"Effect of foliar sprays of boron, iron and zinc on plant growth, seed yield and seed quality of lentil (*Lens culinaris* Medik.)"

Thesis

SUBMITTED TO THE

V. C. S. G. Uttarakhand University of Horticulture and Forestry
College of Forestry, Ranichauri-249199

By

Ranjithkumar. H. R.
UUHF/15315

IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Agriculture

(Seed Science and Technology)

May, 2017

ACKNOWLEDGEMENT

The ability of mine to complete this research work much effectively efficiently and with self-satisfaction goes to Swami Vivekananda in whom I see the omnipresent almighty, who empowered me not only with the knowledge but also with the power to move with the odds and across the problems that I have faced during the course of time.

It's difficult to express in words, the guidance, care and affection showed by Dr. Ajay Kumar, Junior research Officer and chairman of my advisory committee, I thank him with deep sense of gratitude. With great respect, immense pleasure and genuine obligation I thank my Co-Advisor Dr. Bhim Jyoyi, Department of Seed Science and Technology and my advisory committee Dr. Pankaj Kumar, Department of Genetics and Plant Breeding and Dr. Deepa Rawat, Department of Soil Science.

I am highly thankful to Prof. (Dr.) C. M. Sharma, Dean, College of Forestry for his close supervision and providing essential facilities, Dr. Arun Bhatt, Ms. Anupma and Mr. Anil Rawat for their constant encouragement.

I fail to express my reverence on my beloved parents, because of who I'm here, Shri Ramachandra H. D. and Smt. Kanya Kumari. H. P, and Aunt- Anitha Kumari. H. P. I'm bound to my friends Arunima, Rahul and Vijayashree for sharing the pain, moral support and their selfless help showered on me.

I would like to thank my respected seniors Dhanush, Sharath, Ambalal, Yuvraj, Sandeep, Ankit, Lavraj and Aman sir for their beautiful stay and their care as parents, My classmates Suprith, Charan, Prashanth, Ruata, Deepa and Mayank for coping up with me every day and my juniors Nirmal, Ajay, Koki, Arvind, Yonger, Mandeep, Jaggu, Pawan, Rajneesh, Shivaang, Anuraj and Assi for their respect, love, and humorous stay with me.

Finally I would like to thank everyone who I have failed to mention their name in this page for their invaluable support throughout the course of time.

Ranichauri
May, 2017 (RanjithKumar. H. R.)

Dr. Ajay Kumar
Junior Research Officer

Department of Seed Science and Technology
College of Forestry
V. C. S. G. Uttarakhand University of
Horticulture and Forestry, Ranichauri-249199
Dist. Tehri Garhwal, Uttarakhand, India.

CERTIFICATE

This is to certify that the thesis entitled **"Effect of foliar sprays of boron, iron and zinc on plant growth, seed yield and seed quality of lentil (*Lens culinaris* Medik.)"** submitted in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** with major in **Seed Science and Technology**, of the College of Forestry, Ranichauri, is a record of ***bona-fide*** research carried out by **Mr. Ranjithkumar. H. R, Id. No. UUHF/15315**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

(Ajay Kumar)
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee, of **Mr. Ranjithkumar. H. R. Id. No. 15315,** a candidate for the degree of **Master of Science in Agriculture** with major in **Seed Science and Technology**, agree that the thesis entitled **"Effect of foliar sprays of boron, iron and zinc on plant growth, seed yield and seed quality of lentil (*Lens culinaris* Medik.)"** may be submitted in partial fulfilment of the requirements for the degree.

(Ajay Kumar)
Chairman
Advisory committee

(Bhim Jyoti)
Co-Advisor

(Pankaj Kumar)
Member

(Deepa Rawat)
Member

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF SYMBOLS AND ABBREVIATIONS

%	Per cent
/	per
@	at the rate of
ANOVA	Analysis of Variance
B	Boron/Borax
C. D.	Critical Difference
cm	Centimeter
CRD	Completely Randomized Design
DAG	Days after germination
et al.	et alia
etc.	and so on
Fe	Iron sulphate/ Iron
Fig.	Figure
g	Gram
ha	Hectare
hrs	Hours
i.e.	That is
kg	Kilogram
m	Meter
m^2	meter-square
Max.	Maximum
Min.	Minimum
ml	milliliter
mm	millimeter
mm	millimeter
mM	millimolar
nm	nanometer
^oC	Degree Celsius
ppm	Parts per million
RCBD	Randomized Complete Block Design
Zn	Zinc sulphate/ Zinc

Chapter 1 INTRODUCTION

India is largest pulse-growing country which accounts for nearly one-third of the total world area under pulses and one-fourth of the total world production. India stands second in production of lentil after Canada. The major lentil-growing countries of the world include India, Canada, Turkey, Bangladesh, Iran, China, Nepal and Syria (Ahlawat, 2012). Lentil occupies 1469 thousand ha area with the production of 1035 metric tons and a productivity level of 705 kg per hectare in India (indiastat.org, 2016).

Lentil is the third most important pulse crop of North India (Singh *et al.,* 2014) which is mainly grown as rain-fed crop in Uttar Pradesh, Uttarakhand, Madhya Pradesh, Jharkhand, Bihar and West Bengal. Lentil plays an important role in the diet of developing world. Lentils have the second highest ratio of protein per calorie of any legume, after soybean (Mudryj and Aukema, 2014). Lentil provide a variety of essential nutrients to a person's diet, containing high levels of protein (20-30%), minerals (2-5%), vitamin B9 and prebiotic carbohydrates (Thavarajah *et al.,* 2008). Lentil is typically rich in micronutrients and has the potential to provide adequate dietary amounts, especially for iron (Fe), zinc (Zn), and selenium (Se) (Thavarajah *et al*., 2015). Lentil is having the lowest content of lectins and trypsin inhibitors among legumes. It contains phytonutrients like flavonoids, tannins, phytic acid, phytosterols, which has anti-inflammatory, antioxidant, and anticancer effects (Ezzat *et al*., 2012).

Lentil can be grown from sea level to an altitude of 3000m. It can also remain unaffected by rain at any stage of its growth including flowering and fruiting (Ahlawat, 2012).

There is a great need for micronutrients nowadays, because, (i) micronutrient removal from long-term crop production; (ii) increased use of only high-analysis fertilizers; (iii) higher micronutrient requirements accompanying higher crop yields; (iv) less use of animal manures in crop production; and (v) induction of micronutrient deficiencies by high

P concentrations from long-term applications. Micronutrients play an important role in increasing yield of pulses through their effect on the plant itself and on the nitrogen fixing by symbiotic process.

Zinc is an essential trace element which is required in about 200 enzymes and transcription factors (Kabata-Pendias and Pendias, 1999). Zn plays a major role in auxin metabolism, nitrogen metabolism, influence on the activities of enzymes (e.g. dehydrogenase and carbonic anhydrase, proteinases and peptidases) and cytochrome C synthesis, stabilization of ribosomal fractions and protection of cells against oxidative stress (Tisdale *et al*., 1997; Obata *et al*., 1999). Zn deficiency in field crops leads to poor growth, interveinal chlorosis and necrosis of lower leaves. Plants emerged from seeds with low concentrations of Zn could be highly sensitive to biotic and abiotic stresses (Obata *et al*., 1999).

Boron is non-mobile in plant therefore, continuous supply of boron from soil is required for all plant meristems. Boron is essential for cell wall synthesis, lignification, as well as the structural integrity of bio membranes. Boron also maintains stable balance between sugars and starches, pollination and seed production (Gupta *et al*., 1985). Boron is very important in cell division and in pod and seed formation (Vitosh *et al*., 1997). The nitrogen and boron concentrations of grain for lentil were markedly influenced by boron treatment indicating that the boron had a positive role on protein synthesis, but high rates of boron in starter fertilizer can cause toxicity in sensitive crops (Iqtidar and Rahman, 1984). Concentrations of over 200 ppm in mature leaf tissue is indicative of toxic levels of boron in plants (Voss, 1998).

Iron enters in many plant enzymes that play dominant roles in oxidation-reduction reactions of photosynthesis and respiration. Iron participates in content of many enzymes: cytochromes, ferredoxine, superoxide dimutase, catalase, peroxidase and nitrate reductase. The deficiency of iron in plants causes significant changes in the plant metabolism and induces chlorosis, especially in young leaves and leads to very low reutilization.

These micronutrients can be added to crop through soil fertilization, foliar sprays and seed treatment. Each method has the potential to affect plant micronutrient nutrition both in the treated plant directly and in the progeny plants through enrichment of the seeds by micronutrient treatment of the parent. Foliar applications of micronutrient sprays prove to be best to achieve both (Savithri *et al*., 1999). Foliar application has been shown to avoid the problem of leaching out in soils and prompts a quick reaction in the plant. Foliar application of zinc and iron bring the greatest benefit in comparison with addition to soil where they become less available (Odell, 2004).

In present scenario, where continuous application of macro nutrients created deficiency of micronutrient in lentil which ultimately cause reduction in yield and seed quality. There is scanty attention on micronutrient management through foliar application in lentil crop. Therefore this research has been coined with following objectives:

- To study the influence of boron, iron and zinc on plant growth under field condition along with recommended dose of fertilizers.
- To study the influence of boron, iron and zinc on seed yield and yield attributing characters.
- To evaluate the effect of boron, iron and zinc on seed quality parameters.

Chapter 2 REVIEW OF LITERATURE

2.1 Plant growth and morphology

Fawzi *et al.* (1993) from Cairo, Egypt, revealed that plant height, internode length, number of branches, dry weight of the pea plants were significantly increased in response to the foliar applications of iron or its combinations with the other micronutrients like manganese and zinc.

Wang *et al.* (2010) from Beijing, China, reported that rapid inhibition of root elongation was one of the most distinct symptoms of boron toxicity in seedling of cucumber (*Cucumis sativus L.).* The leaf area index, above ground dry matter and crop growth rate of lentil was increased with the application of B and Mo (Chakraborty, 2009) in Sekhampur, Birbhum. Lee *et al.* (1996) reported from South Korea that nutrient solution containing 0.5 mM boron, 5.0 mM Fe, 0.5 mM Zn caused foliar toxicity symptoms in seed geranium and also reported that higher copper and manganese level decreased leaf chlorophyll, whereas elevated levels of Fe increased tissue chlorophyll contents.

Ramirez and Lang (1997) from Texas, USA, while studying the effect of applied iron concentration on growth of holiday cactus claimed that as Fe-EDTA treatment levels increased there was decrease in growth, increased marginal chlorosis on all cultivars and also very slow accumulation of iron in the potting medium.

Deepika and Pitagi (2015) from GKVK, UAS, Bangalore found that combination of RDF+ $ZnSO_4$ @ 10 kg ha^{-1}+ Borax 0.1% spray on radish plants at bud initiation stage was effective in getting maximum plant height, number of leaves per plant. Foliar application of Fe-4%, Mn-1%, Zn-6% and B-0.5% micronutrients on spider lilly had significantly highest plant height, number of leaves, number of flowers per stalk, flowers per plant and ultimately flower yield per hectare at Junagadh, Gujarat, as reported by Elangaivendhan *et al.* (2016).

Abdel-Latif and El-Haggan (2014) from Cairo, Egypt, unearthed the fact that Fe+ Zn+ Mn+ B micronutrient combination as foliar application treatment on soybean plant produced the highest values of plant height at harvest, number of branches per plant while observing the effect of micronutrients as foliar application.

Singh and Singh (2014) from Ludhiana, Punjab, recorded significantly higher plant height, dry matter, leaf-area index and effective tillers per square meter in direct seeded aromatic rice (*Oryza sativa*) due to the foliar application of iron and zinc. In Urmia, Iran, Increasing Zn concentration in soil, plant height and biomass of Sorghum and *Chenopodium album* were decreased significantly, as reported by Mirshekal *et al.* (2012).

Peña-Olmos *et al.* (2014) from Colombia, recorded drastic decrease in the dry matter of broccoli plants, which were subjected to excess Fe^{2+} and also reported that growth indices were progressively decreased with increase in the Fe^{2+} concentrations in the substrate, while distribution of dry matter in the organs varied as a function of the needs of the plants. In China, the foliar toxicity symptoms were induced at the threshold micronutrient concentrations of 0.5 mM B, 4 mM Fe, and 5 mM Zn in french marigold and also reported the reduced dry matter when micronutrient concentrations exceeded 0.5 mM B, 3 mM Fe, and 5 mM Zn in the fertilizer solution and decreased leaf chlorophyll content when the nutrient solution concentrations of Fe, was greater than 3 mM respectively as reported by Choi *et al.* (1996).

Rosen *et al.* (1977) from Lancaster, Pennsylvania, disclosed that high Zn greatly reduced the root and shoot fresh weights which restored normal growth. The chlorosis of Zn-toxic plants were not attributable to diminished total leaf Fe; however, this chlorosis was relieved by increasing nutrient Fe and concluded as Zn and Fe probably interacted at some site, in a study centered to asses zinc toxicity and Zn-Fe interaction in corn.

Cervilla *et al.* (2007) from Spain, reported as B-toxicity treatments on tomato (*Solanum lycopersicum*) plants showed diminished growth and boosted the amount of B, malondialdehyde and H_2O_2 in the leaves, while B toxicity also increased ascorbate concentration in both cultivars and activities of antioxidant- and ascorbate-metabolizing enzymes were also induced. At Zabol University, Iran while studying effects of foliar micronutrient application under water stress on sunflower plant found that under water stress, free proline and total soluble carbohydrate concentration were increased, at all of the three stages of growth in Sunflower, the highest concentration of these two components was found on the flowering stage, reported by Babaeian *et al.* (2011).

Reid *et al.* (2004) from Adelaide, Australia, revealed that internal boron concentrations in the range 1–5 mM inhibited plant growth rapidly across a range of plant types that included monocot, dicot and algal species and also in wheat, at higher B concentrations, many cellular activities were found to be partially inhibited and the toxicity on mature tissues was therefore considered not to arise from the disruption of a single process, but from the accumulated retardation of many cellular processes.

Sagardoy *et al.* (2009) from Zaragoza, Spain, unearthed the fact that high concentrations of zinc sulphate in the nutrient solution (50, 100 and 300 ml) on sugar beet decreased root and shoot fresh and dry mass, and increased root to shoot ratios, when compared to control conditions, whereas total Zn uptake per plant decreased markedly with high Zn supply. Highest plant height, number of branches and number of leaves per plant, earliest flowering and fruiting with boron (0.25%) + APSA-80, followed by multiplex (0.25%) + APSA-80 were recorded in an experiment of foliar application of nutrients on plant growth, yield and quality of fruit and seed of brinjal by Gogoi *et al.* (2014) at Assam Agricultural University, Guwahati, Assam. At TNAU, Coimbatore, Tamil Nadu, Sinta *et al.* (2015) deep laid an experiment to find out the role of micronutrients on growth, seed yield and quality of coriander using iron (Fe), zinc (Zn), and reported that foliar spray of 0.5% $FeSO_4$ induced the highest growth rates in terms of net assimilation rate and crop growth rate.

Hosseini and Poorakbar (2013) from Urmia University, Iran, revealed that excess of zinc on maize plants increased the EC, MDA, H_2O_2 content and non-protein thiols and also increased activities of antioxidant enzymes. Upon addition of two nutrients if there was an increase in crop yield that was more than adding only one nutrient, the interaction was positive (synergistic). Similarly, if adding the two nutrients together produced less yield as compared to individual ones, the interactions was negative (antagonistic) while studying the nutrient interactions in crop plants as stated by Fageria (2001) from Jaipur, India.

Singh *et al.* (2010) from Varanasi, India, reported that foliar application of zinc significantly increased the plant height, number of tillers, and herbage yield in a study aimed to know the effect of foliar application of Zn on palmarosa. Foliar application of N+ micronutrients increased leaf area, specific leaf weight, chlorophyll content, total dry mass, flower number and reproductive efficiency in mungbean at Mymensingh, Bangladesh as reported by Mondal *et al.* (2011).

