) through seed priming with chloride salts, growth and ion transport at early growth stages. *Acta Physiologiae Plantarum*. **23**, 407-414. DOI, 10.1007/ s11738-001-0050-9

Basra, S.M.A., Iftikhar M.N. and Afzal I. (2011). Potential of moringa (*Moringa oleifera)* leaf extract as priming agent for hybrid maize seeds. *International Journal of Agriculture and Biology*. **13**, 1006–1010.

Bates, L.E., Waldern R.P. and Teare I.D. (1973). Rapid determination of free proline for water stress studies. *Plant and Soil*. **39(1)**, 205-207.

Bethapalli, P.R.N., Rai P.K. and Rai A.K. (2021). Assessment of Different Seed Priming Treatments on Quality Parameters of Lentil (*Lens culinaris* Medik.) (Variety Mallika). *The International Journal of Current Microbiology and Applied Sciences*. **10(03)**, 317-323. doi, 10.20546/ ijcmas.2021.1003.042

Bhattacharya, A. (2009). Yield determination in lentil under non-irrigated and irrigated conditions, phenology, dry matter distribution and yield attributes. *Indian Journal of Agricultural Research*. **43(1)**, 1-9.

Blum, A. (2005). Drought resistance, water use efficiency and yield potential, are they compatible, dissonant, or mutually exclusive? *Australian Journal of Agricultural Research*. **56**, 1159-1168.

Bray, Kurtz (1945). Determination of total organic and available forms of phosphorous in soil. *Soil Science*. **59**, 39-45.

Broadley, M.R., White P.J., Hammond J.P., Zelko I. and Lux A. (2007). Zinc in plants. *New Phytologist*. **173**, 677–702.

Cakmak, I. (2000). Role of zinc in protecting plant cells from reactive oxygen species. *New Phytologist*. **146**, 185–205.

Cakmak, I. (2008). Enrichment of cereal grains with zinc, Agronomic or genetic biofortification? *Plant and Soil*. **302**, 1-17.

Catsky, J. (1947a). Direct methods of water content determination. In, Methods of studying plant water relations [*Slavik B*, (eds)]. Berlin, Springer-Verlag, 121-123.

Chandrasekhar, K. and Saraf C.S. (2005). Influence of irrigation and fertility levels on growth and yield of late sown chickpea (*Cicer arietinium* L.). *The Andhra Agricultural Journal*. **52(3&4)**, 322-325.

Clausen, J.J. and Kozlowski T.T. (1965) Use of the relative turgidity technique for measurement of water stresses in gymnosperm leaves. *Canadian Journal of Botany*. **43**, 305-316.

Dastane, N.G. (1972). Practical Manual for Water Use Research in Agriculture. Navbharat Prakashan, Pune, Maharashtra, 120.

Dey, S., Pramanik K., Mukherjee S., Poddar S. and Barik K. (2014). Effect of seed and straw mulching on growth and productivity of chickpea (*Cicer arietinum* L.) under rainfed condition. *SATSA-Mukhapatra-Annual Technical*, **18**, 126-131.

Directorate of Economics Statistics (2020). Agricultural Statistics at a Glance (2019). Government of India Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare Directorate of Economics and Statistics. http,//eands.dacnet.nic.in

Donald, C.M. (1962). In search of high yield. *Journal of Australian Institute of Agricultural Sciences*. **28**, 171-178.

Duary, S. (2017). Response of aerobic rice to irrigation and nitrogen management in red and lateritic soil. M.Sc. Thesis. Department of Agronomy, PSB, Visva-Bharati, Sriniketan.

Fischer, R.A. and Turner N.C. (1978). Plant productivity in the arid and semiarid zones. *Annual Review of Plant Physiology*. **29**, 277-317. DOI, 10.1146/annurev.pp. 29.060178. 001425

Flewury, D. (2023). Growing lentils under irrigation. Saskatchewan Pulse Growers. Saskpulse.com/resources/ growing-lentils-under-irrigation.

