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Response of Lentil (*Lens culinaris Medikus*) to Zinc , Iron and Bio-fertilizers Application in Black Soils

THESIS

Submitted to the

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.)

In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

In

(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

By

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CERTIFICATE – I

This is to certify that the thesis entitled **"Response of Lentil (*Lens culinaris Medikus*) to Zinc ,Iron and Bio-fertilizers Application in Black soils"** submitted in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (Soil Science and Agricultural Chemistry)** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bona-side research work carried out by **Ku. Sangam Raghuwanshi ID.No. 16131305** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any degree or diploma (Certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by the scholar.

Signature

Place: Sehore (Dr. S.C.Gupta)

Date : **Chairman of the Advisory Committee**

MEMBER OF THE STUDENT'S ADVISORY COMMITTEE

Chairman (Dr.S.C.Gupta) ..…………………………..

(Dr.R.C.Jain) ..…………………………..

Member (Dr. R.P.Singh) …………………………….

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CERTIFICATE – II

This is to certify that the thesis entitled **"Response of Lentil (*Lens culinaris Medikus*) to Zinc , Iron and Bio-fertilizers Application in Black soils"** submitted by **Ku. Sangam Raghuwanshi ID.No. 16131305** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfilment of the requirements for the degree of Master of Science in Agriculture in the Department of Soil Science and Agricultural Chemistry, R.A.K. College of Agriculture, Sehore has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.

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Date : **Chairman of Advisory Committee**

Member of the Advisory Committee

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Member	(Dr. R.P.Singh)	…………………….
Head of the Department (Signature)		……………………...
Dean of college (Signature)		………………………
Director Instruction (Signature)		……………………… .

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"Education plays a fundamental role in personal and social development and teachers play a fundamental role in imparting education. Teachers have crucial role in preparing young people not only to face the future with confidence but also to build up it with purpose and responsibility. I start in the name of "God" who has bestowed upon me all the physical and mental attributes that I possess and skills to cut through and heal a fellow human.

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Place : Sehore

Date (Sangam Raghuwanshi)

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Legend
&	And
@	At the rate of
^oC	Degree Celsius
C.D.	Critical Difference
Cm	Centimeter
C.V.	Coefficient of Variation
DAS	Days after sowing
D.F.	Degree of Freedom
et al.	And others
Etc	and the rest
Fig.	Figure (s)
G	Gram
ha	Hectare
HI	Harvest Index
i.e.	That is
K	Potassium
Kg/ha	Kilogram per hectare
L	Litre
MSS	Mean sum of square
Mg	Miligram
M	Meter (s)
N	Nitrogen
No.	Number (s)

NS	Non significant
P	Phosphorus
T	Tonnes
R.V.S.K.V.V.	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
R.A.K.	Rafi Ahmed Kidwai
RH	Relative humidity
₹	Rupees
S.Em.±	Standard error of mean
S.S.	Sum of Square
Viz.	Namely
√	Square root
%	Percent
±	Plus or Minus

CHAPTER I

INTRODUCTION

Lentil (*Lens culinaris Medikus*) is a self pollinated and annual cool season grain legume. The important lentil producing countries are Canada, India, Turkey, Nepal, Australia, China, Iran, The United States, Syria, and Ethiopia (Harish *et al*., 2012).

In India, lentil harvested area was 15 lakh ha with production of 9.5 lakh tonnes and productivity of 633.33 kg ha^{-1} during 2016. In Madhya Pradesh, lentil harvested area was 6.1 lakh ha with production of 4.2 lakh tonnes and productivity of 679 kg ha^{-1} during 2016 (Agriculture Statistics, 2016).

Lentil seeds are valued source of food for quality protein and fiber (Tickoo *et al*., 2005). Lentil is important source of energy, protein, carbohydrate, fiber, mineral, vitamin and antioxidant compound. Lentil is good source of vitamin A, vitamin B complex, potassium, zinc and iron. Lentil has an excellent macro and micronutrients profile and favorable levels of mineral bioavailability enhancing factors. Lentil straw is equally valuable as animal feed and fodder. In India, lentil is mainly grown as rainfed crop in Uttar Pradesh, Madhya Pradesh, Jharkhand, Bihar and West Bengal.

Iron (Fe) deficiency is a common nutritional disorder observed in many crops (Erskine et al., 1993) including lentil. Losses in the yield of susceptible genotypes varied between 18 and 25%. The Fe^{2+}concentration of the leaf tissue, compared with the total iron content, was closely correlated with the Fe-deficiency symptoms, and was found to be a useful index to identify soil where response to Fe application can be expected (Sakal *et al*.,1984). Iron is a constituent of the nitrogenase enzyme, leghemoglobin and ferrodoxin. The bacteria uses this element during the nitrogen fixation period. Iron deficiency generally decreases nodule formation, leghemoglobin production and nitrogenase activity, leading to low nitrogen concentrations in the shoots of some legumes.