Kumar *et al.* (2015) from U.P, India, recorded highest dry matter accumulation and no of effective tiller per square meter with three foliar sprays of 2.0% iron sulphate followed by three foliar sprays of 0.5% iron chelate on aerobic rice.

2.2 Yield and yield attributing characters

Fawzi *et al.* (1993) unveiled from Cairo, Egypt that number of pods, grain yield per plant and seed yield (kg/ha) were increased with foliar applications of Fe and Mn, or their combinations, seed weight was also increased in pea plants by the application of Fe, Mn, and Zn as an individual element or in combination. Foliar application of micronutrients (iron and zinc) significantly increased 1000-kernel weight, biological yield, grain yield, harvest index and oil yield in rapeseed (*Brassica napus L.*) in Khuzestan, Iran as reported by Bahrani (2015). In Santa Catarina State, Brazil, application of Zn to the soil increased onion yield in all three years and maximum yield was obtained with Zn @ 2.7 kg per ha, as Kurtz and Ernani (2010) tried to measure the effect of B and Zn fertilizers on yield and quality of onion bulbs.

Deepika and Pitagi (2015) hailing from GKVK, UAS Bangalore, reported that combination of RDF+ ZnSo4 @ 10 kg per ha + Borax 0.1% spray on radish plant during bud initiation stage was effective in maximum length of inflorescence, number of siliqua per plant, siliqua weight per plant, siliqua length, number of seeds per siliqua and seed yield.

Karan *et al.* (2014) from Bihar, India, conducted a trial to investigate the response of lentil cultivars on yield and nutrient balance in the soil in relation to various levels of zinc and boron and they rout out that grain yield, straw yield and biological yield of lentil (PL-639) were significantly increased with the application of 1 kg B per ha. At Cairo, Egypt, Abdel-Latif and El Haggan (2014) reported that Fe+ Zn+ Mn+ B combination as foliar application produced the higher of number of pods per plant, 100-seed weight, seed yield per plant, seed yield (kg/ ha), oil content and oil yield in soybean cultivars.

Salehin and Rahman (2012) from Dhaka, Bangladesh, carried out an experiment to study the effects of zinc spray (0 and 1 g/l) on yield and yield components of *Phaseolus vulgaris* and recorded the highest seed yield (1996 kg/ha.) under zinc @ 1 g/l.

Singh and Singh (2014) from Ludhiana, Punjab, recorded significantly higher panicle length, spikelets per panicle, grains per panicle, 1000-seed weight, grain yield, straw yield and B: C ratio over the control, due to the foliar application of iron and zinc on rice. Zn fertilization caused significant increase in grain yield, straw yield and grain quality of wheat in calcareous soils of Tehran, Iran as reported by Ziaeian and Malakouti (2001).

Quddus *et al.* (2014) from Madaripur, Bangladesh, evaluated the effect of zinc (Zn) and boron (B) on the yield and yield contributing characters of lentil and revealed that the combination of Zn+ B produced significantly higher seed yield than control and also mentioned that the combined application of zinc and boron were superior to their single application.

Babaeian *et al.* (2011) from Zabol University, Iran, reported that the use of foliar micronutrient on sunflower increased grain yield in water stress, and use of Mn foliar application had the highest positive effect on yield components and grain yield.

Movahhedy-Dehnavy (2009) Tehran, Iran, reported that foliar Zn application could improve the seed yield under draught stress after evaluating the effect of foliar application of zinc on the growth and development of safflower. All the treatments of micronutrients mixture resulted in improvement of seed yield characteristics in tomato viz. 100 seed weight, seed yield per plant and seed yield per hectare as reported by Sivaiah *et al.* (2013) from Bhubaneswar, India.

Rao *et al.* (2012) from Hyderabad, Andhra Pradesh, in a trial on sweet sorghum cultivar ICSV-93046 under tropical conditions recorded the highest stalk yield for treatments N and P with foliar application of 0.1 % sodium borate, N and P with foliar application of 0.5 % $ZnSO_4$ and 0.1 % sodium borate in main crop and in the ratoon crop. Arvindkumar *et al.* (2012) from Raichur, Karnataka in an effort to find out the influence of boron spray on seed yield and quality of bitter gourd found that boron @ 4 ppm produced highest number of seeds per fruit, seed yield and test weight.

Gogoi (2014) from Assam Agricultural University, Guwahati, Assam brought into light that treatment with boron (0.25%) + APSA-80 resulted in highest number of fruits per plant, total yield and B: C ratio of 4.07 & 4.63 for fruit and seed production in a study to know the effect of foliar application of nutrients on plant growth, yield and quality of fruit and seed of brinjal.

Zehtab-Salmasi *et al.* (2012) hailing from Phuket, Thailand, in an intended effort to know the effects of foliar application of micronutrients (iron and zinc) on yield of psyllium, recorded increased seed yield due to foliar application of Fe and Zn, compared with control. From TNAU, Coimbatore, Tamil Nadu, Sinta *et al.* (2015) established that Foliar spray of 0.5% $FeSO_4$ on coriander induced maximum number of umbels per plant and highest seed yield per hectare, while studying the effect of micronutrients on growth, seed yield and quality in coriander using iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn).

Du *et al.* (2009) from Lanzhou, China, in a study to know effects of micronutrients boron, iron, zinc on seed yield and yield components of alfalfa revealed that boron was more critical for alfalfa seed production and also mentioned that Boron increased seed yield, fertile shoots per unit area, number of racemes per shoot, number of pods per raceme, number of seeds per pod and 1000-seed weight.

Mei *et al.* (2009) from Wuhan, China, reported that combined application of B with Zn on rapeseed plant resulted in higher seed yield than the application of B or Zn alone, and the seed yield of the B+ Zn treatment was the highest in all treatments in comparison to the control. Zinc application significantly affected the plant height, seed weight per plant and 1000-seed weight in the first year and the plant height, seed weight per plant, biological yield per plant, 1000- seed weight and harvest index of the genotypes during the second year in safflower plants as reported by Aytac *et al.* (2014) from Skisehir, Turkey.

Movahhedy-Dehnavy *et al.* (2009) from Tehran, Iran, evaluated the effect of foliar application of zinc on the growth and development of safflower and the results suggested that foliar Zn application could improve the seed quality of safflower grown under drought stress.

Mondal *et al.* (2011) from Mymensingh, Bangladesh, revealed that foliar application of N+ micronutrients increased both yield attributes and yield over the control while studying the effect of foliar application of nitrogen and micronutrients on mungbean.

2.3 Seed quality and quality parameters

Fang *et al.* (2008) from Nanjing, China, investigated the effect of Zn, and Fe foliar fertilization on yield of rice and revealed that Zn was the main variable influencing the Zn and Fe content of rice, and also found that under the optimal application condition, Zn and Fe content of rice could be significantly increased. Seeds treated with Zn @ 0.5kg/ha during sowing in Baraut, India, significantly increased protein content, higher fat and carbohydrate content as against in control while studying the effect of Zn on the contents of protein, carbohydrate and fat in lentil (*Lens culinaris*) as reported by Kumar *et al.* (2015).

Deepika and Pitagi (2015) from GKVK, UAS Bangalore, India, revealed that $ZnSO_4$ @ 10 kg ha^{-1} + Borax 0.1% spray at bud initiation stage was found effective in maximum germination per cent, seedling vigour index I &II compared to control in a study to know the effect of zinc and boron on growth, seed yield and quality of radish (*Raphanus sativus* L.).

Abdel-Latif and El Haggan (2014) from Cairo, Egypt, in trial to reveal that micronutrients Fe+ Zn+ Mn+ B combination produced the highest values of protein content and protein yield compared with control treatment in soybean.

Khathutshelo *et al.* (2016) from Florida, South Africa, unwrapped that foliar application of Fe (100 ml/l) led to a significant increase in the Zn, Fe, Cu, and B content and improved chemical composition of bush tea.

Movahhedy-Dehnavy *et al.* (2009) from Tehran, Iran, revealed that foliar application of Zn increased the concentration of Zn in seed, germination rate, germination percentage, seedling dry weight and final seedling emergence, while they worked on safflower. In a study on soybean to know the effect of application of boron on water stressed soybean plants at Stoneville, USA, Bellaloui *et al.* (2013) found that seeds of water stressed + foliar boron applied plants had higher protein, oleic acid, sucrose, glucose, and fructose compared with water stressed plants.

Arvindkumar *et al.* (2012) from Raichur (Karnataka), India, carried out a study to find out the influence of boron spray on seed yield and quality in bitter gourd and revealed that that boron at 4 ppm produced highest seedling length, seedling dry weight, seedling vigour index-II and dehydrogenase enzyme activity. Application of micronutrients improved Zn concentration in different plant parts and seeds and also increased the seed iron (Fe) concentration as reported by Yamunarani *et al.* (2016) from Karnataka.

Johnson *et al.* (2005) from New York, USA, found that soil B fertilization increased B content of the grain of lentil (*Lens culinaris*), chickpea (*Cicer arietinum*), and wheat (*Triticum aestivum*) by a factor of two to five.

Gogoi (2014) from Guwahati, Assam reported the highest seed viability in seeds of brinal were obtained with boron (0.25%) + APSA-80 compared to other treatment.

Sankaranarayanan *et al.* (2010) from TNAU, Coimbatore, Tamil Nadu, reported that specific fiber quality parameters in cotton, such as ginning per cent and uniformity ratio were significantly enhanced by soil application of $FeSO_4$ @ 50 kg/ha and borax @ 5 kg/ha separately. At Solan, HP, Kumari (2012) recommended foliar application of boron for enhancing germination percentage of tomato, whereas multiplex treatment was found best for increasing seedling length, total soluble solids, vitamin C and lycopene content in the fruits of tomato.

Ziaeian and Malakouti (2001) from Tehran, Iran, found that Zn fertilization caused significant increase in 1000 grain weight, number of seeds per spikelet and also noted that with the application of these nutrients, their concentration and total uptake in grain, flag leaves and the grain protein content increased significantly in wheat under the calcareous soils of Iran.

Peishi *et al.* (1999) reported that, Seeds stored at 25^{o}C and 38^{o}C germinated better than seeds stored at 5 and 15^{o}C, but only after about 8 months of storage for Australian asteraceae. Plant under moisture stress may induce a positive carbon balance, so that resistant genotypes achieve a greater net gain of carbon than water stress susceptible ones, Blum (1989). Soluble sugars were accumulated in leaves during water stress, these sugars might contribute to osmoregulation at least under moderate stress as reported by Jones *et al.* (1980).

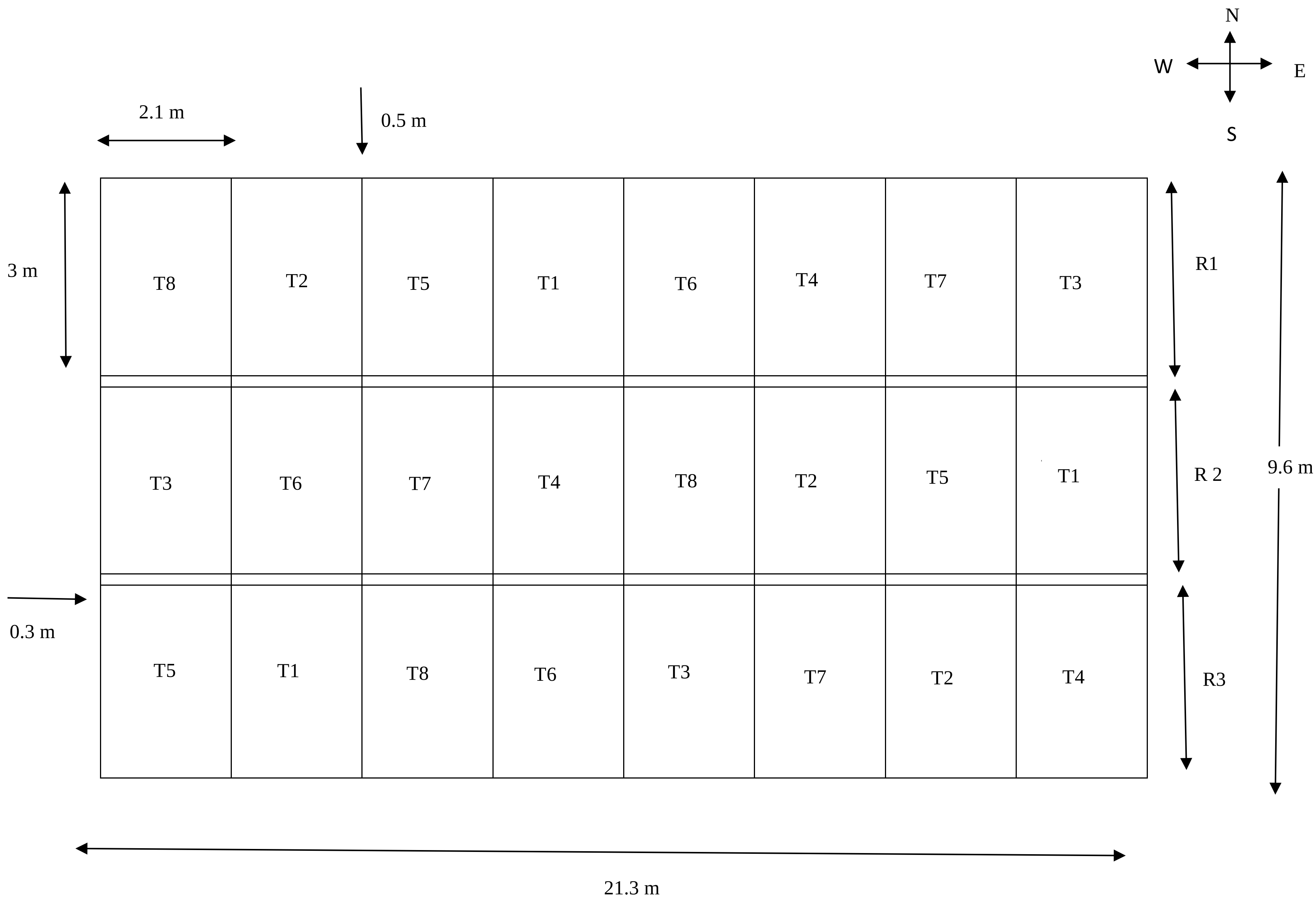


Fig. 3.2 Layout of the plot

In this chapter, results of the experiment obtained during the course of investigation are summarized with the help of suitable table and graphs.

4.1 Growth and developmental studies

4.1.1 Plant population studies

Table 4.1: Effect of micronutrients on plant population and mortality percentage

S. No.	Treatments	Initial plant population (plants/row)	Plant population at maturity (plants/row)	Mortality percentage
T0	**RDF**	18.53	16.00	13.56
T1	**RDF+ Zn 50 ppm**	18.53	16.27	12.21
T2	**RDF+ Zn 100 ppm**	18.13	15.60	13.96
T3	**RDF+ Fe 50 ppm**	18.60	17.50	5.87
T4	**RDF+ Fe 100 ppm**	18.13	16.20	10.68
T5	**RDF+ B 50 ppm**	17.53	16.07	8.31
T6	**RDF+ B 100 ppm**	18.80	16.67	11.30
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	18.60	16.53	10.98
	CD 5%	NS	0.78	1.03
	SEm±	0.33	0.26	0.34

The results pertaining to the plant population studies as evident from the data in **Table 4.1, Appendix III and Fig. 4.1.** RDF+ Fe 50 ppm has recorded significantly higher plant population at maturity in comparison to the RDF. There was no significant difference in initial plant population. RDF+ Fe 50 ppm has recorded significantly lower mortality percentage in comparison to the RDF.

RDF+ Zn 100 (13.96) ppm recorded the highest mortality percentage in comparison to all the treatments.