Gomez, K.A. and Gomez A.A. (1984). Statistical Procedures for Agricultural Research. International Rice Research Institute, John Wiley and Sons, Second Edition, New York, 139-240.

Hiscox, T.D. and Israelstam G.F. (1979).A method for the extraction of chlorophyll from leaf tissues without maceration. *Canadian Journal of Botany*. **57**, 1332–1334.

Hosseini, F., Nezami A., Parsa M. and Hajmohammadnia G.K. (2011). Effects of supplementary irrigation on yield and yield components of lentil (*Lens culinaris* Medik.) cultivars in Mashhad climate. *Journal of Water and Soil* (*Agricultural Sciences and Technology*). **25(3)**, 625-633.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 498.

Johnson, S.E., Lauren J.G., Welch R.M. and Duxbury J.M. (2005). A comparison of the effects of micronutrient seed priming and soil fertilization on the mineral nutrition of chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Nepal. *Experience Agriculture*. **41**, 427–448.

Kahraman, A., Mohd. Kamran khan M.K., Pandey A. and Dogan E. (2016). Effect of supplemental irrigation on lentil yield and growth in semi-arid environment. Notulae Botanicae *Horti. Agrobotanici Cluj-Napoca*. **44(1)**, 237-244.

Kaya, C. and Higgs D. (2002). Response of tomato (*Lycopersicon esculentum* L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. *Scientia Horticulturae*. **93**, 53–64.

Kazem Ghassemi-Golezani., Afsaneh Chadordooz-Jeddi. and SaeidZehtab-Salmasi (2014). Effect of seed size and ageing on field performance of lentil (*Lens culinaris*Medik.) under different irrigation treatments. *Acta agri cutturae Slovenica*. **103(2)**, 158-166.

Khourgami, A., Maghooli E., Rafiee M. and Bitarafan Z. (2012). Lentil response to supplementary irrigation and plant density under dry farming condition. *International Journal of Science and Advanced Technology*. **2(2)**, 51-55.

Khurana, N. and Chatterjee C. (2001). Influence of variable zinc on yield, seed oil content, and physiology of sunflower.*Communications* in *Soil Science and Plant Analysis*. **32**, 3023-3030.

Koleyoreas, S.A. (1958). A new method for determining drought resistance. *Plant Physiology*. **33**, 232-233.

Lindsay, W.L. and Norvell W.A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal*. **42**, 421–428.

Mahato, K. (2017). Response of chickpea (*Cicer arietinum* L.) to micronutrient application under different tillage practices in lateritic soil of West Bengal. M.Sc. Thesis. Department of Agronomy, PalliSiksha Bhavana, Visva-Bharati, Sriniketan, West Bengal.

Mahato, K., Pradhan G., Mondal S., Panda D. and Pramanik K. (2017). Response of chickpea to different tillage and micro nutrient application under rainfed in red and lateritic soil of West Bengal. 163.

Mansur, C.P., Palled Y.B., Halikatti S.I., Chetti M.B. and Salimath P.M. (2010). Effect of dates of sowing and irrigation levels on biometric growth parameters of kabuli chickpea. *Karnataka Journal Agriculture Science*. **23(4)**, 566-569.

Marschner, H. (2012). Marschner's Mineral Nutrition of Higher Plants. 3rdFdn. Academic Press. 645-51. doi,10.1016/ C2009-0-63043-9.