Micronutrient malnutrition caused due to non/poor availability of minerals is a major problem in developing countries. At global level over 3 billion people (UNSCN, 2004) and in India 230 million people are affected

(Lodha *et al*., 2005) by micronutrient malnutrition.Iron deficiency results in anemia, affects cognitive development, growth, reproductive performance and work productivity (Bouis, 2002), whereas the zinc deficiency causes anorexia, depression, impaired growth and development, altered reproductive biology, gastro-intestinal problems and impaired immunity (Solomons, 2003).Dietary diversification, supplements and fortified foods are the possible means to reduce micronutrients malnutrition. Bio fortification involves increasing levels of specific, limiting micronutrients in edible tissues of crops by combining crop management. Zn and Fe deficiency in soil is also responsible for reduced crop yield. Biofertilizers like *Rhizobium* and *PGPR* also have shown beneficial effect on growth and yield of legumes.

Keeping above facts in view the present investigation was undertaken with the following objectives :-

1. To study the effect of Zn, Fe and bio fertilizers application on nodulation ,growth and yield of lentil .
2. To study the effect of Zn, Fe and bio fertilizers application on Zn and Fe content and uptake in Lentil.
3. To study the effect of various treatments on available N,P, Zn & Fe in soil after crop harvest.

CHAPTER II
REVIEW OF LITERATURE

Lentil is an important pulse crop of India and also dominant in Madhya Pradesh. This chapter deals with the compilation of research work carried out so far on the effect of supplements of Iron and Zinc along with bio-fertilizer inoculation on growth attributes, yield attributes, grain yield, nutrient uptake and analysis of lentil. The research work has been reviewed and presented in this chapter with following headings:

2.2 Effect of Zn , Fe and bio-fertilizer application on growth attributing characters of lentil :

Bhanavase *et. al*. (1994) noted that application of $FeSO_4$ @10 kg ha^{-1} and $ZnSO_4$ @25 kg ha^{-1} significantly increased chlorophyll content of leaves, nodulation and dry weight of nodules $plant^{-1}$ of soybean crop over control.

Krishnareddy *et. al*. (1996) reported that application 5 kg of Zn ha^{-1} as zinc sulphate resulted in marked improvement in growth parameters in lentil.

Pathak *et. al.*(2003) reported that the plant height, branches $plant^{-1}$, root nodulation $plant^{-1}$ in chickpea were maximum with 68 kg P_2O_5 ha^{-1} through DAP, PSB + 10 FYM t ha^{-1} and 12.5 kg $ZnSO_4$ ha^{-1} which proved the most beneficial .

Sharma and Sharma (2004) determined the effects of P (0, 20 and 40 kg ha^{-1}), potassium (0 or 20 kg ha^{-1}) and *Rhizobium* inoculation on the growth and yield of lentil cv. L-4147. The mean number of branches, nodules and pods $plant^{-1}$; 100-seed weight and seed yield were highest with the application of P @ 40 kg ha^{-1}, whereas mean plant height and plant stand row length were highest with the application of 20 kg P ha^{-1}.

Kumawat *et al*. (2006) reported that soil application of iron @ 25 kg $FeSO_4$ ha^{-1} and foliar spray of 0.5 per cent $FeSO_4$ + 0.1 per cent citric acid solution both at branching and flowering being at par recorded significantly higher seed and straw yield of summer mungbean over control.

Singh *et al.* (2006) studied four bio-fertilizer inoculations [*Rhizobium*, *phosphate solubilizing bacteria (PSB), Rhizobium* + PSB and no inoculation] and four phosphorus (0, 20, 40 & 60 kg P_20_5 ha^{-1}) levels to study the interaction of bio-fertilizers and phosphorus on growth and yield of lentil. Dual inoculation of *Rhizobium* and *PSB* resulted in taller plants, higher dry matter, nodules $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, 100-seed weight and seed and straw yield.

Mousavi *et al*. (2013) in a review article, reported that the crop growth significantly increased with the application of micronutrients such as zinc (Zn), iron (Fe), boron (B), copper (Cu), manganese (Mn) of pulse crop over control.

Sagar *et al.* (2015) studied the effect of four levels of phosphorus (0, 20, 30 and 40 kg P_2O_5 ha^{-1}) and four bio fertilizer treatments [uninoculated control, *Rhizobium*, plant growth promoting *rhizobacteria* (*PGPR)* and *Rhizobium* + *PGPR*] on growth and grain yield of lentil. The periodic data recorded at 30, 60, 90, 120 days after sowing (DAS) and at harvest showed the beneficial effect of inoculation and P application on growth parameters i.e. plant height, branches $plant^{-1}$ and shoot dry matter accumulation etc.