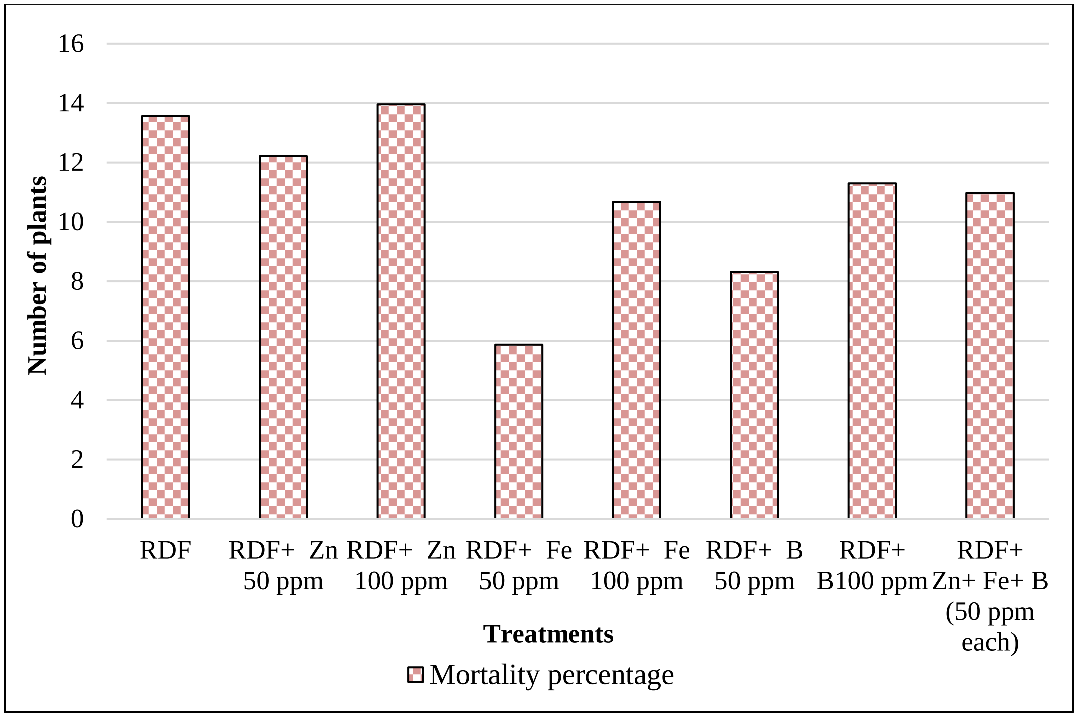


Fig. 4.1: Effect of micronutrient treatment on plant population

4.1.2 Plant height

The data pertaining to the plant height was given in the **Table 4.2 and Appendix IV.** The plant height increased slowly till 90 DAG which soared to the highest at harvest of the crop in all the treatments. The treatments RDF+ Zn 50 ppm, RDF+ Fe 50 ppm and RDF+ B 50 ppm had higher plant height than RDF+ Zn 100 ppm, RDF+ Fe 100 ppm, RDF+ B 100 ppm and RDF+ Zn+ Fe+ B (50 ppm each). The lowest plant height was recorded in the RDF. There was no significant difference in plant height up to 30 DAG.

There was a significant difference in plant height due to the micronutrient treatments at 60 DAG, 90 DAG and at harvest of the crop. The highest plant height was recorded in RDF+ Fe 50 ppm at all the four stages compared to the RDF, followed by RDF+ B 50 ppm. Both RDF+ Fe 50 ppm and RDF+ B 50 ppm registered significantly higher plant height compared to the RDF at the harvest.

Table 4.2: Effect of micronutrients on plant height (cm) of lentil

S. No.	Treatments	30 DAG	60 DAG	90 DAG	At Harvest
T0	**RDF**	2.91	3.31	5.35	17.48
T1	**RDF+ Zn 50 ppm**	2.92	4.19	5.56	19.93
T2	**RDF+ Zn 100 ppm**	2.77	3.69	5.30	18.83
T3	**RDF+ Fe 50 ppm**	2.98	4.93	6.57	21.67
T4	**RDF+ Fe 100 ppm**	2.52	3.65	5.28	18.69
T5	**RDF+ B 50 ppm**	2.78	4.43	6.54	21.17
T6	**RDF+ B 100 ppm**	2.73	4.16	5.70	19.68
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	2.93	3.72	5.23	18.11
	CD 5%	NS	0.86	1.00	2.64
	SEm±	0.21	0.28	0.33	0.87

4.1.3 Plant spread

The results pertaining to the plant spread as evident from the data in **Table 4.3 and Appendix V** revealed that plant spread was significantly influenced by different micronutrient

Table 4.3: Influence of micronutrients on plant spread (cm) of lentil

S. No.	Treatments	30 DAG	60 DAG	90 DAG	At Harvest
T0	**RDF**	1.78	2.22	3.15	9.04
T1	**RDF+ Zn 50 ppm**	1.77	2.58	3.36	10.67
T2	**RDF+ Zn 100 ppm**	1.76	3.09	3.67	10.55
T3	**RDF+ Fe 50 ppm**	1.78	3.61	4.63	11.50
T4	**RDF+ Fe 100 ppm**	1.76	2.33	3.03	9.72
T5	**RDF+ B 50 ppm**	1.88	3.30	4.36	11.47
T6	**RDF+ B 100 ppm**	1.77	2.66	3.57	10.10
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	1.76	2.67	3.39	9.93
	CD 5%	NS	0.51	0.72	1.48
	SEm±	0.14	0.17	0.24	0.49

treatments. The plant spread decreased with the increase in the concentration of micronutrient from 50 to 100 ppm.

Plant spread increased very slowly till 90 DAG and after that grow at faster rate till harvest of the crop. At harvest, plant spread was increased up to three folds compared to the plant spread during 90 DAG. RDF+ Zn 50 ppm, RDF+ Zn 100 ppm, RDF+ Fe 50 ppm and RDF+ B 50 ppm treatments had significant variation in the plant spread compared to the RDF during harvest of the crop.

4.1.4 Number of compound leaves

A close perusal of data indicated that the treatments had significant influence on the number of compound leaves during 60 DAG and 90 DAG **(Table 4.4 and Appendix VI).** No of compound leaves increased gradually from 30 DAG to 90 DAG. Here the treatments RDF+ Zn 50 ppm, RDF+ Fe 50 ppm and RDF+ B 50 ppm had higher number of compound leaves than the treatments RDF+ Zn 100 ppm, RDF+ Fe 100 ppm, RDF+ B 100 ppm and RDF+ Zn + Fe+ B (50 ppm each).

The maximum number of compound leaves were recorded under RDF+ Fe 50 ppm (16.07) and the minimum under RDF (10.27) at 90 DAG. RDF+ Fe 50 ppm, RDF+ B 50

Table 4.4: Effect of micronutrients on number of compounds leaves of lentil

S. No.	Treatments	30 DAG	60 DAG	90 DAG
T0	**RDF**	3.00	7.53	10.27
T1	**RDF+ Zn 50 ppm**	3.27	9.13	12.53
T2	**RDF+ Zn 100 ppm**	3.20	8.67	11.93
T3	**RDF+ Fe 50 ppm**	3.80	11.13	16.07
T4	**RDF+ Fe 100 ppm**	3.33	8.13	11.00
T5	**RDF+ B 50 ppm**	3.23	11.00	15.33
T6	**RDF+ B 100 ppm**	3.27	9.93	13.33
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	3.27	9.13	12.40
	CD 5%	NS	1.97	2.53
	SEm±	0.21	0.65	0.83

ppm, and RDF+ B 100 ppm had significantly higher number of compound leaves compared to the RDF at 90 DAG. Treatment RDF+ Fe 50 ppm was statistically on par with treatment RDF+ B 50 ppm at 90 DAG stage of the crop.

4.1.5 Dry matter accumulation

The data pertaining to the dry matter accumulation was presented in the **Table 4.5 and Appendix VII.** Dry matter accumulation in the plant increased at a higher rate from 30 DAG and reached the maximum at 90 DAG. At 30 DAG there was non-significant difference among the treatments.

Table 4.5: Effect of micronutrient on dry matter accumulation

S. No.	Treatments	30 DAG	60 DAG	90 DAG
T0	**RDF**	0.285	0.601	1.603
T1	**RDF+ Zn 50 ppm**	0.277	0.687	1.968
T2	**RDF+ Zn 100 ppm**	0.240	0.544	1.848
T3	**RDF+ Fe 50 ppm**	0.282	0.963	2.474
T4	**RDF+ Fe 100 ppm**	0.278	0.712	1.579
T5	**RDF+ B 50 ppm**	0.286	0.928	2.115
T6	**RDF+ B 100 ppm**	0.257	0.698	2.101
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	0.272	0.771	1.499
	CD 5%	NS	0.129	0.380
	SEm±	0.020	0.043	0.125

Dry matter accumulation was adversely affected by the increase in micronutrient concentration as well as combination. The effect of RDF+ Fe 50 ppm (2474.33 mg) , RDF+ B 50 ppm (2115.00 mg) and RDF+ B 100 (2100.67 mg) ppm were statistically on par with each other in relation to dry matter accumulation and significantly higher than the RDF (1.603) at 90 DAG.

4.1.6 Number of nodules, dry weight of roots per plant and dry weight of shoots per plant at 50 % flowering

Data pertaining to the number of nodules per plant, dry weight of roots per plant and dry weight of shoots per plant at 50% flowering were presented in the **Table 4.6 and Appendix VIII.** No of nodules per plant, Dry weight of roots per plant and Dry weight of shoots per plant were significantly affected by the micronutrient treatments.

Table 4.6: Effect of micronutrients on number of nodules per plant, dry weight of roots per plant and dry weight of shoots per plant

S. No.	Treatments	No of nodules per plant	Dry weight of roots per plant (mg)	Dry weight of shoots per plant (mg)
T0	**RDF**	3.67	38.13	144.07
T1	**RDF+ Zn 50 ppm**	8.00	44.27	250.00
T2	**RDF+ Zn 100 ppm**	3.40	40.60	166.87
T3	**RDF+ Fe 50 ppm**	10.27	61.60	330.13
T4	**RDF+ Fe 100 ppm**	6.33	39.23	152.00
T5	**RDF+ B 50 ppm**	9.67	57.30	313.47
T6	**RDF+ B 100 ppm**	7.80	36.40	205.93
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	7.20	43.33	184.73
	CD 5%	1.51	8.66	48.71
	SEm±	0.50	2.86	16.06

RDF+ Fe 50 ppm recorded the maximum number of nodules per plant, dry weight of roots per plant and dry weight of shoots per plant at 50% flowering, whereas the lowest was recorded by the RDF. RDF+ Zn 50 ppm, RDF+ Fe 50 ppm and RDF+ B 50 ppm recorded the significantly higher number of nodules per plant, Dry weight of roots per plant and Dry weight of shoots per plant at 50 % flowering than the RDF+ Zn 100 ppm, RDF+ Fe 100 ppm and RDF+ B 100 ppm.

4.2 Yield attributing characters

All Yield attributing characters such as number of seeds per pod, number of branches per plant and number of pods per plant, 1000 seed weight and grain weight per plant were presented in **Table 4.7 and Appendix IX.** There were significance difference between the treatments in all the yield attributing characters except 1000 seed weight. The effect of RDF+ Fe 50 ppm and RDF+ B 50 ppm were significantly superior on number of seeds per pod, number of branches per plant and number of pods per plant than all the other treatments at all the growth stages of lentil

Table 4.7: Influence of micronutrient treatments on the yield attributing characters

S. No.	Treatments	Seeds per pod	Branches per plant	Pods per plant	1000 seed weight	grain weight per plant (g)
T0	**RDF**	1.60	34.87	31.60	22.77	952.27
T1	**RDF+ Zn 50 ppm**	1.83	40.07	37.47	23.07	1349.53
T2	**RDF+ Zn 100 ppm**	1.77	37.13	26.47	22.84	976.00
T3	**RDF+ Fe 50 ppm**	1.87	46.80	42.33	23.74	1526.47
T4	**RDF+ Fe 100 ppm**	1.80	35.67	30.94	22.97	1017.00
T5	**RDF+ B50 ppm**	1.83	44.80	41.33	23.40	1511.40
T6	**RDF+ B100 ppm**	1.80	39.13	37.15	22.94	1200.00
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	1.70	39.87	38.55	23.37	1254.47
	CD 5%	0.135	7.36	8.61	NS	232.28
	SEm±	0.045	2.43	2.84	0.63	76.58

RDF+ Zn 50 ppm, RDF+ Zn 100 ppm, RDF+ Fe 50 ppm, RDF+ Fe 100 ppm, RDF+ B 50 ppm and RDF+ B 100 ppm recorded significant difference for seeds per pod compared to the RDF. The maximum 1000 seed weight was recorded for RDF+ Fe 50 ppm (23.74g) and RDF+ B (23.40g) and the minimum 1000 seed weight was recorded for the RDF (22.77g).

4.3 Yield

Seed yield of lentil (kg/ha) **(Fig. 4.2),** straw yield (kg/ha), Biological yield (kg/ha), harvest index and B:C ratio were presented in the **Table 4.8 and Appendix X.** The data revealed that RDF+ micronutrient treatments had a statistically significant effect on seed yield, straw yield, Biological yield (kg/ha), harvest index and B: C ratio of lentil crop. RDF+ Fe 50 ppm (1543 kg/ha), RDF+ B 50 ppm (1479 kg/ha) and RDF+ Zn 50 ppm (1301 kg/ha) recorded significantly higher seed yield than RDF+ Fe 100 ppm (1237 kg/ha), RDF+ B 100 ppm (1299 kg/ha), RDF+ Zn 100 ppm (1217 kg/ha) and RDF+ Zn+ Fe+ B (50 ppm each). The lowest seed yield was recorded under RDF+ Zn+ Fe+ B (50 ppm each) 1191 kg / ha. Maximum seed yield was recorded in RDF+ Fe 50 ppm (1543kg/ha) and minimum was recorded in RDF (1160 kg/ha). Application of RDF+ Fe 50 ppm and RDF+ B 50 ppm along with RDF recorded 33.0% and 27.5% increase in seed yield respectively.

Table 4.8: Effect of micronutrient treatments on the seed yield (kg/ha), Straw yield (kg/ha), harvest Index and B: C ratio

S. No.	Treatments	Seed yield (kg/ ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest Index	B:C ratio
T0	**RDF**	1161	5472	6633	21.11	3.65
T1	**RDF+ Zn 50 ppm**	1301	4884	6185	26.58	4.13
T2	**RDF+ Zn 100 ppm**	1219	4888	6107	24.92	3.67
T3	**RDF+ Fe 50 ppm**	1543	5464	7007	29.99	4.57
T4	**RDF+ Fe 100 ppm**	1237	4995	6232	24.79	3.73
T5	**RDF+ B 50 ppm**	1479	4941	6420	28.27	4.35
T6	**RDF+ B 100 ppm**	1299	5274	6573	24.62	3.91
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	1191	5506	6697	21.58	3.66
	CD 5%	237.84	438.84	515.54	3.79	0.61
	SEm±	78.41	144.68	169.97	1.25	0.20

Maximum Straw yield was recorded in RDF+ Zn+ Fe+ B (50 ppm each) (5506 kg/ha) and minimum was recorded in RDF+ Zn 50 ppm (4884 Kg/ha). RDF + Fe 50 ppm, RDF+ Zn+ Fe+ B (50 ppm each) and RDF recorded significantly higher straw yield than RDF+ Zn 100 ppm.

Maximum Biological yield was recorded in RDF+ Fe 50 ppm (7007 Kg/ha) and minimum was recorded in RDF+ Zn 100 ppm (6107 Kg/ha). RDF+ Fe 50 ppm, RDF+ B 100 ppm, RDF+ Zn+ Fe+ B (50 ppm each) and RDF recorded significantly higher straw yield than RDF+ Zn 50 ppm.