Mengel, K., Kirkby E.A., Kosegarten H. and Appel T. (2001). Principles of Plant Nutrition, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Mondal, S. and Bose B. (2019). Impact of micronutrient seed priming on germination, growth, development, nutritional status and yield aspects of plants, *Journal of Plant Nutrition*. **42(19)**, 2577-2599, DOI, 10.1080/01904167. 2019.1655032

Mondal, S. and Bose B. (2021). Seed Priming, An Interlinking technology between seeds, seed germination and seedlingestablishment. In, Plant Reproductive Ecology - Recent Advances [Rustagi A, Chaudhry B (eds)] Intechopen. DOI, 10.5772/intechopen.100804. Available from, https,//www.intechopen.com/online-first/ 79025

Mondal, S., Panda D. and Bose B. (2022). Seed biopriming with biopesticide, A key to sustainability of agriculture. In, New and Future Developments in Microbial Biotechnology and Bioengineering [Singh HB, Vaishnav A (eds)]. Elsevier, 265-287. ISBN, 978-0-323-85577-8. DOI,10.1016/B978-0-32-385577.8.00005-6.

Musa, A.M., Harris D., Johansen C. and Kumar J. (2001). Short duration chickpea to replace fallow after aman rice, the role of on-farm seed priming in the High Barind Tract of Bangladesh. *Experimental Agriculture*. **37(4)**, 509-521.

Mustafa, M.N., Karuna Sagar G., Chandrika V. and Reddy P.M. (2008). Growth and yield of chickpea as influenced by irrigation and nutrient management. *Legume Research*. **31(3)**, 221-223.

Nazran, A., Ahmed J.U., Sirajul Karim A.J.M. and Ghosh T. (2019). Physiological responses of mungbean (*Vigna radiata* L.) varieties to drought stress. *Bangladesh Journal of Agricultural Research*. **44(1)**, 1-11. DOI, 10.3329/bjar.v44i1.40899

Nema, S., Pandey S.B., Kumar A., Sachan R., Sirohiya A. and Singh AK. (2022). Interaction effect of phosphorus and boron on yield components, productivity parameters and quality traits of lentil (*Lens culinaris* L.). *International Journal of Environment and Climate Change*. **12(11)**, 1426-1433.

Olson, R., Smith B.G., Ferraboschi C. and Kraemer K. (2021). Food Fortification, The advantages, disadvantages and lessons from sight and life programs. *Nutrients*. **13(4)**, 1118. doi, 10.3390/nu13041118

Oweis, T., Hachum A. and Pala M. (2004). *Lentil production under supplemental irrigation in a Mediterranean environment*. **68(3)**, 251-265. DOI,10.1016/j.agwat. 2004.03.013

Panahyan-e-Kivi, M., Ebadi A., Tobeh A. and Jamaati-e-Somarin S. (2009). Evaluation of yield and yield components of lentil genotypes under drought stress. *Research Journal of Environmental Sciences*. **3(4)**, 456-460.

Parthasarathi, T., Vanitha K., Lakshamanakumar P. and Kalalyarasi D. (2012). Aerobic rice mitigating water stress for the future climate change. *International Journal of Agronomy and plant production*. **3**, 241-254.

Perry, L.J. and Compton W.A. (1977). Serial measures of dry matter accumulation and forage quality of leaves, stalks and ear of three corn hybrids. *Agronomy Journal*. **69**, 751-755.

Petrov, P.I. (2012). Ion leakage and leaf anatomy of barley plants subjected to dehydration. *Genetics and plant physiology*. **2**, 15-23.

Piper, C.S. (1966). Soil and Plant Analysis. Hans Publication, Bombay, 197-284.

Pour, A.P., Farahbakhsh H., Saffari M. and Keramat B. (2012). Effects of seed priming on germination and seedling growth under salinity stress in fenugreek. *International Journal of Agriculture and Crop Sciences*. **4(12)**, 779-786.

Reddy, A.A. (2009). Pulses Production Technology, Status and Way Forward, Economic & Political Weekly. 26 December, **xliv(52)**, 73-80.

Rerkasem, B. and Jamjod S. (2004). Boron deficiency in wheat, a review. Field Crops Research. **89**, 173–186.

Singh, K.M. and Singh A.K. (2014). Lentil in India, An Overview. *Munich Personal RePEc Archive*. **13**, 53. https,// mpra.ub.uni-muenchen.de/59319.