2.2 Effect of Zinc, Iron and bio-fertilizer application on Yield Attributes in lentil:

Krishnareddy *et al*. (1996) in a study on lentil cultivars Microsperma (JL 1) and Macrosperma (Lens 4076) treated with the bio fertilizers *Rhizobium* and *VAM* fungi reported higher values of LAI, root nodulation, yield attributes (number of pods $plant^{-1}$, number of grains pod^{-1} and grain yield $plant^{-1}$), grain yield and harvest index from JL 1 whereas plant height and 1000 grain weight were higher in Lens 4076. Application of 17.2 kg P ha^{-1} as single superphosphate (SSP) along with @ 5 kg Zn ha^{-1} as zinc sulphate resulted in marked improvement in growth and yield attributes of Lentil

Chowdhury *et. al.* (1998) in a study on effect of *Rhizobium,* given N or P fertilization in lentil (Lens culinaris) genotypes reported that Lentil Yield was highest with *Rhizobium*, nodule number and nodule dry weight were highest with *Rhizobium* alone or with N + P, while plant height and pods $plant^{-1}$ were highest with *Rhizobium* + N + P.

Ahmed *et. al*.(1999) studied the effect of the application of zinc (0, 200 and 400 ppm) and manganese (0, 50 and 100 ppm) as foliar treatments in combination with phosphorus (15.5, 31.0 and 46 kg kg P_2O_5 ha^{-1}) as soil treatment in lentil and found that in general, application of 46 kg P_2O_5 + 400 ppm Zn + 50 or 100 ppm Mn was the best treatment in enhancing the growth and yield of lentil.

Singh *et. al*.(2000) in a field trial on sandy loam soil on application of 0-90 kg S ha^{-1}, 0-38.7 kg P ha^{-1} and of *Rhizobium* inoculation in lentils cv. K 75 and reported better effect of 60 kg S and 25.8 kg P, and also of *Rhizobium* inoculation on growth and yield .

Singh *et al*. (2001) in a study on the effect of *Rhizobium leguminosarum* and *Glomus fasciculatum* and P application in lentil reported better pods $plant^{-1}$ and yield with 20 kg P_2O_5 ha^{-1} + *Rhizobium leguminosarum*+ *Glomus fasciculatum* in lentil cv. LL 147.

Pathak *et al*. (2003) found that the pods $plant^{-1}$, grains pod^{-1}, 100 grain weight and yield were significantly higher in treatment applied with @ 68 kg P_2O_5 ha^{-1} through DAP + PSB + 10 FYM t ha^{-1} and 12.5 kg $ZnSO_4$ ha^{-1} compared to control.

Hossain and Suman (2005) carried out an experiment to evaluate the effect of *Azotobacter, Rhizobium* and different levels of urea N on growth, yield and N-uptake of lentil. Among the treatments *Azotobacter* + *Rhizobium* inoculation had significant effect on nodule formation, plant height, number of seeds, seed and Stover yields, compared to un inoculated controls. The highest seed yield was recorded for the treatment *Azotobacter*+*Rhizobium* that was statistically similar to that of 100% N and *Rhizobium* with the corresponding yields of 1533 and 1458 kg/ha, respectively.

Kanase *et al.* (2006) in an experiment on soybean cv. JS-335 in Nagpur, Maharashtra rported that the application of 75% RN+25% N through weed biomass+ PSB and *Rhizobium* increased the growth and yield contributing parameters, i.e. plant height, number of branches $plant^{-1}$, dry matter $plant^{-1}$, leaf area $plant^{-1}$, leaf area index, number of pods $plant^{-1}$, weight of grains $plant^{-1}$, grain yield ha^{-1}, straw yield ha^{-1} and test weight, which was at par with other promising treatments.

Kumar and Kumar (2006) reported the response of farmyard manure (FYM), phosphorus (P) application and phosphate solubilizing bacteria on lentil. The application of 5 t FYMha^{-1} increased the grain yield of lentil by 7.91 and 7.07% during the first and second year respectively. The successive increase in P application up to 60 kg P_2O_5 ha^{-1} improved the grain yield and yield attributes of lentil.

Kumar and Uppar (2007) conducted a field experiment to evaluate the effects of organic manures, bio fertilizers, micronutrients and plant growth regulators on the seed yield and quality of mothbean. RDF + FYM @ 10 tha^{-1} recorded the highest values for the different seed yield and quality attributes of moth bean.

Singh *et.al.*(2007) reported that the application of *Rhizobium* + PSB ,Vermi-compost. Number of pods, and grain and straw yields significantly increased up to 150% RDF. Application of *Rhizobium* + PSB ,vermi-compost also showed significant response to plant height, dry matter production, number of pods, and grain and straw yields.

Mavarkar *et al*. (2008) obserbed that the response of cowpea to zinc application under rainfed conditions and found that foliar spray of $ZnSO_4$ @ 1.0% at 25 DAS resulted in the highest grain yield (1166 kg ha^{-1}) and yield attributes (number of pods plant^{-1}, number of seeds pod^{-1}, and test weight) whereas minimum grown yield was recorded under control.

Kobraee. (2011) in an experiment on soybean with three levels of Zn (0, 20, 40 kg), Fe (0, 25, 50 kg) and Mn (0, 20, 40 kg) having source of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ respectively reported that applying zinc resulted in increased plant height, number of pods plant^{-1}, biological yield, harvest index and seed yield as compared to control.