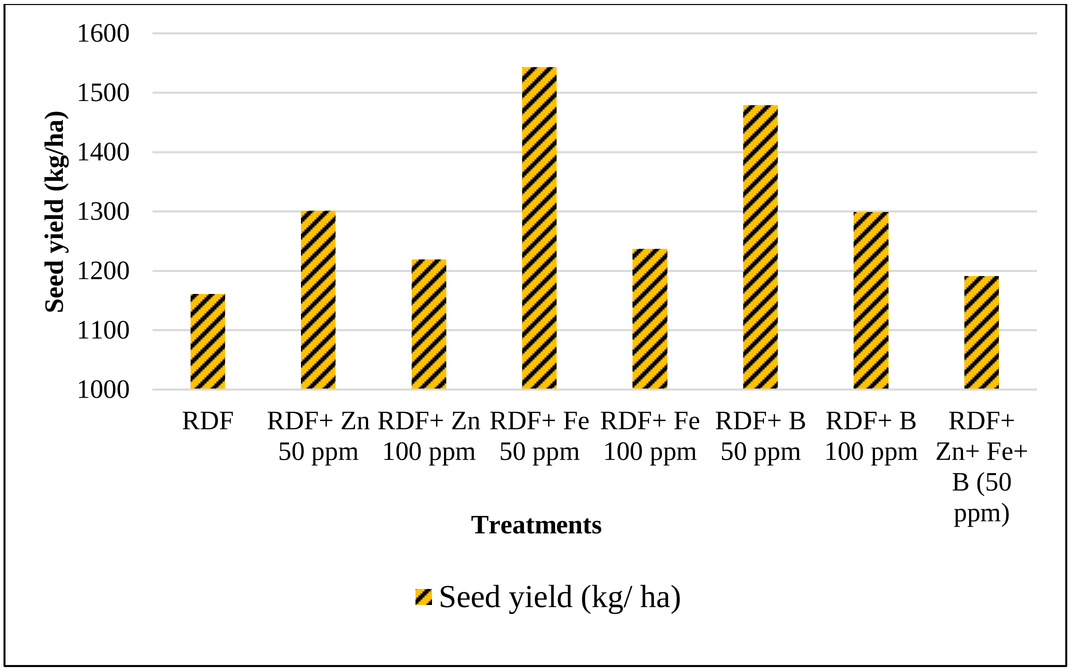


Fig. 4.2: Effect of micronutrient treatment on the yield

Maximum Harvest Index was recorded in RDF+ Fe 50 ppm (29.99) and the minimum was recorded in RDF (21.11). There was significant difference in harvest Index. RDF+ Zn 50 ppm, RDF+ Zn 100 ppm, RDF+ Fe 50 ppm and RDF+ B 50 ppm recorded significantly higher harvest index than RDF. Maximum B: C ratio was recorded for RDF+ Fe 50 ppm (4.57) which was statistically on par with RDF+ B 50 ppm (4.35) and RDF+ Zn ppm 50 (4.13) ppm. Minimum B: C ratio was recorded in RDF (3.65).

4.4 Seed quality

4.4.1 Number of viable seeds, germination percentage and un-germinated seeds

Data of number of viable seeds and germination % and number of un- germinated seeds of standard germination test and accelerated ageing test were presented in the **Table 4.9 and Appendix XI.** The table depicts that there was no significant difference among the RDF+

micronutrient treatments for number of viable seeds and almost all the seeds were viable in all the micronutrient treatments except in the treatment RDF+ B 100 ppm.

Table 4.9: Influence of micronutrient treatments on the number of viable seeds, germination percentage and number of un-germinated seeds

			Standard germination test		**Accelerated ageing test**	
S. No.	**Treatments**	**Viable seeds (%)**	**Germination (%)**	**Un-germinated seeds (%)**	**Germination (%)**	**Un-germinated seeds (%)**
T0	**RDF**	100	87.00	13.00	91.50	8.50
T1	**RDF+ Zn 50 ppm**	100	92.00	7.50	93.00	7.00
T2	**RDF+ Zn 100 ppm**	100	91.50	8.50	92.00	8.00
T3	**RDF+ Fe 50 ppm**	100	95.50	4.50	96.50	3.50
T4	**RDF+ Fe 100 ppm**	100	92.50	7.50	92.00	8.00
T5	**RDF+ B 50 ppm**	100	91.50	8.50	93.00	7.00
T6	**RDF+ B 100 ppm**	99	89.00	11.00	92.00	8.00
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	100	89.50	10.50	93.00	7.00
	CD 1%	NS	5.34	1.14	3.33	1.14
	SEm±	0.09	1.35	0.29	0.84	0.29

In the Standard Germination test RDF+ Fe 50 ppm and RDF+ Fe 100 ppm recorded significantly higher germination % and RDF+ Fe 50 ppm recorded significantly lower number un- germinated seeds compared to the RDF. The maximum germination percent was achieved by the RDF+ Fe 50 ppm (95.5%) and the minimum in the RDF (87.0%). The maximum number of un-germinated seeds were found in the RDF (13%) and the minimum in the RDF+ Fe 50 ppm (4.5%). Accelerated ageing test recoded higher germination percentage and less no of un- germinated seeds in all treatments in comparison to the standard germination test. There was significantly higher germination percentage in RDF+ Fe 50 ppm (96.5 %) compared to the RDF (91.5%). There was decrease in the number of un-germinated seeds (8.5%) in accelerated ageing test in comparison to standard germination test (13%) in RDF treatment. RDF+ Fe 50 ppm recorded the minimum no of un-germinated seeds (3.5%) in the accelerated ageing test.

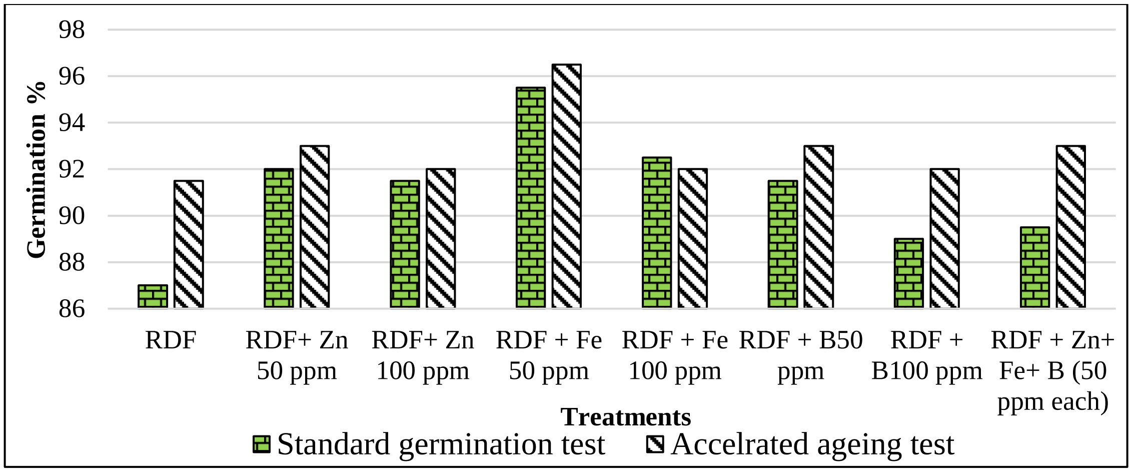


Fig. 4.3: Effect of micronutrients on germination percentage

4.4.2 Growth index

Data regarding growth index was presented in the **Table 4.10 and Appendix XII** Statistically superior growth index was recorded in RDF+ Fe 50 ppm compared to the RDF.

Table 4.10: Effect of micronutrients on growth index

S. No.	Treatments	4th day	5th day	6th day	7th day	8th day
T0	**RDF**	7.77	9.95	13.30	16.59	19.21
T1	**RDF+ Zn 50 ppm**	7.94	10.95	14.31	18.48	21.52
T2	**RDF+ Zn 100 ppm**	7.77	11.10	14.78	17.98	21.18
T3	**RDF+ Fe 50 ppm**	8.41	11.38	16.33	19.15	22.53
T4	**RDF+ Fe 100 ppm**	8.02	10.91	15.16	18.30	20.22
T5	**RDF+ B 50 ppm**	8.27	10.66	13.89	17.61	20.87
T6	**RDF+ B 100 ppm**	7.63	10.38	14.67	18.03	19.34
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	7.85	10.62	13.90	17.50	19.83
	CD 1%	0.57	0.94	1.70	1.44	2.26
	SEm±	0.14	0.24	0.43	0.36	0.57

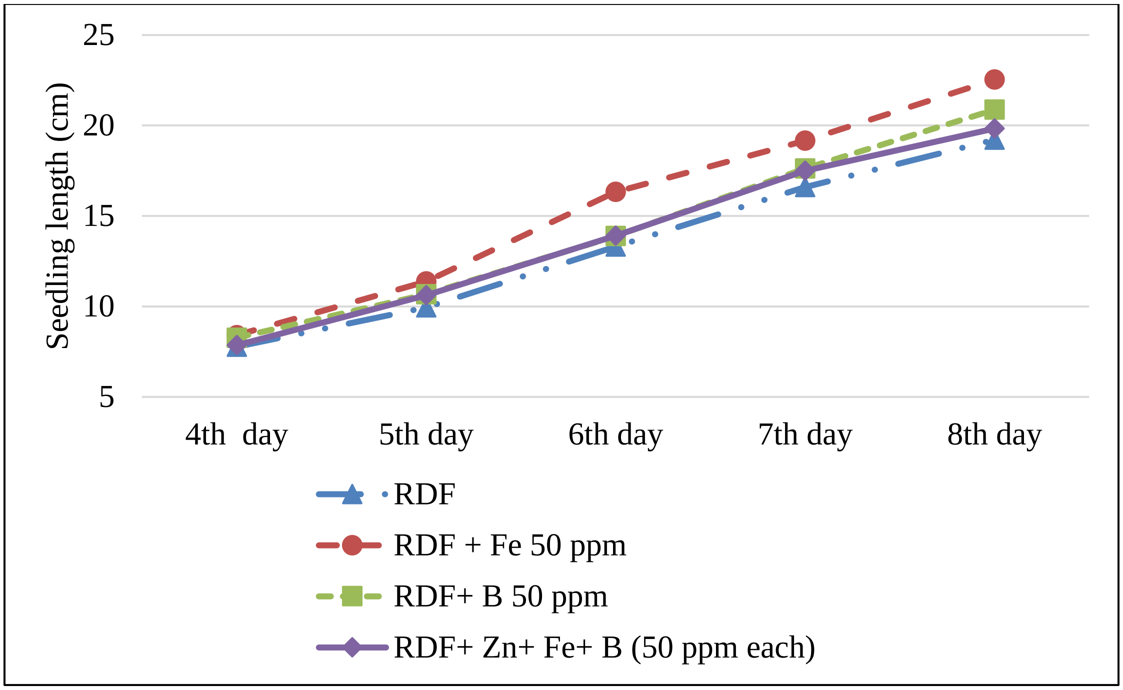


Fig. 4.4: Effect of micronutrient treatment on the seedling growth index

On 8th day there was 17.2% higher growth index recorded in the RDF+ Fe 50 ppm than RDF, while 7.9% higher growth index in RDF+ Fe 50 ppm than RDF+ B 50 ppm. RDF+ Fe 50 ppm recorded the maximum growth index on all the days from 4th to 8th day which was followed by RDF+ B 50 ppm and the lowest growth index was recorded for RDF on all the days **(Fig. 4.4)**

4.4.3 Standard germination and Accelerated ageing test

Data pertaining to first count, final count and vigour index I and II under standard germination and accelerated ageing test were given in the **Table 4.11 and Appendix XIII** RDF+ Fe 50 ppm recorded significantly higher first count, final count, Vigour index I and II in both standard germination and accelerated ageing test compared to the RDF. Both first count and final count recorded maximum in all the treatments in accelerated ageing test except RDF+ Fe 100 ppm compared to the Standard germination test.

Vigour index I and II were decreased in all the treatments under accelerated ageing test compared to the standard germination test. RDF+ Fe 50 ppm recorded maximum vigour index I (3175) and vigour index II (1976) under standard germination test and while accelerated ageing test recorded 2845; vigour index I and 1930; vigour index II in RDF+ Fe 50 ppm.

4.4.4 Cold test and Cool germination test

Data related to germination percentage and vigour index I and II under cold test and cool germination test were given in the **Table 4.12 and Appendix XIV.** RDF+ Fe 50 ppm recorded significantly higher germination percentage, Vigour index I and II in both cold test and cool germination test compared to the RDF.

The lowest germination percentage, vigour index I and II in both cold test and cool germination test were recorded in the treatment RDF+ Zn+ Fe+ B (50 ppm each).

Germination percentage, vigour index I and II of cool germination was higher than germination percentage, vigour index I and II of cold test.

Table 4.12: Influence of micronutrient treatments on cold test and cool germination test

		Cold test			**Cool germination test**		
S. No.	**Treatments**	**Germination (%)**	**Vigour index 1**	**Vigour index 2**	**Germination (%)**	**Vigour index 1**	**Vigour index 2**
T0	**RDF**	88.50	1488	1715	93.50	1851	1637
T1	**RDF+ Zn 50 ppm**	97.00	1773	1849	97.00	2263	1883
T2	**RDF+ Zn 100 ppm**	96.50	1568	1848	95.50	2078	1805
T3	**RDF+ Fe 50 ppm**	98.00	1966	2218	98.00	2285	2050
T4	**RDF+ Fe 100 ppm**	96.00	1725	1851	94.50	2003	1823
T5	**RDF+ B 50 ppm**	96.00	1642	1810	96.50	2119	1855
T6	**RDF+ B 100 ppm**	96.00	1710	1808	96.25	1984	1835
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	92.00	1643	1755	93.50	2075	1648
	CD 1%	6.43	278.89	270.21	2.61	268.92	252.14
	SEm±	1.63	70.51	68.31	0.66	67.99	63.74

Table 4.11: Effect of micronutrient treatments on the first count, final count and vigour index I and II under standard germination and accelerated ageing test

		Standard germination				Accelerated Ageing Test			
S. No.	**Treatments**	**First count**	**Final count**	**Vigour index 1**	**Vigour index 2**	**First count**	**Final count**	**Vigour index 1**	**Vigour index 2**
T0	**RDF**	84.8	87.0	2412	1575	83.5	91.5	2379	1616
T1	**RDF+ Zn 50 ppm**	88.5	92.0	2770	1807	91.5	93.0	2549	1741
T2	**RDF+ Zn 100 ppm**	89.0	91.5	2834	1728	91.5	92.0	2418	1698
T3	**RDF+ Fe 50 ppm**	94.5	95.5	3176	1976	92.0	96.5	2845	1930
T4	**RDF+ Fe 100 ppm**	92.0	92.5	2794	1751	90.0	92.0	2472	1630
T5	**RDF+ B 50 ppm**	91.0	91.5	2551	1715	92.0	93.0	2644	1760
T6	**RDF+ B 100 ppm**	83.5	89.0	2317	1681	90.0	92.0	2524	1768
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	85.5	89.5	2666	1680	85.5	93.0	2543	1685
	CD 1%	7.65	5.34	359.26	245.81	6.71	3.33	289.43	190.67
	SEm±	1.93	1.35	90.83	62.14	1.70	0.84	73.17	48.20

4.4.5 Speed of germination

Table 4.13: Influence of micronutrient treatments on speed of germination

S. No.	Treatments	4^{th} day	5^{th} day	6^{th} day	7^{th} day	8^{th} day
T0	**RDF**	8.0	50.5	74.5	81.0	85.0
T1	**RDF+ Zn 50 ppm**	18.5	54.0	79.5	87.0	92.5
T2	**RDF+ Zn 100 ppm**	20.0	56.0	81.0	89.0	90.3
T3	**RDF + Fe 50 ppm**	12.5	61.5	83.5	91.5	95.5
T4	**RDF + Fe 100 ppm**	17.5	60.5	79.0	91.0	93.3
T5	**RDF + B50 ppm**	16.5	58.0	78.5	88.0	89.8
T6	**RDF + B100 ppm**	11.0	49.5	73.5	83.5	88.0
T7	**RDF + Zn+ Fe+ B (50 ppm each)**	19.5	56.5	75.5	86.0	89.5
	CD 1%	1.34	7.30	7.06	6.83	6.72
	SEm±	0.34	1.85	1.79	1.73	1.70