Singh, Y.P., Tomar S.S., Singh A.K. and Yadav R.P. (2017). Effect of nutrition management and irrigation methods and schedule on productivity, economics and water-use efficiency in soybean (*Glycine max*)–chickpea (*Cicer arietinum*) cropping sequence in alluvial soil. *Indian Journal of Agronomy*. **62(4)**, 424-430.

Soltani, M., Liaghat A.M., Sotoodehnia A., Heidari A. and Kamali B. (2015). Conjunctive effects supplemental irrigation and planting date on rainfed lentil in Qazvin Plain, Iran. *Journal of Irrigation and Drainage Engineering*. **141(12)**, 0501-5005.

Sood, A., Sandhu S., Alok K. and Singh S. (2017). Proline content and membrane permeability index in response to water stress in recombinant inbred lines of lentil. *International Journal of Plant Reseach*. **30(2)**, 63. DOI, 10.5958/2229-4473.2017.00136.7

Srivastava, S.P., Yadav C.R., Rego T.J., Johansen C. and Saxena N.P. (1997). Diagnosis and alleviation of boron deficiency causing flower and pod abortion in chickpea (*Cicer arietinum* L.) in Nepal. In, Boron in soils and plants,Developments in Plant and Soil Sciences 76 [Bell RW, Rerkasem B (eds)]. Kluwer Academic Publishers, Dordrecht, The Netherlands. 95-99.

Subbiah, B.V. and Asija G.L. (1956). A rapid procedure for the estimation of available nitrogen in the soils. *Current science*. **25**, 779-782.

Swetha, D. (2014). Influence of moisture regimes on growth, yield, and quality of chickpea (*Cicer arietinium* L.) cultivars. M.Sc. Thesis, Department of Agronomy, College of Agriculture Acharya N. G. Ranga Agricultural University Rajendranagar, Hyderabad.

Swetha, D. and Hussain, S.A. (2017). Influence of moisture regimes on yield and water use efficiency of chickpea cultivars (*Cicer arietinium* L.). *International Journal of Pure &Applied Bioscience.* **5(4)**, 1141-1145.

Turner, N.C. (1986). Crop water deficit, a decade of progress. *Advances in Agronomy*. **39**, 1-51.

Turner, N.C. and Begg J.E. (1981). Plant water relation and adaptation to stress. *Plant Soil*. **58**, 97-105.

Ullah, A., Farooq M., Hussain M. and Wakeel A. (2019). Zinc seed priming improves stand establishment, tissue zinc concentration and early seedling growth of chickpea. *Journal of Animal and Plant Sciences*. **29**, 1049–1053.

Venugopalan, V.K., Nath R., Sengupta K., Nalia A., Banerjee S., Chandran M.A.S., Ibrahimova U., Dessoky E.S., Attia A.O., Hassan M.M. and Hossain A. (2021). The response of lentil (*Lensculinaris* Medik.) to soil moisture and heat stress under different dates of sowing and foliar application of micronutrients. *Frontiers of Plant Sciences*. **12**, 679469. DOI,10.3389/fpls.2021.679469.

Wahid, A., Noreen A., Basra S.M.A., Gelani S. and Farooq M. (2008). Priming-induced metabolic changes in sunflower (*Helianthus annuus*) achenes improve germination and seedling growth. *Botanical Studies*. **49**, 343-350.

Watson, D.J. (1952). The physiological basis of variation in yield. *Advances in Agronomy*. **4**, 101-145.

Zulfiqar, U., Hussain S., Ishfaq M., Matloob A., Ali N., Ahmad M., Alyemeni M.N. and Ahmad P. (2020). Zinc-Induced Effects on Productivity, Zinc Use Efficiency, and Grain Biofortification of Bread Wheat under Different Tillage Permutations. *Agronomy*. **10**, 1566. DOI,10.3390/ agronomy10101566.