Togy *et al*. (2015) in a study to determine the effect of different levels of iron (0, 5, 10 and 20 kg ha^{-1}) and molybdenum (0, 2, 4 and 6 g kg^{-1} seed) on the yield and yield components in lentil (Lens culinaris Medic. cv. Sazak-91) reported the highest seed yield with 20 kg ha^{-1} iron and 6g kg^{-1}seed molybdenum levels.

Bahure *et al*. (2016) reported that the application of RDF + $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @10 kg ha^{-1} + $MgSO_4$@ 10 kg ha^{-1} + 1.5 % foliar application $ZnSO_4$, $FeSO_4$ and $MgSO_4$ at 30 and 50 DAS significantly increased the growth, yield and economic character followed by treatment of RDF + $ZnSO_4$ @10 kg ha^{-1} + 1% $ZnSO_4$ through foliar application at 30 and 50 DAS.

2.3 Effect of Zn ,Fe and bio-fertilizer application on nutrient content, uptake and quality protein

Mahriya (1997) noted that application of Fe up to 4 kg ha^{-1} significantly increased protein content of cowpea whereas Fe content of cowpea seeds significantly increased with the application of iron @ 6.0 kg ha^{-1} in over lower levels.

Ahmed *et. al.* (1999) in an experiments to evaluate the response of lentil cv. Giza-9 to zinc (0, 200 and 400 ppm) and manganese (0, 50 and 100 ppm) as foliar treatments in combination with phosphorus (15.5, 31.0 and 46 kg P_2O_5 ha^{-1} $feddan^{-1}$) as soil treatment reported beneficial effect of integration on protein yield in lentil.

Selim *et. al.* (2002) reported that two field experiments were carried out in low fertility sandy soils in South El-Tahrir Region, to evaluate the effect of different fertilizer application treatments, i.e., recommended rate of chemical fertilizers, organic manure (sawdust compost), bio-fertilizer and their combinations .The beneficial effect of integration on seed protein and fat content reported.

Pathak *et al*. (2003) reported that application of 12.5 kg $ZnSO_4$ ha^{-1} significantly increased the N and Zn concentration in seed and straw of chickpea over control.

Vasanthi and Subramanian (2004) reported beneficial effect of application of organic manures (vermicompost +FYM) and fertilizer (25:50:0 kg ha^{-1} N, P_2O_5 and K_2O) on the uptake of nutrients and crude protein content in black gram.

Hossain and Suman (2005) carried out an experiment to evaluate the effect of *Azotobacter, Rhizobium* and different levels of urea N on growth, yield and N-uptake of lentil. The dual inoculation of *Azotobacter* and *Rhizobium* significantly influenced all the crop characters including N contents, N uptake by seed and shoot as well as protein content of seed. The highest N-uptake by seed (78.61 $kgha^{-1}$) was recorded for the treatment *Azotobacter+Rhizobium* and N-uptake by shoot (53.87 $kgha^{-1}$) was recorded for the treatment 100% N.

Arya *et al.* (2007) revealed that integrated nutrient application (INA) 50% recommended dose of fertilizer (RDF)+FYM at 5 t ha^{-1} + bio fertilizers (*Rhizobium*+PSB)] significantly enhanced total uptake of nitrogen, phosphorus and potassium in chickpea and mustard.

Singh *et al.* (2007) conducted a field experiment to assess the effect of fertility, PSB and vermi-compost on growth, yield and quality of large seeded lentil. Protein content showed significant increased up to the 150% RDF and PSB+Vermi-compost.

Ravi *et al.* (2008) reported significantly higher uptake of N, P, K, Zn and Fe with foliar fertilization of zinc compared to control.

Wani *et. al.* (2008) reported that zinc is a plant nutrient at low levels, Zn ions can be highly phytotoxic at higher concentrations found in contaminated soils. Plant growth-promoting rhizobacteria can be used to decrease this toxicity. He reported that when the rhizobacterium strain RL9 was added to soil contaminated with Zn at 4890 mg kg^{-1}, lentil dry matter increased by 150% and grain protein by 8%, compared with un inoculated plants.

Kumar *et al*. (2009) conducted an experiment to study the effect of organic, inorganic and bio fertilizers on french bean. Results showed that the superimposition of 25% N (recommended dose of N through vermicompost) to 100% NPK (recommended dose of NPK through fertilizers), being at par with 100% NPK+50% N resulted in significant improvement in nutrient (N, P, K, S, Zn and Fe) uptake

Singh *et al*. (2010) reported that the recommended fertilizers combined with application FYM (10 t ha^{-1}) + $ZnSO_4$ (25 kg ha^{-1}) + seed treatment gave the highest N, P, K, S and Zn content as well as their uptake in seed.

Tripathi *et al*. (2011) conducted a field experiment on chickpea and reported that the application of 5 kg Zn ha^{-1} significantly increased the uptake of nitrogen, potassium, sulphur and zinc.

Gupta (2012) reported that application of 3 kg Zn ha^{-1} recorded significantly higher protein content in fennel seed over control.

Togay *et al*. (2015) In a study on the effect of Fe (iron) and Mo (molybdenum) application on the yield and yield parameters of lentil (Lens culinaris Medic.) reported that seed nutrient contents such as protein , phosphorus, manganese, copper and molybdenum significantly increased under the influence of iron and molybdenum treatments over control.