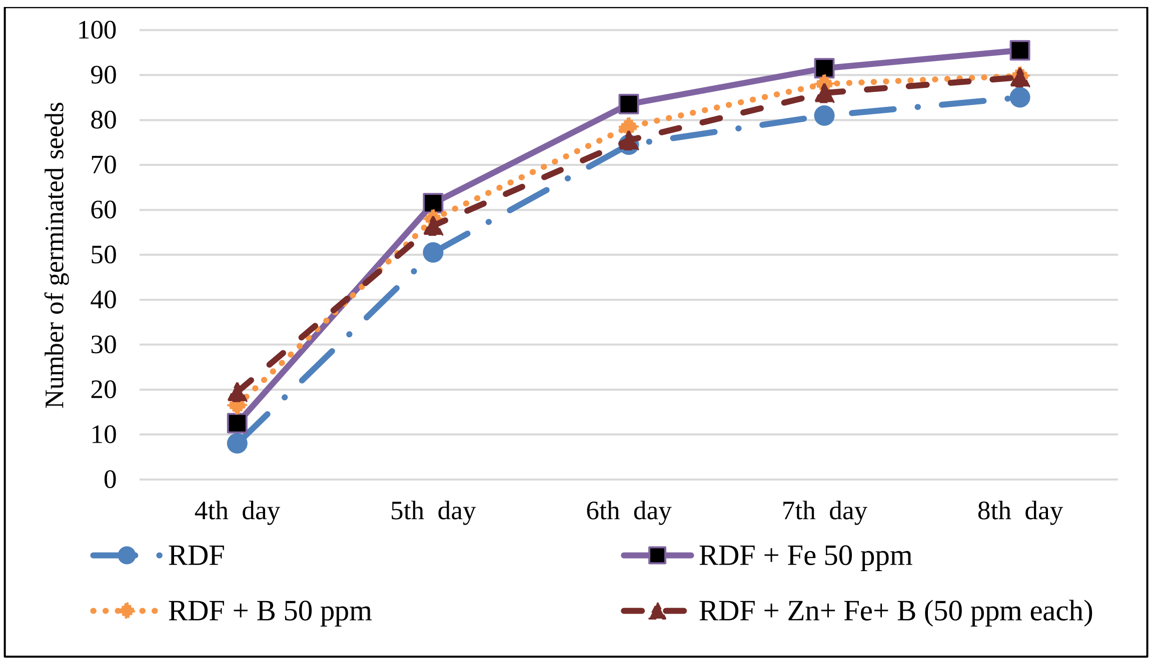


Fig. 4.5: Influence of micronutrients on speed of germination

Speed of germination data were presented in the **Table 4.13 and Appendix XV.** RDF+ Fe 50 ppm recorded significantly higher speed of germination with respect to RDF. On 8^{th} day there was 12.3% higher speed of germination in RDF+ Fe 50 ppm than RDF, while 6.4% higher speed of germination was recorded in RDF+ Fe 50 ppm than RDF+ B 50 ppm. Speed of germination was found maximum for RDF+ Fe 50 ppm on 5th day and onwards **(Fig. 4.5).**

4.4.6 Seed metabolic efficiency, mobilization efficiency and absorbance of seed hydrogenase at 480 nm

Seed metabolic efficiency, mobilization efficiency and absorbance of seed hydrogenase @ 480 nm were given in the **Table 4.14 and Appendix XVI.**

RDF+ Fe 50 ppm recorded significantly higher mobilization efficiency and absorbance of seed hydrogenase @ 480 nm compared to the RDF. Seed metabolic efficiency was recorded statistically lower in RDF+ Fe 50 ppm in comparison to RDF.

Table 4.14: Influence of micronutrient treatments on seed metabolic efficiency, mobilization efficiency and absorbance of seed hydrogenase @ 480 nm

S. No	Treatments	Seed metabolic efficiency	Mobilization Efficiency	Absorbance of seed hydrogenase @ 480 nm
T0	**RDF**	1.71	50.49	619
T1	**RDF+ Zn 50 ppm**	2.15	64.66	713
T2	**RDF+ Zn 100 ppm**	2.60	59.12	683
T3	**RDF+ Fe 50 ppm**	1.06	72.18	984
T4	**RDF+ Fe 100 ppm**	1.48	61.47	645
T5	**RDF+ B 50 ppm**	1.68	63.50	761
T6	**RDF+ B 100 ppm**	1.96	54.51	620
T7	**RDF+ Zn+ Fe+ B (50 ppm each)**	1.58	54.92	748
	CD 1%	0.24	7.33	96.34
	SEm±	0.06	1.85	24.36

4.4.7 Water sensitivity test

Water sensitivity observations were presented in **Table 4.15 and Appendix XVII** Data revealed that RDF+ Fe 50 ppm recorded significantly higher seedling fresh weight (mg), seedling dry weight (mg) and seedling length (cm) in both higher and lower moisture condition in comparison to the RDF. Seedling dry weight under low moisture condition was recorded higher than the high moisture condition under water sensitivity test **(Fig. 4.6).**

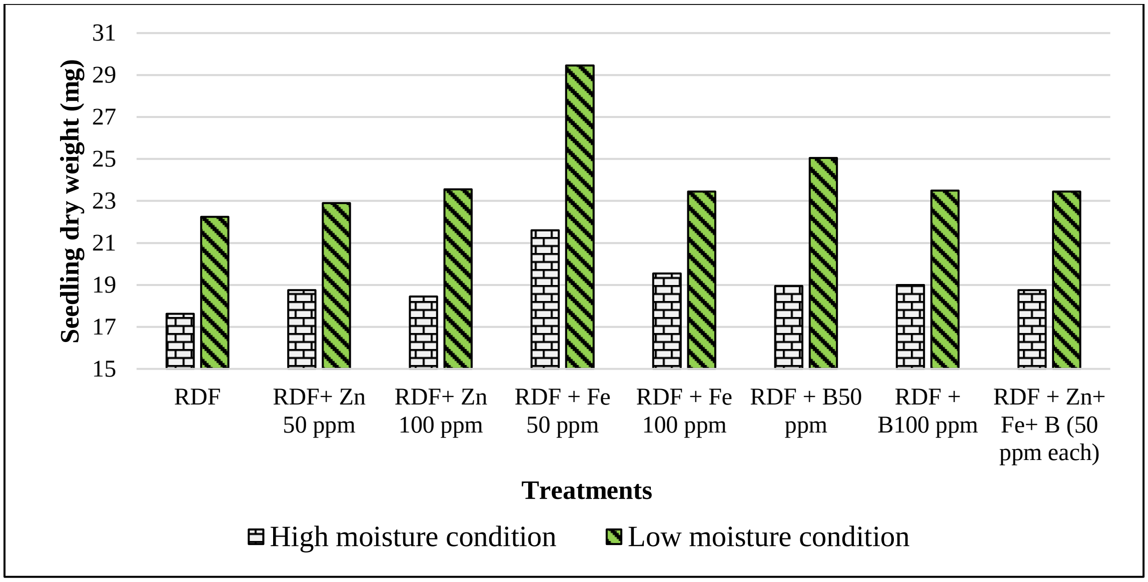


Fig. 4.6: Influence of micronutrients on water sensitivity of lentil crop

Table 4.15: Effect of micronutrient treatment on water sensitivity

		High moisture condition			Low moisture condition		
Sl. No	**Treatments**	**Seedling fresh weight (mg)**	**Seedling dry weight (mg)**	**Seedling length (cm)**	**Seedling fresh weight (mg)**	**Seedling dry weight (mg)**	**Seedling length (cm)**
T0	**RDF**	177.65	17.63	27.61	177.65	22.25	27.51
T1	**RDF+ Zn 50 ppm**	188.35	18.75	30.21	188.35	22.90	28.61
T2	**RDF+ Zn 100 ppm**	191.45	18.45	28.45	200.20	23.55	29.07
T3	**RDF + Fe 50 ppm**	221.23	21.60	33.40	217.48	29.45	32.86
T4	**RDF + Fe 100 ppm**	197.40	19.55	29.74	203.65	23.45	27.99
T5	**RDF + B 50 ppm**	188.50	18.95	29.02	201.00	25.05	27.89
T6	**RDF + B100 ppm**	191.15	19.00	29.90	191.15	23.50	27.95
T7	**RDF + Zn+ Fe+ B (50 ppm each)**	180.90	18.75	29.72	180.90	23.45	28.36
	CD 1%	26.56	2.44	2.82	26.23	2.59	2.90
	SEm±	6.71	0.62	0.71	6.63	0.65	0.73

Chapter 5 DISCUSSION

The experimental evidences were presented the in foregoing chapter, in order to quantify the relative contribution of different micronutrient treatments, provide a detailed account of performance of lentil in terms of growth, seed yield and seed quality. The major experimental findings, their cause and effect relationship have been discussed with possible scientific causes and support of available literatures as follows:

Application of micronutrient treatment RDF+ Fe 50 ppm which was statistically on par with the RDF+ B 50 ppm increased the plant height **(Table 4.2)**, plant spread **(Table 4.3),** number of compound leaves **(Table 4.4)**, dry matter accumulation **(Table 4.5)**, nodules per plant , dry weight of roots per plant and dry weight of shoots per plant **(Table 4.6)**. RDF+ Fe 50 ppm performed very well since iron acts as catalyst in the synthesis of chlorophyll molecule and helps in the absorption of other elements and it is also a key element in various redox reactions of respiration, photosynthesis and reduction of nitrates and sulphate as supported by Yellamandha and Sankara, (2002).Higher plant height might be due to presence of iron which helps in higher energy transfer within the plant, also acts as a component of enzymes (like phytase), proteins, nitrogen fixation and by increasing iron concentration in root cells as reported by Abbas *et al*., (2012). Increase in plant spread which is mostly due to the higher internodal length which was increased by the higher biosynthesis of gibberellin, caused by iron application, same result was also reported by as Hansch and Mendel, (2009).

Higher plant dry weight and number of branches per plant were recorded since, Fe had a more pronounced effect during the vegetative growth period of the plant which was also reported by Fawzi (1993) in pea and cowpea.

As given in the table plant growth in terms of plant height, plant spread, no of compound leaves, dry matter accumulation and nodules were increased slowly from germination till 90 DAG due to less temperature during that period and there by soaring to the maximum at harvest stage of the crop was mainly due to the rise in temperature.

Final yield of the crop is the cumulative effect of yield attributes and factors, which directly and indirectly influence grain yield **(Table 4.8 and Fig. 4.2)**. The crop can only fetch us a good reap if it's having maximum leaf area for the photosynthesis. The results obtained during the investigation indicate that applying RDF+ Fe 50 ppm increased most of the yield attributing characters such as number of seeds per pod, number of branches per plant, number of pods per plant and 1000 seed weight **(Table 4.7)**. Bahrani (2014) also reported similar results, the increase in number of pod per plant, kernel weight per plant and 1000-kernel weight in rapeseed with the application of iron as foliar spray. Fe application caused a significant increase in the number of ear heads per tiller, number of seeds per ear, grain yield per plant and 1000 grains weight in rice, as reported by Hemantranjan and Grag, (1988).

Higher grain yield, biological yield and harvest index were recorded under RDF+ Fe 50 ppm **(Table 4.8)** in comparison to the control, might be since, iron improves photosynthesis and assimilates transportation to sinks and finally increased seed yield as reported by Ebrahimian and Ahmed, (2011) and Bameri *et al* (2012). Hemantaranjan and Grag, (1988) also reported that iron had significant role in formation of chlorophyll, and increasing photosynthetic products rate, photosynthetic material devoted to grain and the grain weight.

All the growth parameters like plant height and plant spread were reduced at 100 ppm concentration of micronutrients than 50 ppm concentration without any visual toxicity symptom which may be because slightly higher concentration of micronutrient at 100 ppm. Lee (1996) reported similar results as beyond 2 mM B concentration in the nutrient solution caused stunted plant growth with reduced leaf size and marginal necrosis and also stated there was no visual symptoms of toxicity until Fe levels in the solution exceeded 4 mM, thereafter beyond 5 mM concentration it reduced leaf sizes and produced large purplish-black spots in some leaves in seed geranium.

The yield and some other growth parameters were greatly reduced in the treatment RDF+ (Zn+ Fe+ B) 50 ppm, might be due to the interaction of Zn, B, and Fe in the spray solution and formation of higher micronutrient concentration beyond tolerable limit in the sprayed solution which adversely affected the performance of the crop, similar results were also reported by Fageria (2001).

Seed quality parameters like growth index **(Table 4.10 and Fig. 4.4)**, speed of germination **(Table 4.13 and Fig. 4.5)**, higher germination percentage **(Table 4.11 and Fig. 4.3)**, lower number of un-germinated seeds **(Table 4.9)**, vigour index I and II both in standard germination test and accelerated ageing test **(Table 4.11)** were recorded under RDF+ Fe 50 ppm, which might be due to the earliness in germination caused by enhanced metabolites and their activity, which helps in resumption of embryonic growth during germination. Foliar application of iron increased concentration of N, P, K, Ca, Mg, Fe, Mn and Zn in the seeds of the on the mother plant. Similar results were presented by Hamouda (2015) and Radpoor and Rimaz, (2007) in case of priming of dill seeds with $FeSO_4$. Speed of germination is one of the oldest seed vigor concepts. Higher Seed vigour index I and II represents higher speed of germination because they are positively correlated to each other, that was also reported by Rezapour-Osalou (2015) in corn with application of Fe_3O_4.

Even though all the seeds were viable **(Table 4.9)** standard germination test had more number of un-germinated seeds in comparison to the accelerated ageing test, the reason might be the reduction of dormant seeds. The harvested seeds might had immature embryos thereby reducing the germination percentage in the standard germination test, as the seeds were artificially aged in the Accelerated ageing test the number of immature seeds reduced and the germination percentage increased in the Accelerated ageing test, similar results were reported by Dresch *et al*. (2014) in case of *A. coriacea* .

In case of accelerated ageing test **(Table 4.9)** germination percentage was higher due to hastened dormancy loss by increasing the storage temperature that was reported by Baldos and DeFrank, (2014) and Li *et al.* (2005) in *D. Sophia* seeds.

Table 4.11 shows the comparison between Standard germination test and the accelerated ageing test, where in there is increase in the first count and final count in the standard germination test in all the treatments but decrease in the vigour index I and II compared to the accelerated ageing test. Possible reason may be the adverse effect of higher temperature along with higher humidity on the seeds which might have increased the respiration rate and metabolic rate there by reducing the stored food material of the seed and loss of integrity of the membrane. Similar findings were reported by Jain *et al.* (2006) and Copeland and McDonald (2001).

The rate of germination are strongly governed by temperature. Negi *et al.* (1995). The data regarding cold and cool germination **(Table 4.12)** depicts that, there was increase in germination percentage in all the treatments in comparison to the standard germination and accelerated ageing test. There was increased Seed vigour index I of cool germination test in comparison to the cold test. The phenomenon behind may be due to the decrease in the number of un-germinated seeds as a result of cold temperature treatment for seven days both in cold test and cool germination test which has reduced the seed dormancy considerably. Since lentil is a cold season crop which may require a low temperature before the germination for higher field stand of the crop as evident from Pons (1993) who stated as temperature affects the germination and the state of dormancy of the seeds and the seasonal changes of the dormancy state of the seeds of some species is directly related to the seasonal temperature changes.

From the **Table 4.14** it's evident that RDF+ Fe 50 ppm recorded significantly higher Seed metabolic efficiency and Absorbance of seed hydrogenase @ 480 nm, and significantly lower mobilization efficiency for RDF+ Fe 50 ppm might be due to increased performance in terms of seedling growth, higher enzymatic activity, production of higher plant growth promoting substances like gibberellins, and auxins and higher concentration of some macro and micro nutrients in the seeds as a result of foliar application of iron.