2.4 Effect of Zn ,Fe and bio-fertilizer application on soil nutrient content after crop harvest:

Bandhyopadhyay and Puste (2002) reported that seed inoculation of pulses with *Rhizobium* sp. played a positive role towards the total crop productivity and residual soil fertility status.

Gupta (2004) reported on increase in available N and P balance after harvest of chickpea in black soils with the use of bio-fertilizer viz. *Rhizobium ,PSB* and *Azotobacter.*

Gupta *et.al*. (2011) reported beneficial effect of *Rhizobium ,PSB* and *PGPR* inoculation on soil available N status after chickpea harvest in black soils of Madhya Pradesh .

Jat *et al*. (2015) in a field experiment at Jobner, Rajasthan during rabi season of 2005-06 on the study the effects of FYM and mineral nutrients on the performance of Indian mustard indicated that the availability of N, S, Zn and Fe content in soil at harvest stage of crop was significantly increased with the supplementation of mineral nutrients (S + Zn + Fe).

CHAPTER III

MATERIALS AND METHODS

Present investigation on "Response of Lentil (*Lens culinaris Medikus*) to Zinc, Iron and Bio fertilizers Application in Black soils" was carried out at the Research farm of R.A.K., college of Agriculture, Sehore, M.P during the rabi season of 2016-17.The details of materials used and methods employed during the course of experimentation have been presented in this chapter under different heads.

3.1 Experimental site:

The present study was conducted in the research field of All India Co-ordinated Research project on Chickpea at R.A.K. College of Agriculture, Sehore (M.P.).

3.2 Climate and weather condition

Sehore is situated in sub tropical zone of Vindhyan Plateau of Madhya Pradesh, North of 23º 06^{0}'' latitude and East of 77.05^{0}' 'longitude with an altitude of 498.77 from above mean sea level. The average rainfall varies from 1000 to 1200 mm concentrated mostly from June to September. The mean annual maximum and minimum temperature are 27.80ºC and 10.92ºC, respectively. During the experiment period (November 2016 to march 2017) march was the hottest month having a maximum temperature up to 38.44º C. Winter month experienced mild cold with an average temperature from 5.88º C to 19.21º C. January is the coldest month as minimum temperature reaches up to 5º C. Meteorological data recorded during the period of experimentation are given in table 3.1.

The weekly meteorological data on rainfall, temperature, relative humidity and rainy days during crop season were recorded in meteorological observatory of R.A.K. College of Agriculture, Sehore.

The data in table 3.1 indicates that during the crop season the March was the hottest while December and January were the coolest months, maximum and minimum rainfall, ranged from 4.0 mm to 6.0 mm. The maximum and minimum temperature during crop season, ranged from 21.34℃ to 38.44℃ and 5.88℃ to 19.21℃, respectively, while relative humidity varied from 62.85% to 76.19%, respectively.

Table 3.1: Meteorological data during the crop season (November, 2016 to March 2017)

Month	Standard Week no.	Dates	Temperature °C		Relative Humidity (%)	Rainfall (mm)	Rainy Days (No)
			Max	Min			
November	47	19-25	27.86	9.84	70.57	0.0	0
	48	26-02	27.46	8.87	68.14	0.0	0
	Average		**28.46**	**9.49**	**69.35**		
December	49	03-09	24.77	7.80	67.85	0.0	0
	50	10-16	24.51	7.51	64.14	0.0	0
	51	17-23	24.54	6.83	64.14	0.0	0
	52	24-31	25.61	9.06	62.57	0.0	0
	Average		**24.86**	**7.80**	**64.67**		
January	1	01-07	24.78	7.28	63.00	0.0	0
	2	08-14	21.34	5.88	67.42	0.0	0
	3	15-21	22.74	11.44	66.14	0.0	0
	4	22-28	26.53	13.56	63.28	4.2	1
	5	29-04	26.71	10.16	62.85	0.0	0
	Average		**24.42**	**9.66**	**64.54**		
February	6	05 –11	25.99	12.64	66.14	4.0	1
	7	12–18	25.37	10.51	65.67	0.0	
	8	19 –25	29.74	13.66	67.84	6.0	1
	9	26–04	32.27	13.74	70.26	0.0	0
	Average		**28.34**	**12.64**	**67.47**		
March	10	05 –11	29.53	12.63	69.73	0.0	0
	11	12 –18	29.71	12.11	68.11	0.0	0
	12	19 –25	34.14	16.21	75.84	0.0	0
	13	26–01	38.44	19.21	76.19	0.0	
	Average		**32.96**	**15.04**	**72.46**		0
					GT	14.2	3

Source: Meteorological observatory, R.A.K. College of Agriculture, Sehore (M.P.).

3.2 Soil

The soil of the experimental field was clay loam. In order to find out the fertility status of the experimental field, the representative soil samples were taken from each plot before sowing. The soil samples were drawn with the help of soil Auger cut through 0-25 cm top layer from randomly selected spots in each plot. The samples were made composite and subjected to appropriate mechanical and chemical analyses. The results, thus obtained are presented in Table 3.2

Table 3.2.1: Mechanical analysis physio-chemical properties of soil of experimental site.

S NO.	Constitution	Quantity %	Method of determination
1	Sand	21.5	International Pipette method (Piper,1950)
2	Silt	31.8	-do-
3	Clay	42.6	-do-
4	Inert matter	2.5	-do-

Table:3.2.2 Chemical analysis of N, P, Zn and Fe in soil.

S. No	Chemical analysis	Quantity	Method adopted
1	Available nitrogen (kgha^{-1})	205.8 kg ha $^{-1}$	Alkaline permanganate method (Subbiah and Asija) 1956
2	Available phosphorous(kgha^{-1})	13.67 kg ha $^{-1}$	Olsen's Colorimetric method (Olsen *et al*., 1954)
3	Available Zn Available Fe (ppm)	0.46 10.68	DTPA extraction method Lindsay and Norvell (1978)
4	Soil pH	7.8	Buckman Glass Electrode pH meter (Piper,1950)
5	Organic carbon %	0.38	Walkley and Black rapid titration method (1934)
6	E.C.(dSm^{-1})	0.49	Solubridge method (Jackson, 1967)

3.2.3: **Plant analysis N ,P , Zn & Fe content in Grain and Straw of Lentil and their uptakes.**

s.no	Parameters	Method Adopted
1.	Nitrogen content(%)	Micro Kjeldhal Method as described by (Jackson,1973)
2.	Phosphorus content (%)	Vanadomolybdo Yellow colour method Koeing and Jhonson ,1942
3.	Zinc content (ppm)	Di-acid digestion methods (AOAC,1984)
4.	Iron content (ppm)	Di-acid digestion methods (AOAC,1984)

3.3 Cropping history of the experimental field:

The cropping sequence followed during preceding years on the experimental field from 2013-14 to 2016-17 is given in Table 3.3.

Table 3.3: Cropping sequence of experimental field

Year	Kharif season	Rabi season
2013-14	Soybean	Chickpea
2014-15	Soybean	Chickpea
2015-16	Soybean	Chickpea
2016-17	Urd been	Present experiment

It is apparent from the cropping pattern of the experimental site that the same type of crop rotation was followed since 2013-14.

3.5 Experimental details:

The experiment was laid out in randomized block Design with 12 treatments and each treatment was replicated three times. The details of layout plan and treatments are given as follows:

Design	:	Randomized Block Design
Treatments	:	12
Replications	:	3
Total number of plots	:	36
Gross plot size	:	5.0 m × 3.6 m
Net plot size	:	4.5 m × 2.7 m
Distance between replications	:	0.7 m
Distance between plots	:	0.7 m
Crop	:	RVL 11-6 (Lentil)
Seed rate Distance between rows	: :	40 kg ha-1 30 cm

3.6 Treatments details:

Treatments	
T_1	Absolute control
T_2	Seed inoculation with biofertilizer (bfr) LNm 43 a(*Rhizobium* +*PGPR*)
T_3	RDF(20-17-16-20 kg NPKSha$^{-1)}$
T_4	RDF + 0.5%Zn foliar application +SI with bfr LNm 43a
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm43a
T_6	RDF+0.5% Zn & 0.1% Fe foliar Application + SI with bfr LNm 43a
T_7	RDF+ Seed treatment 1g $ZnSO_4$kg^{-1} Seed + SI with bfr LNm 43a
T_8	RDF+Seed treatment 1g $FeSO_4$kg^{-1} Seed + SI with bfr LNm 43a
T_9	RDF + Seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$kg^{-1} Seed + SI with bfr LNm 43a
T_{10}	RDF+ Soil application of $ZnSO_4$ 25 kgha^{-1} + SI with bfr LNm 43a
T_{11}	Customized fertilizer (CFG_1) + SI with bfr LNm 43a
T_{12}	Customized fertilizer (CFG_2) + SI with bfr LNm 43a

*SI=Seed Inoculation

CFG_1 : 5.5-4.6-4.5-8.3-1.4-0.0-0.08-0.0 kg (N,P,K,S,Zn,Fe,B & Mo)

CFG_2 : 5.5-4.6-4.5-8.3-1.4-0.8-0.08-0.034 kg (N,P,K,S,Zn,Fe,B & Mo)

Customized fertilizer – This is a concept around balanced plant nutrition .Customized fertilizer contains macro and/or micro nutrients.These are manufactured through systematic process of granulation and satisfy crops nutritional demand specific to area , soil and growth stage of plant.

3.7 Characteristic of Variety

RVL- 11-6:

The lentil variety RVL 11-6 was developed from All India Coordinate Research Project (AICRP) on MULLaRP in Sehore in 2015 and parent of this variety is JL3 X DPL62. This variety is high yielding and semi spreading in nature with maturity ranged from 112-114 days. The leaf size large and flower color white with light pink on standard petal.

3.8 Cultivation practices:

3.8.1 Field preparation:

After the harvest of soybean crop during the month of October 2016, one tillage operation was done by tractor, thereafter cross Bukhering was done after attainment of workability followed by Pata and leveler.