The micronutrient spray RDF+ Fe 50 ppm recorded higher seedling dry weight in low moisture condition than in the higher moisture condition **(Table 4.15)**. The possible reason may that those plant under moisture stress have accumulated more sugars for osmoregulation, might have increased the carbon accumulation in the plant and they might have planned for early flowering to escape from the drought condition. That was also reported by Akıncı (1997). The findings of Kramer and Boyer, (1995) also support that

Dehydration postponers with higher water use efficiency would accumulate more dry weight under moisture stress condition.

Chapter 6 SUMMARY AND CONCLUSION

The present investigation entitled "Effect of foliar sprays of boron, iron and zinc on plant growth, seed yield and seed quality of lentil (*Lens culinaris* Medik.)" was carried out during 5th November 2015 to 21st April 2016 at crop improvement block and Department of Seed Science and Technology, V. C. S. G. UUHF, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand.

Experimental treatments include T0- RDF, T1- RDF+ Zn 50 ppm, T2- RDF+ Zn 100 ppm, T3- RDF+ 50 ppm, T4- RDF+ Fe 100 ppm, T5- RDF+ B 50 ppm, T6- RDF+ B 100 ppm and T7- RDF+ Zn+ Fe+ B (50 ppm each).

A field experiment was conducted in a randomized block design to find out the effect of foliar spray of micronutrients on the plant growth, seed yield and seed quality of lentil. The observations recorded on characters namely plant height, plant spread, number of compound leaves, dry matter accumulation, plant population, mortality percentage, number of nodules, dry weight of roots per plant and dry weight of shoots per plant, seeds per pod, branches per plant, pods per plant, 1000 seed weight, grain weight per plant, grain yield, straw yield, biological yield, harvest index and B: C ratio.

The laboratory experiments were conducted in complete randomized design with four replications to investigate the quality of seed. The observations were recorded under laboratory condition on seed quality parameters, viz., viable seeds, un-germinated seeds, growth index, first count, final count, vigour index I, vigour index II, accelerated ageing test, cold test, cool germination test, speed of germination, seed metabolic efficiency, mobilization efficiency, absorbance of seed hydrogenase @ 480 nm and water sensitivity.

The data obtained during the course of investigation in the field and lab were analyzed by using standard statistical procedure for randomized block design (CD @ 5% level of significance) and complete randomized design (CD @ 1% level of significance) respectively.

The experimental findings are summarized below:

- ☒ RDF+ Fe 50 ppm registered significantly lower plant mortality percentage during the growth period.
- ☒ There was no significant difference in initial plant population among the RDF+ micronutrient treatments.
- ☒ RDF+ Fe 50 ppm recorded significantly higher plant height, plant spread, number of compound leaves, dry matter accumulation and plant population during maturity.
- ☒ Number of nodules, dry weight of roots per plant and dry weight of shoots per plant at 50% flowering stage were significantly higher in RDF+ Fe 50 ppm in comparison to the RDF.
- ☒ The effect of RDF+ Fe 50 ppm and RDF+ B 50 ppm were significantly superior on number of seeds per pod, number of branches per plant and number of pods per plant, 1000 seed weight and grain weight per plant.
- ☒ Significantly higher grain yield was recorded in RDF+ Fe 50 ppm (1543kg/ha) in comparison to the RDF (1160 kg/ha). Application of RDF+ Fe 50 ppm and RDF+ B

50 ppm along with RDF recorded 33.0% and 27.5% increase in grain yield respectively.

- RDF+ Fe 50 ppm, RDF+ Zn+ Fe+ B (50 ppm each) and RDF recorded significantly higher straw yield than RDF+ Zn 100 ppm.
- Maximum Straw yield was recorded in RDF+ Zn+ Fe+ B (50 ppm each) (5506 kg/ha) and minimum was recorded in RDF+ Zn 50 ppm (4884 Kg/ha).
- RDF+ Fe 50 ppm recorded significantly higher biological yield, harvest index and B: C ratio in comparison to the RDF. For every rupee spent in the production of lentil crop, we got Rs. 4.57 and Rs. 4.35 rupees in RDF+ Fe 50 ppm and RDF+ B 50 ppm respectively.
- RDF+ Fe 50 ppm recorded significantly higher viable seeds, first count, final count, vigour index I, vigour index II in standard germination test and accelerated ageing test.
- RDF+ Fe 50 ppm recorded significantly superior germination percentage, vigour index I and vigour index II in cold test and cool germination test.
- Significantly higher growth index and speed of germination were recorded for RDF+ Fe 50 ppm.
- Mobilization efficiency, absorbance of seed hydrogenase @ 480 nm and water sensitivity were found significantly higher in case of RDF+ 50 ppm in comparison to the control.
- RDF+ Fe 50 ppm recorded significantly lower un-germinated seeds (%) and seed metabolic efficiency in comparison to the RDF.

Conclusion:

Based on the results of this experiment, it could be concluded that foliar spray with micronutrients along with RDF increase plant growth, grain yield and seed quality.

In the light of results summarized above it can be concluded that, for getting higher grain yield and seed quality of **lentil (VL-126)** farmers of Uttarakhand use **RDF (N:P:K-20:40:20 kg/ha)** along with two foliar spray of RDF+ Fe 50 ppm at 30 DAG and 50% flowering. On the basis of benefit cost ratio farmer can gain **Rs.4.57** with every rupee invested in case the of RDF+ Fe 50 ppm.

Chapter 7 LITERATURE CITED

Abbas, G.; Hussain, F.; Anwar, Z.; Khattak, J.Z.K.; Ishaque, M. and Asmat, U. 2012. Effects of iron on the wheat crop (*Triticum aestivum* L.) by uptake of nitrogen, phosphorus and potassium. *Asian J. Agric. Sci.* **4(3)**: 229-235.

Abdel-Latif, M.E. and El-Haggan, A. 2014. Effect of micronutrients foliar application on yield and quality traits of soybean cultivars. *Int. J. of Agric. and Crop Sci*.7-11.

Abdul-Baki, A.A. and Anderson, J.D. 1973. Vigour determination in soybean seeds by multiple criteria. *Crop Sci.* **13**: 630-632.

Ahlawat, I.P.S. 2012. Agronomy- Rabi crops, Lentil. Division of Agronomy. Indian Agricultural Research Institute, New Delhi.

Akıncı, S. 1997. Physiological responses to water stress by *Cucumis sativus* L. and related species. Ph. D. Thesis, University of Sheffield. U. K.

Arvindkumar, P.R.; Vasudevan, S.N.; Patil, M.G. and Rajrajeshwari, C. 2012. Influence of NAA, triacontanol and boron spray on seed yield and quality of bitter gourd *(Momordica charantia*) cv. Pusa visesh. *The Asian J. of horti*. **7**: 36-39.

Aytac, Z.; Gulmezoglu, N.; Sirel, Z.; Tolay, I. and Torun, A.A. 2014. The Effect of Zinc on yield, yield components and micronutrient concentrations in the Seeds of Safflower Genotypes (*Carthamus tinctorius* L.). *Not. Bot. Horti. Agrobo*. **42(1)**: 202-208.

Babaeian, M.; Tavassoli, A.; Ghanbari, A.; Esmaeilian, Y. and Fahimifard, M. 2011. Effects of foliar micronutrient application on osmotic adjustments, grain yield and yield components in sunflower (Alstar cultivar) under water stress at three stages. *African J. of Agric. Research.* **6(5)**: 1204-1208.

Bahrani, A. 2015. Effect of some micro and macro nutrients on seed yield and oil content of rapeseed (*Brassica Napus L*.). *Int. J. of Che. Envi. & Biological Sci.* **3(1)**: 2320-4087.

Baldos, O.C. and DeFrank, J. 2014. Storage humidity and temperature affect dormancy loss and viability of tanglehead (*Heteropogon contortus*) Seeds. *Hortscience.* **49(10)**:1328–1334.

Bameri, M.; Abdolshahi, R.; Mohammadi-Nejad, G.; Yousefi, K. and Tabatabaie, S.M. 2012. Effect of different microelement treatment on wheat (*Triticum aestivum* L.) growth and yield. *Intl. Res. J. Appl. Basic. Sci.,* **3 (1)**: 219-223.

Bellaloui, N.; Hu, Y.; Mengistu, A.; Kassem, M.A. and Abel, C.A. 2013. Effects of foliar boron application on seed composition, cell wall boron, and seed δ15n and δ13c isotopes in water-stressed soybean plants. *Plant Nutrition.* **4**: Article 270.

Blum, A. 1989. Breeding methods for drought resistance. *In*: Plants under stress: Biochemistry, physiology and ecology and their application to plant improvement. Cambridge University Press, Cambridge. pp. 197-215.

Cervilla, L.M.; Blasco, B.; Rios, R.J.; Romero, L. and Ruiz, J.M. 2007. Oxidative stress and antioxidants in tomato (*Solanum lycopersicum)* plants subjected to boron toxicity. *Annals of Bot.* **100**: 747-756.

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

Choi, J.M.; Pak, C.H. and Lee, C.W. 1996. Micro nutrient toxicity in french marigold. *J. of Plant Nutrition*. **19(6)**: 901-916.

Copeland, L. and McDonald, M. B. 2001. Seed Science and Technology,4th Edition, Kluwer Academic Publishers. pp. 192- 229

Daiane, D.M.; Silvana, P.Q.S. and Tathiana, M.E. 2014. Effect of storage in overcoming seed dormancy of *Annona coriacea* Mart. Seeds. *A. of the Brazilian Academy of Sci*. **86(4)**: 2077-2085.

Deepika, C. and Pitagi, A. 2015. Effect of zinc and boron on growth, seed yield and quality of radish *(Raphanus sativus L.)* Cv. Arka Nishanth. *Current Agric. Research J.* **3(1)**: 85-89.

Delouche, Y.C. and Baskin, C. 1973. Accelerated ageing techniques for predicting the relative storability of seeds lots. *Seed Sci. Technol.* **1**: 427-452.

Devagiri, G.M. 1988. Evaluation of seed source variation in seed and seedling traits in *Dalbergia sissoo Roxb*. Thesis Ph. D, FRI, Dehradun. pp.190.

Dresch, D. M.; silvana P. Q.; Scalon and T. E. Masetto. 2014. Effect of storage in overcoming seed dormancy of *Annona coriacea* Mart. Seeds. *An Acad. Bras. Cienc*. **86 (4).**

Du, W.H.; Tian, X.H.; Cao, Z.Z. and Humphries, A. 2009. Effects of Micronutrients on Seed Yield and Yield Components of Alfalfa. *Journal of Plant Nutrition*. **32**: 809–820.

Ebrahimian, E. and Ahmed, B. 2011. Effect of iron foliar fertilization on growth, seed and oil yield of sunflower grown under different irrigation regimes. *Middle-East J. of Sci. Res.* **9 (5)**: 621-627.

Elangaivendhan, A.; Barad, A.V.; Nilima, B. and Pooja, M. 2016. Effect of multi-micronutrient formulations on growth, flowering behavior and yield in ratoon crop of spider lily (*Hymenocallis literolis L*) Cv. Local. *Int J of Agric sci.* **8(46)**: 1929-1932.

Ezzat, F.M.A.; Takruri, H.R.; Issa, A.Y. 2012. Role of lentils (*Lens Culinaris L*.) in human health and nutrition: A review. *J. Nutr*. **6**: 3-16.

Fageria, V. D. 2001. Nutrient interactions in crop plants. *J. of plant nutrition*, **24(8):** 1269-1290.

Fang, A. Y.; Wang, L.; Xin, Z.; Zhao, L.; An, X. and Hu, Q. 2008. Effect of foliar application of zinc, selenium, and iron fertilizers on nutrients concentration and yield of rice grain in China. *J. Agric. Food Chem.* ***56:*** 2079–2084.

Fawzi, A.F.A.; El-Fouly, M.M. and Moubarak, Z.M. 1993. The need of grain legumes for iron, manganese, and zinc fertilization under Egyptian soil conditions: effect and uptake of metalosates. *J. of Plant Nutrition*, **16(5)**: 813-823.

Gogoi, S.; Das, M. R.; Bora, P. and Mazumder, N. 2014. Effect of foliar application of nutrients on fruit and seed production of brinjal. *IJAAS*. **2**: 23-27.

Gupta, U.; Jame, Y.W.; Campbell, C.A.; Leyshon, A.J. and Nicholaichuk, W. 1985. Boron toxicity and deficiency: A review. *Canadian J. of Soil Sci.* **65**: 381-409.

Hamouda, H.A.; El-Dahshouri, M.F.; Manal, F.M. and Thalooth, A.T. 2015. Growth, yield and nutrient status of wheat plants as affected by potassium and iron foliar application in sandy soil. *Int. J. of Chem. Tech. Research*. **8(4)**: 1473-1481.

Hansch, R. and Mendel, R.R. 2009. Physiological functions of mineral micronutrients (Cu, Zn, Mn, Fe, Ni, Mo, B, and Cl). *C. Opinion in Pla. Bio*. **12**: 259-266.

Hemantaranjan, A. and Grag, O.K. 1988. *J. Plant Nutr.* **11**: 1439-1450.

Hosseini, Z. and Poorakbar, L. 2013. Zinc toxicity on anti-oxidative response in (*Zea mays* L.) At two different P^H. *J. of Stress Physiology & Bio-chem*. 9(1): 66-73.

Indiastat.org, 2016. http://www.indiastat.com/agriculture/2/pulses/17213/masoorlentil/19570/stats.aspx

International Seed Testing Association. 1995. Handbook of Vigour Test Methods. 3rd ed. Internaitonal Seed Testing Association. Zurich. Switzerland.

Iqtidar, A. and Rahman, S.F. 1984. Effect of boron on the protein and amino acid composition of wheat grain. *J. Agric. Sci.*, **2:** 75-80.

Jain, N.; Koopar, R. and Saxena, S. 2006. Effecet of ageing on seeds of radish. *Asian j. of plant Sci*. **5(3)**: 461-464.

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*). *Nepal expl agric*. **41**:427-448.

Jones, M. M.; Osmond, C. B. and Turner, N. C. 1980. Accumulation of solutes in leaves of sorghum and sunflower in response to water deficits. *J. Plant Physiol*. **7**: 193-205.

Kabata-Pendias, A. and Pendias, H. 1999. Biogeochemistry of trace elements. PWN, Warsaw, Poland. 398.

Karan, D.; Singh, S.B. and Ramkewal. 2014. Effect of Zinc and Boron application on Yield of Lentil and Nutrient Balance in the Soil under Indo-Gangetic Plain Zones. *J. of agrisearch.* **1(4)**: 206-209.

Khathutshelo, M.V.; Mpumelelo, N.; Wonder, N. and Fhatuwani, M.N. 2016. Effects of foliar spray application of selected micronutrients on the quality of bush tea. *Hortscience.* **51(7)**: 873-879.

Kramer, P. J. and Boyer, J. S. 1995. Water relations of plants and soils. Academic Press. San Diego.

Kumar, A.; Rathi, B. and Kumar, S. 2015. Effects of PGPR, sulphur, and some micronutrients on protein, carbohydrate, and fat contents in lentil (*Lens culinaris*). *Legume Research*, **38(5):** 707-709.

Kumari, S. 2012. Effect of micronutrients on quality of fruit and seed in tomato (*Solanum lycopersicum* L). *Int. J. of Farm Sci.* **2(1)**: 43-46.

Kurtz, C. and Ernani, P.R. 2010. Onion yield influenced by micronutrient application. *R. Bras. Ci. Solo*, **34**: 133-142.

Lee, C.W.; Choi, J.M. and Pak, C.H. 1996. Micronutrient toxicity in seed geranium (*Pelargonium* × *hortorum*). *J. Amer. Soc. Hort. Sci*. **121(1)**: 77-82.

Li, W.Q.; Liu, X.J.; Khan, M.A.; Kamiya, Y.; Yamaguchi, S. 2005. Hormonal and environmental regulation of seed germination in flixweed (*Descurainia sophia*). *Plant Growth Regul*. **45 (3)**: 199–207.

Mathews, S. and Collins, M.T. 1975. Laboratory measures of field emergence potential in barley. *Seed Sci. Technol.* **3**: 863-870.

Mei, Y.; Lei, S.; Sen, X.F.; Wei, L.J. and Hua, W.Y. 2009. Effects of B, Mo, Zn, and their interactions on seed yield of rapeseed (*Brassica napus* L.). *Pedosphere* **19(1)**: 53–59.

Mirshekali, H.; Hadi, H.; Amirnia, R. and Khodaverdiloo, H. 2012. Effect of zinc toxicity on plant productivity, chlorophyll and zinc contents of sorghum (*Sorghum bicolor*) and common lambsquarter (*chenopodium album*). *Int. J. of Agric*: **2(3)**: 247-254.

Mondal, M.M.A.; Rahman, M.A.; Akter, M.B. and Fakir, M.S.A. 2011. Effect of foliar application of nitrogen and micronutrients on growth and yield in mungbean. *Legume Research.* **34(3)**: 166-171.

Movahhedy-Dehnavy, M.; Modarres-Sanavy, S.A.M. and Mokhtassi-Bidgoli, A. 2009. Foliar application of zinc and manganese improves seed yield and quality of safflower (*Carthamus tinctorius* L.) grown under water deficit stress. *Industrial Crops and Products*. **30**: 82-92.

Mudryj, A.N.; Yu, N. and Aukema, H.M. 2014. Nutritional and health benefits of pulses. *Appl Physiol Nutr Metab*. **39(11)**: 1197–1204.

Negi, A.K.; Chauhan, S. and Todaria, N.P. 1995. Effect of temperature on germination pattern of some trees of Garhwal Himalaya. *Jr. of Tree science*. **14**: 11-13.

Obata, H.; Kawamura. S.; Senoo. K. and Tanaka. A. 1999. Changes in the level of protein and activity of Cu/Zn superoxide dismutase in zinc deficient rice plant, (*Oryza sativa* L.) *Soil Sci. Plant Nutr.* **45**: 891-896.

Odell, C. 2004. Foliar feeding of nutrients. Issue of American vegetable grower.

Peishi, Z.; Plummer, J.A.; Turner, D.W.; Choengsat, D. and Bell, D.T. 1999. Low and high-temperature storage effects on viability and germinability of seeds of three Australian asteraceae. *Australian J. of Botany*. **47**: 265-275.

Pena-Olmos, J.E.; Casierra-Posada, F. and Olmos-Cubides, M.A. 2014. The effect of high iron doses (Fe^{2+}) on the growth of broccoli plants (*Brassica oleracea var. Italica*). *Agronomía Colombiana.* **32(1)**: 22-28.

Perry, D.A. 1973. Interacting effects of seed vigour and the environment. In. W. Heydecker (ed) *Seed ecology*. pp. 311-323.

Pons, T.L. 1993. Seed responses to light. In: Fenner, M. (Ed.). *Seeds: The ecology of regeneration in plant communities*. New York: CAB International, pp.259–284.

Purohit, M. and Jamaluddin. 2003. Effect of different storage containers on germination and mycoflora of *pongamia pinnata* seeds. *J. Trop. For*. **19**: 16-20.

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

Radpoor, R.R.A. 2007. Rapid germination and higher vigor in seedlings of fennel (*Foeniculum vulgare*) due to seed priming with microelements. *Iran J Crop Sci.* **7**: 237-248.

Ramirez, D. and Lang, H.J. 1997. Effect of applied iron concentration on growth and phylloclade marginal chlorosis of holiday cactus (*Schlumbergera sp*.). *J. of American society for Horti. Sci.***122 (3)**: 438-444.

Rao, P.S.; Kumar, C.G.; Malapaka, J.; Kamal, A. and Reddy, B.V.S. 2012. Effect of micronutrient treatments in main and ratoon crops of sweet sorghum Cultivar ICSV-93046 under tropical conditions. *Sugar Tech*. **14(4)**: 370-375.

Reid, R.J.; Hayes, J.E.; Post, A.; Stangoulis, J.C.R. and Graham, R.D.A. 2004. Critical analysis of the causes of boron toxicity in plants. *Plant, Cell and Environment.* **25**: 1405-1414.

Rezapour-Osalou. 2015. Foliar application of nano-Fe_3O_4 induced Iron Content and Phytase Activity in corn seed Single Cross 704. *AGRIS*. Vol **36 (3)**: 664-671.

Rosen, J.A.; Pike, C.S. and Golden, M.L. 1977. Zinc, iron, and chlorophyll metabolism in zinc-toxic corn'. *Plant Physiol*. **59**: 1085-1087.

Sagardoy, R.; Morales, F.; Millan, A.F.L.; Abadıa, A. and Abadia, J. 2009. Effects of zinc toxicity on sugar beet (*Beta vulgaris* L.) plants grown in hydroponics. *Plant Biology*. **11**: 339-350.

Salehin, F. and Rahman, S. 2012. Effects of zinc and nitrogen fertilizer and their application method on yield and yield components of *Phaseolus vulgaris* L. *Agric Sci.* **3(1)**: 9-13.

Sankaranarayanan, K.; Praharaj, C.S.; Nalayini, P.; Bandyopadhyay, K. and Gopalakrishnan, N. 2010. Effect of magnesium, zinc, iron and boron application on yield and quality of cotton (*Gossypium hirsutum*). *Indian J. of Agric Sci*. **80(8)**: 699-703.

Savithri, P.; Perumal, R. and Nagarajan, R. 1999. Soil and crop management technologies for enhancing rice production under micronutrient constraints. *Nutrient Cycling in Agro ecosystems.* **53**: 83–92.

Singh, G.J. and Singh, W.S. 2014. Effect of foliar application of iron, zinc and manganese on direct seeded aromatic rice (*Oryza sativa*). *Indian J. of Agro*. **59(1)**: 80-85.

Singh, R.P.; Yadav, P.K.; Singh, S.N.; Chandel, S.K.S. and Singh, R.K. 2010. Effect of foliar application of Zn on herbage and oil yield of palmarosa (*Cymbopogon Martinii*). *Agri Sci. Digest*. **30(3)**: 215-217.

Singh, S.S.; Singh, A.K. and Sundaram, P.K. 2014. Agro-technological options for up scaling agricultural productivity in eastern indo gangetic plains under impending climate change situations: A review. *J. of Agrisearch.* **1 (2)**: 55-65.

Sinta, I.; Vijayakumar, A. and Srimathi, P. 2015. Effect of micronutrient application in coriander (*Coriander sativum L*) cv.CO-4. *African J. of Agric Research*. **10(3)**: 84-88.

Sivaiah, N.K.; Swain, S.K.; Raju, B. and Varma, S.V. 2013. Effect of micronutrients foliar application on seed yield in tomato (*Lycopersicon esculentum* mill). *Int. J. of Plant and Animal Sciences*. **1(7)**: 070-072.

Srivastava, A.K. and Sareen, K. 1974. Physiology and biochemistry of deterioration of soybean seeds during storage. Mobilization efficiency and N-metabolism. *Seed Res*. **3**: 39-44.

Sultana, N.; Ikeda, T. and Kashem, M.A. 2001. Effect of foliar spray of nutrient solutions on photosynthesis, dry matter accumulation and yield in seawater-stressed rice. *Environ. Exp. Bot.* **46**:129-140.

Thavarajah, D.; Johnson, C.; McGee, R. and Thavarajah, P. 2015. Phenotyping nutritional and antinutritional traits. *In*: phenomics in crop plants: Trends, options and limitations; Kumar, J., Pratap, A., eds.; Springer: New Delhi, India. pp. 223–233.

Thavarajah, D.; Thavarajah, P.; Sarker, A. and Vandenberg, A. 2008. Lentils (*Lens culinaris.* Medik.): A whole food for increased iron and zinc intake. *J. Agric. Food Chem.* **57**. 5413–5419.

Tisdale, I.S.; Nelson. I.W.; Beaton, D.J. and Havlin, I. J. 1997. Soil Fertility and Fertilizers. 5th ed. Prentice Hall of India.

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

Voss, R. 1998. Micronutrients. Department of Agronomy. Iowa State University.

Wang, B.; Shi, L.; Li, Y. and Zhang, W. 2010. Boron toxicity is alleviated by hydrogen sulfide in cucumber (*Cucumis sativus* L.) seedlings. *Planta*. **23(1)**: 1301.

Yamunarani, R.; Ramegowda, V.; Geetha, G.; Jalendrakumar, H.G.; Udayakumar, M. and Shankar, A.G. 2016. Effect of Zn application on its uptake, distribution and concentration of Fe and Cu in finger millet (*Eleusine coracana* (L.) Gaertn.). *J. of Plant Nutrition*. **39(4)**: 569-580.

Yellamandha, R.T. and Sankara, R.G.H. 2002. Principles of Agronomy. Kalyani Publishers, Ludhiana. pp. 204-206.

Zehtab-Salmasi, S.; Behrouznajhad, S. and Golezani, K.G. 2012. Effects of foliar application of Fe and Zn on seed yield and mucilage content of psyllium at different stages of maturity. International conference on environment, agriculture and food sciences, Phuket (Thailand).

Ziaeian, A.H. and Malakouti, M.J. 2001. Effects of Fe, Mn, Zn and Cu fertilization on the yield and grain quality of wheat in the calcareous soils of Iran. *Plant nutrition.* : 840-841.

Appendix- I

Weekly average weather data during the crop period 2015-2016

Week	Temperature (ºC)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hrs)	Evaparation	Soil temperature at 5 cm		Soil temperature at 10 cm	
	Max.	Min.	Max.	Min.				Min.	Max.	Min.	Max.
27 Aug - 02 Sep	23.6	15.1	94	79	3.1	8	3.1	19	30.7	19.5	29.9
03 Sep - 09 Sep	22.8	14.2	87	86	2.9	8.1	2.9	19	32.3	19.4	31.5
10 Sep - 16 Sep	23.6	14.8	91	87	3.2	8.3	3.2	19.7	33.4	20.1	32.1
17 Sep - 23 Sep	23.0	14.2	88	78	2.6	5.4	2.6	18.8	27.3	19.2	26.6
24 Sep - 30 Sep	21.8	12.1	82	81	2.0	7.7	2.0	16	29.3	16.5	28.8
01 Oct - 07 Oct	23.0	12.3	70	56	2.9	8.8	2.9	16.2	32.1	16.8	31.4
08 Oct - 14 Oct	22.0	11.9	86	69	2.4	7.3	2.4	16.2	28.8	16.6	28.2
15 Oct -21 Oct	20.2	10.3	84	65	1.7	6.9	1.7	13.1	27.2	13.7	26.3
22 Oct - 28 Oct	20.3	8.2	70	50	2.3	8.4	2.3	11.9	26.2	12.7	25.2
29 Oct - 04 Nov	18.5	7.9	82	53	2.0	7.3	2.0	11.4	25.1	12.1	24.1
05 Nov - 11 Nov	17.8	6.3	73	49	1.9	7.8	1.9	10	23.7	10.7	22.6
12 Nov - 18 Nov	18.7	7.1	75	47	2.1	8.2	2.1	9.8	23	10.5	21.8
19 Nov - 25 Nov	18.2	7.2	84	56	1.7	8.2	1.7	9.2	21.3	9.7	20.3
26 Nov - 02 Dec	17.0	5.8	74	52	1.7	6.2	1.7	7.4	18.0	8.2	17.1
03 Dec - 09 Dec	14.9	4.6	88	65	1.2	6.5	1.2	6.5	16.2	7.1	15.7
10 Dec - 16 Dec	12.1	2.5	90	68	0.8	4.5	0.8	4.8	12.8	5.4	12.3
17 Dec - 23 Dec	10.6	-0.4	87	53	0.8	6.7	0.8	1.3	11.1	2.0	10.4
24 Dec - 31 Dec	14.6	2.7	62	42	1.6	7.3	1.6	2.5	13.8	3.0	12.8

week	Temperature (ºC)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hrs)	Evaparation	Soil temperature at 5 cm		Soil temperature at 10 cm	
	Max.	Min.	Max.	Min.				Min.	Max.	Min.	Max.
01 Jan - 07 Jan	14.0	3.0	69	54	0	6.3	1.5	3.4	13.5	4.0	12.8
08 Jan - 14 Jan	12.5	1.2	83	55	0.1	6.8	1.3	2.8	13.3	2.8	12.7
15 Jan - 21 Jan	11.3	0.6	81	50	0.6	6.1	1.3	2.4	13.6	2.4	12.8
22 Jan - 28 Jan	11.2	1.8	82	51	0	7.5	1.4	2.3	15.0	2.3	13.9
29 Jan - 04 Feb	13.6	4.7	72	46	0.5	7.2	1.8	8.6	17.9	8.5	16.6
05 Feb - 11 Feb	14.7	4.7	79	58	28.7	7.2	1.9	11.1	16.2	10.8	15.2
12 Feb - 18 Feb	13.2	3.9	75	50	25.5	7.0	1.6	9.3	16	9	14.7
09 Feb - 25 Feb	17.6	8.0	77	60	14.1	6.5	2.3	13.0	19.1	12.6	17.8
26 Feb - 04 Feb	17.4	7.5	85	47	0	8.6	2.2	11.3	22.8	11.3	21.3
05 Mar - 11 Mar	17.7	8.2	73	56	5.2	6.7	2.5	8.9	20.6	9.4	19.6
12 Mar - 18 Mar	15.1	6.3	83	66	38.5	4.0	2.1	7.6	17.7	8.4	16.9
19 Mar - 25 Mar	19.7	9.3	56	44	1.9	7.8	3.2	8.7	24.1	9.2	22.8
26 Mar - 01 Apr	22.1	11.6	64	42	0	7.8	3.5	12.5	27.8	13.1	26.7
02 Apr - 08 Apr	23.4	13.0	62	43	12.8	6.2	4.0	14.2	26.9	14.8	26
09 Apr - 15 Apr	23.5	12.4	45	29	0	9.7	4.5	13.6	29.7	14.2	28.7
16 Apr - 22 Apr	26.4	15.0	52	33	0.7	8.5	5.0	17.2	33.4	17.7	31.2
23 Apr - 29 Apr	25.1	12.7	34	19	1.8	10.4	5.5	15.2	34.6	16.2	31.7
30 Apr - 06 May	26.4	14.3	48	36	25.5	8.0	4.7	17.1	33.3	17.9	31.1

Appendix- II

Mean data obtained during seed metabolic efficiency and mobilization efficiency

Treatments	10 seeds weight (g)	Dry weight of shoot (mg)	Dry weight of root (mg)	Respired food material
RDF	0.227	0.061	0.031	0.081
RDF+ Zn 50 ppm	0.231	0.069	0.028	0.041
RDF+ Zn 100 ppm	0.232	0.067	0.032	0.019
RDF+ Fe 50 ppm	0.220	0.061	0.024	0.054
RDF+ Fe 100 ppm	0.237	0.056	0.021	0.099
RDF+ B 50 ppm	0.231	0.076	0.035	0.035
RDF+ B 100 ppm	0.232	0.056	0.029	0.059
RDF+ Zn+ Fe+ B (50 ppm each)	0.220	0.050	0.025	0.051

Appendix- III

Analysis of variance for plant population (number of plant per meter row length) and mortality (%)

Source of variation	D. F.	Mean sum of squares		
		Population studies		
		Initial plant population	Plant population at maturity	Mortality percentage
Replication	**2**	0.70	0.36	0.425673
Treatment	**7**	0.49**	0.96**	21.58298**
Error	**14**	0.32	0.20	0.34333

Appendix- IV

Analysis of variance for plant height (cm) at various stage of crop growth

Source of variation	D. F.	Mean sum of squares			
		30 DAG	60 DAG	90 DAG	At harvest
Replication	**2**	0.320	0.029	0.683	6.640
Treatment	**7**	0.068 NS	0.813*	0.922*	6.340*
Error	**14**	0.132	0.243	0.326	2.260

* Significant at 0.05 level of probability
**Significant at 0.01 level of probability