3.8.2 Seed rate and seed treatment:

A recommended seed rate of 40 kg ha^{-1}, was used with row spacing of 30 cm was taken. Before sowing the seeds were treated with fungicide (Thirum 2g + Carbaxin1g/kg seed). Bio-fertlizers inoculation of seed was done by LNm 43 a(*Rhizobium* +*PGPR*) as per the treatments @ **5g kg^{-1} seed.**

3.8.3 Row spacing:

The row to row spacing was taken as 30 cm.

Table 3.4 Schedule of the operations:

S. No.	Operation	Date	Remark
1.	Field operations		
	(a) Ploughing	19/10/2016	By tractor drawn plough
	(b) Bukharing	26/10/2016	By desi bakhar
	(c) Levelling	30/10/2016	By bullock drawn leveller
2	Layout of the experiment	07/11/2016	Manual
3	Sowing	09/11/2016	By bullock drawn dufan
4	Intercultural operation	19/12/2016	By khurpi & hand hoe
5	Irrigation	21/12/2016	Pre sowing by strip method
7	Harvesting	06/03/2017	Manual
8	Threshing	13/03/2017	Manual

3.8.4 Intercultural operation:

Weeds like Motha (*Cyperus rotundus*), Hiran khuri (*Convolvulus arvensis*) were predominant in the field after sowing. They were kept under control at the stage of 25-30 DAS by hand weeding and hoeing.

3.8.5. Harvesting and Threshing:

The harvesting of the experiment was done on 06/03/2017and 13/03/2017. To avoid the border effect, border rows were first harvested before the harvest of net plot. The produce of each plot was tied in bundles and weighed with the help of spring balance. The produce of each lot was recorded in kg plot^{-1} and yield ha^{-1} was worked out.

3.9 Details of observations recorded:

Various observations were recorded during the growth period of the crop and data were recorded at various stages as per schedule. The observation schedule is presented in the Table 3.5.

Table 3.5 Observations recorded during the crop period.

S.No.	Observation	Size of sample	Stage
1.	**Pre-harvest studies**		
A	Plant height plant^{-1} (cm)	3 tagged plants	At 45,60 DAS & at maturity
B	Number of branches plant^{-1}	-do-	At 45,60 DAS& at maturity
C	Number of root length plant^{-1}	-do-	At 45,60DAS & at maturity
D	Dry weight plant^{-1} (g)	-do-	At 45,60 DAS& at maturity
E	Number of root nodules plant^{-1}	-do-	At 45, 60 DAS
F	Dry weight of root nodules plant^{-1}(mg)	-do-	At 45,60 DAS
	DAS = Days After Sowing		
2.	**Post harvest studies**		
A	Number of pods plant^{-1}	3 tagged plants	At maturity
B	Number of seeds pod^{-1}	-do-	-do-
C	Seed yield plant^{-1} (g)	-do-	-do-
D	Seed index (g)	-do-	-do-
E	Seed yield plant^{-1}(g)	Per plot	-do-
F	Seed yield kg plot^{-1}	Per plot	-do-
G	Straw yield kg plot^{-1}	Per plot	-do-
3.	**Parameters to be computed**		
A	Seed yield kg ha^{-1}	3 tagged plants	At maturity
B	Straw yield kg ha^{-1}	-do-	-do-
C	Harvest index (%)	-do-	-do-

3.10.Pre harvest studies:

Plant height plant^{-1} (cm):

Height of the three randomly selected plants in each plot was measured from the soil surface to the main apical bud.

Number of branches plant^{-1}:

The branches emerging from the base of five-tagged plants were recorded.

Root length plant^{-1} (cm)

Five randomly selected plants were uprooted from each plot and measure it with scale then take mean of it.

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

Five randomly selected plants were uprooted from each plot and oven dried in an oven at 70°C and dry weight was recorded at 45 & 60 days after sowing and at maturity stage.

Number of root nodules plant^{-1}:

The number of root nodules of three randomly selected plants was recorded in each plot at 45 and 60 days after sowing. Plants were uprooted carefully and after washing root nodules were separated from the roots of the plants. The dark pink colored root nodules of plants were counted and the number was recorded.

Dry weight of root nodules plant^{-1} (mg):

The dry weight of root nodules of five randomly selected plants was recorded in each plot at 45 and 60 days after sowing. Isolated root nodules were kept in an oven for 24 hours at 70^0 C temperatures and subsequently the dry weight of nodules was recorded.

3.11 Post harvest studies:

Number of pods per plant:

The total number of pods was counted in tagged plants and their average was used for statistical analysis.

Number of seeds pod^{-1}:

After threshing the bunch of three plants, number of seeds were counted and divided with total number of pods recorded from these three plants.

Seed yield plant^{-1} (g):

After threshing, the total yield of three tagged plants per plot was weighed and the resultant was divided by the total tagged plants and the seed yield per plant was obtained.

Seed index (g):

One hundred seeds were taken randomly from finally cleaned produce of each net plot and weighed separately by physical balance.