Appendix- V

Analysis of variance for plant spread (cm) at various stage of crop growth

Source of variation	D. F.	Mean sum of squares			
		30 DAG	60 DAG	90 DAG	At harvest
Replication	**2**	0.046	0.017	0.231	2.055
Treatment	**7**	0.005 NS	0.698**	0.969**	2.177*
Error	**14**	0.059	0.085	0.167	0.716

Appendix- VI

Analysis of variance for number of compound leaves at various stage of crop growth

Source of variation	D. F.	Mean sum of squares		
		30 DAG	60 DAG	90 DAG
Replication	**2**	0.120	1.582	1.152
Treatment	**7**	0.154 NS	4.964*	11.994**
Error	**14**	0.128	1.267	2.081

Appendix- VII

Analysis of variance for Dry matter accumulation (g/m^2) at various stage of crop growth

Source of variation	D. F.	Mean sum of squares		
		30 DAG	60 DAG	90 DAG
Replication	**2**	0.333167	6.10467	67.0533
Treatment	**7**	0.755994 NS	63.9239 **	332.152**
Error	**14**	1.21798	5.46057	47.0559

Appendix- VIII

Analysis of variance for number of nodules, dry weight of roots per plant and dry weight of shoots per plant at 50 % flowering

Source of variation	D. F.	Mean sum of squares		
		No of nodules per plant	Dry weight of roots per plant (mg)	Dry weight of shoots per plant (mg)
Replication	**2**	0.255	39.833	3070.620
Treatment	**7**	18.842**	258.770**	15599.800**
Error	**14**	0.741	24.463	773.563

* Significant at 0.05 level of probability

**Significant at 0.01 level of probability

Appendix- IX

Analysis of variance for yield attributing character

Source of variation	D. F.	Mean sum of squares				
		Seeds/pod	Branches per plant	Pods per plant	1000 seed weight	Grain weight per plant (g)
Replication	**2**	0.01167	56.222	42.855	1.625	10504.50
Treatment	**7**	0.02042*	52.737*	91.615*	0.337 NS	158373.00**
Error	**14**	0.00595	17.648	24.172	1.196	17593.00

Appendix- X

Analysis of variance for yield

Source of variation	D. F.	Mean sum of squares				
		Grain yield (kg/ ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest Index	B:C ratio
Replication	**2**	62663.80	197359.00	46666.70	11.937	0.15125
Treatment	**7**	57107.50*	233409.00*	325285.00*	27.734**	0.37658*
Error	**14**	18446.20	62797.10	86666.70	4.679	0.12268

Appendix- XI

Analysis of variance for number of viable seeds, germination percentage and number of un-germinated seeds

Source of variation	D. F.	Mean sum of squares				
		Tetrazolium test	Standard germination test		Accelerated ageing test	
		Viable seeds	Germinatio n (%)	No. Of hard seeds	Germinatio n (%)	No. Of hard seeds
Treatment	**7**	9.93**	26.41**	27.07**	9.93**	9.93**
Error	**24**	0.33	7.29	0.33	2.83	0.33

Appendix- XII

Analysis of variance for growth index

Source of variation	D. F.	Mean sum of squares				
		4th day	5th day	6th day	7th day	8th day
Treatment	**7**	0.296978**	0.789235**	3.48881**	2.302341**	5.269507**
Error	**24**	0.081866	0.223553	0.737526	0.530521	1.302607

* Significant at 0.05 level of probability

**Significant at 0.01 level of probability

Appendix- XIII

Analysis of variance for standard germination and accelerated ageing test

Source of variation	D. F.	Mean sum of squares							
		Standard germination				Accelerated ageing test			
		First count	Final count	Vigour index		First count	Final count	Vigour index	
				I	II			I	II
Treatment	**7**	59**	26**	291181**	54695**	42**	9.9**	85355**	39078**
Error	**24**	15	7.3	32997	15448	12	2.8	21417	9294

Appendix- XIV

Analysis of variance for cold and cool germination test

Source of variation	D. F.	Mean sum of squares					
		Cold test			Cool germination test		
		Germination %	Vigour index I	Vigour index II	Germination %	Vigour index I	Vigour index II
Treatment	**7**	39.7**	82605**	94399**	10.9**	82795**	69586**
Error	**24**	10.6	19886	18667.29	1.7	18489	16253

Appendix- XV

Analysis of variance for speed of germination

Source of variation	D. F.	Mean sum of squares				
		4^{th} day	5^{th} day	6^{th} day	7^{th} day	8^{th} day
Treatment	**7**	77.55**	74.84**	46.50**	51.64**	42.67**
Error	**24**	0.46	13.63	12.75	11.92	11.55

Appendix- XVI

Analysis of variance for seed metabolic efficiency, mobilization efficiency and absorbance of seed hydrogenase @ 480 nm.

Source of variation	D. F.	Mean sum of squares		
		Seed metabolic efficiency	Mobilization efficiency	Absorbance of seed hydrogenase @ 480 nm.
Treatment	**7**	0.86**	189.45**	56921.79**
Error	**24**	0.01	13.73	2372.79

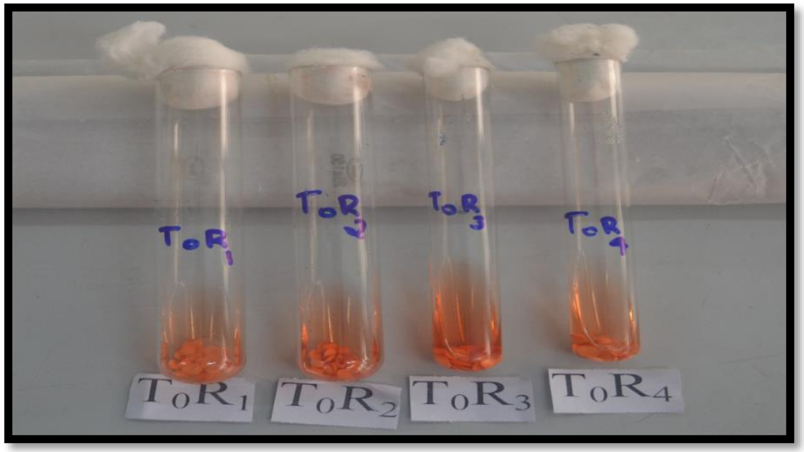
* Significant at 0.05 level of probability
**Significant at 0.01 level of probability.

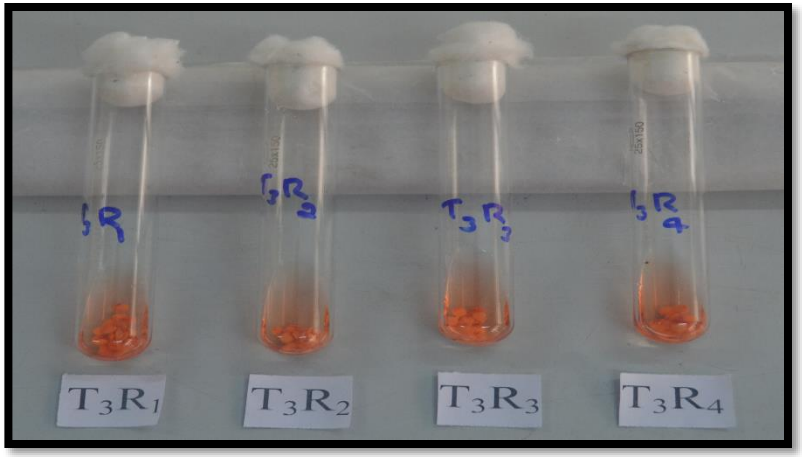
Appendix- XVII

Analysis of variance for water sensitivity test

Source of variation	D. F.	Mean sum of squares					
		High moisture			Low moisture		
		Seedling fresh weight (mg)	Seedling dry weight (mg)	Seedling length (cm)	Seedling fresh weight (mg)	Seedling dry weight (mg)	Seedling length (cm)
Treatment	**7**	707.97**	5.33**	11.63**	686.77**	20.47**	11.81**
Error	**24**	180.35	1.52	2.04	175.90	1.71	2.16

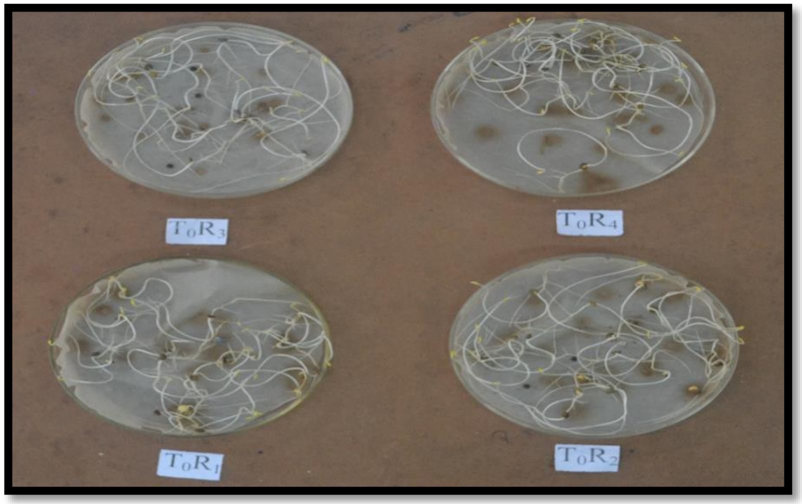
* Significant at 0.05 level of probability
**Significant at 0.01 level of probability

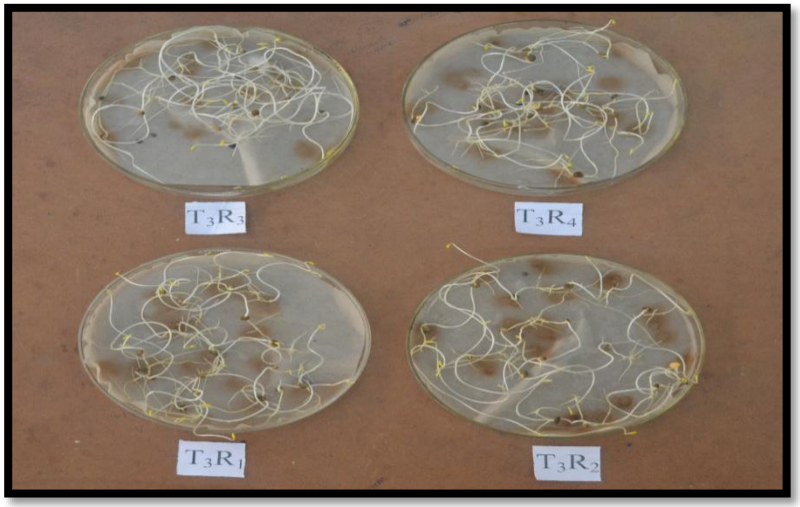




T0: RDF

T3: RDF+Fe 50 ppm





T0: RDF

T3: RDF+Fe 50 ppm

Plate 4: Effect of micronutrinet treatment on Tetrazoilium and Cold test

Layout of the plot

Field during harvesting stage

Plate 1: Layout of the plot and crop during harvest stage of the crop

T0: RDF

T3: RDF+ Fe 50 ppm

T5: RDF+B 50 ppm

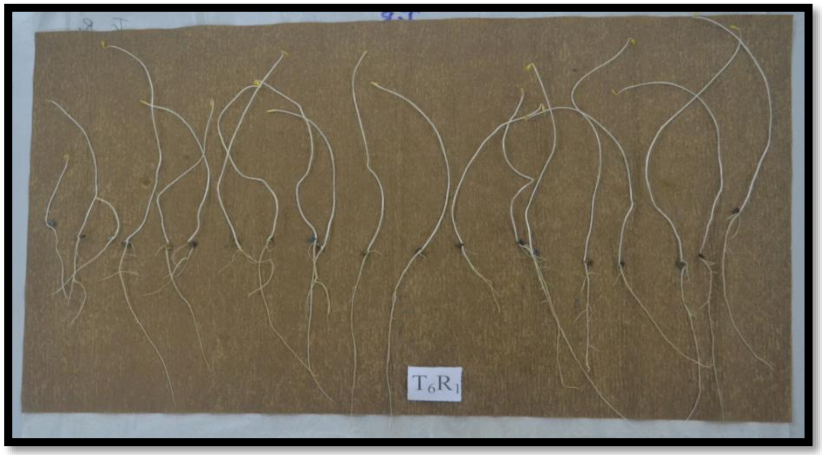
T7: RDF+ Zn+ Fe+ B (50 ppm each)

Plate 2: Influence of micronutrient treatments on plant growth at 50% flowering stage

T0: RDF

T3: RDF+ Fe 50 ppm

T4: RDF+ Fe 50 ppm



T6: RDF+ B 50 ppm

Plate 3: Effect of micronutrient treatment on seedling length of lentil

VITA

The author was born on 10th July 1993 at Heggadadevana Kote, Distt.-Mysuru, Karnataka. He passed High school in 2009 and Intermediate examination in 2011 from St. Mary's High School and St. Mary's Composite Junior College respectively. He did his graduation in B.Sc (Agriculture) from College of Agriculture, V. C. Farm, Mandya, UAS Bangalore, Karnataka. He joined V. C. S. G. Uttarakhand University of Horticulture and Forestry, Bharsar in 2015 for the degree of M.Sc. (Ag) Seed Science and Technology.

Permanent Address

Ranjithkumar. H. R.
S/O Shri. Ramachandra. H. D.
#2247, Hospital layout
H. D. Kote town, H. D. Kote, Taluk
Mysuru, Karnataka, 571114
E-mail: ranjithramachandra7@gmail.com
Mobile No- 8197716737

ABSTRACT

Name **: Ranjithkumar. H. R.** **Id. No : UUHF/15315**
Semester and **Degree : M. Sc (Ag)**
Year admission : I[st] Semester, 2015-16 **College : College of Forestry, Ranichuri**
Department (Major) : Seed Science and Technology **V.C.S.G. UUHF**

Advisor: Dr. Ajay Kumar (Junior Research Officer)

Title: "Effect of foliar sprays of boron, iron and zinc on plant growth, seed yield and seed quality of lentil (*Lens culinaris* Medik.)"

Lentil (*Lens culinaris* Medik.) is an important rabi pulse, which is one of the oldest grain legume known to the mankind. Continuous application of macro nutrients created deficiency of micronutrient in lentil which ultimately cause reduction in yield and seed quality. Micronutrients are essential nutrients required by the plant to complete their lifecycle, which are even though required in very small amounts plays a very vital role.

In the present investigation, we used three micronutrients viz., boron, zinc and iron for foliar application. A series of field and laboratory experiment were conducted in a randomized complete block design at Crop Improvement Block, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand during rabi, 2015 to evaluate the effect of micronutrients foliar sprays on plant growth, seed yield and seed quality of lentil. The micronutrient treatments comprised of T0- RDF (N:P:K- 20:40:20 kg/ha), T1- RDF+ Zn 50 ppm, T2- RDF+ Zn 100 ppm, T3- RDF+ Fe 50 ppm, T4- RDF+ Fe 100 ppm, T5- RDF+ B 50 ppm, T6- RDF+ B 100 ppm and T7- RDF+ Zn+ Fe+ B (50 ppm each)

RDF (N:P:K- 20:40:20 kg/ha)+ Fe 50 ppm recorded significantly higher plant height, plant spread, plant population at maturity, number of nodules per plant. Seed yield was recorded maximum under RDF+ Fe 50 ppm which was statistically on par with RDF+ B 50 ppm. There was 33% increase in seed yield in RDF+ Fe 50 ppm than the RDF. B: C ratio also registered maximum (4.57) in RDF+ Fe 50 ppm.

All seed quality parameters like first count, final count, vigour index I and II, growth index, speed of germination, germination percentage in cold and cool germination test and dry weight of seedling in water sensitivity were recorded significantly higher in case of RDF+ fe 50 ppm in comparison to the RDF.

On the basis of investigation among the treatments RDF+ Fe 50 ppm proved to be the best micronutrient for foliar spray for enhancing the growth, yield and seed quality parameters of lentil.

(Ajay Kumar)
Advisor

(Ranjithkumar. H. R.)
Author