Seed yield (kg $plot^{-1}$):

Seed yield of each net plot was weighed and recorded after threshing and winnowing.

Straw yield (kg $plot^{-1}$):

Straw yield was calculated in kg by subtracting the grains yield from the biological yield.

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

Seed yield of each net plot was weighed and recorded in kg after threshing and winnowing.

Straw yield (kg ha^{-1}):

Straw yield was calculated in kg by subtracting the grains yield from the biological yield.

Harvest index (HI):

It was calculated by using the following formula proposed by Nichiporovich (1967):

$$\textbf{HI} = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain} + \text{straw)}} \times 100$$

3.12 Soil analysis

3.12.1. Preparation of Soil Samples

Initial soil samples collected from the randomly selected spots in the experimental field and these samples were mixed together and finally a composite soil sample was prepared. Soil samples were also collected from individual plots experimental plots after harvesting of crop. These samples were air dried. The soil samples were crushed with the help of wooden pestle and mortal and passed through 2 mm sieve and they were stored for chemical analysis in polythene bags.

3.12.2.Soil pH

The pH of soil was determined by using digital pH meter using 1:2.5 soil water suspensions (Jackson, 1973).

3.12.3.Electrical conductivity (dSm^{-1})

The same 1:2.5 soil water suspensions used for pH determination was used for the determination of electrical conductivity with the conductivity bridge as described by Jackson,(1973).

3.12.4.Organic carbon (%)

From previously prepared soil sample one gram soil sample was taken in 500 ml conical flask and 10 ml of 1N $K_2Cr_2O_7$ (Potassium dichromate) was pipette poured and swirled a little. 20 ml concentrated H_2SO_4 (Sulphuric acid) was run in and swirled. The flask was allowed to stand for 30 minutes and thereafter 200ml of distilled water was added. After incorporation of 10 ml of phosphoric acid and 1 ml of diphenylamine indicator the contents were titrated with Ferrous Ammonium Sulphate solution till the color flashes from blue violet to green. Simultaneously a blank was run without soil.

3.15.5.Estimation of Nitrogen

In a digestion tube of automatic Kjeldhal instrument 2 gm of soil was taken. To this 20 ml of distilled water and 25 ml of 0.32% $KMnO_4$ and 25 ml of 2.5% NaOH was added in the Kjeldhal tube. Before doing this 25 ml of mixed indicator solution of boric acid kept in a conical flask for ammonia absorption . Thereafter, distillation process carried out . After distillation conical flask was removed and titrated against 0.02 N H_2SO_4 until original pinkish shade appeared. Blank reading (without soil) was also taken for the final calculation.

3.15.6. Estimation of phosphorus

Extraction

2.5 grams of processed soil sample was shaken with 50 ml of 0.5 M $NaHCO_3$ extractant of the pH to 8.5 (Olsen *et al.* 1954) together with 1 g of Darco G-60 (free from soluble phosphorus) for 30 minutes in a 250 ml conical flask on mechanical shakers and then filtered through filter paper.

Development of colour

5 ml of colourless filtrate was taken in 25 ml volumetric flask for determination and then 5 ml of 1.5 per cent ammonium molybdate solution was added. The contents were diluted to about 20 ml with distilled water shaken and then 1 ml of fresh working solution of (stannous chloride) was added to develop blue colour and diluted to the mark and shaken thoroughly. The colour intensity was measured in a Spectrophotometer within 10 minutes

at 660 nm wavelength after setting the instrument to zero with blank prepared similarly but without soil as described by Jackson (1973) The amount of available phosphorus was calculated and the results were expressed in kg P ha $^{-1}$ by using standard curves.

3.13. Plant Analysis

3.13.1 Estimation of nitrogen

Nitrogen in plant samples was determined by the Macro kjeldhal method.

Extraction

0.5 gram of oven dry plant sample was taken, 3 g of digestion mixture was added (consisting of Copper sulphate and Potassium sulphate in the ratio of 1:5) and 10 ml of conc. H_2SO_4 was placed into digestion tube. The contents were digested initially at 150 ^{0}C for 2 hours and thereafter at high temperature (300-400 ^{0}C) till the content of digestion tube becomes clear solution of light green color. Then content transfer in volumetric flask (100ml) and makeup the volume with distill water.

Distillation

10 ml of the digested material was taken and transferred in to micro kjeldahl distillation tube while in conical flask, 10 ml of 4% boric acid solution containing bromocresol green and methyl red indicators was taken which is placed at the condenser outlet from where ammonia came. After adding the aliquot, the funnel of the apparatus was washed with 2.3 ml of deionized water and 10 ml of 40% NaOH solution was the added. Subsequently 100 ml aliquot was distilled to the flask containing 10 ml of boric acid. After distillation the distillate was titrated against 0.02 N H_2SO_4. Blank without taking aliquot of digested sample was also run.

3.13.2 Estimation of phosphorus

Phosphorus determination in the plant samples was done by Vanado molybdo-phosphoric acid yellow colour method of Koeing and Johnson (1942)

Extraction

One gram of oven dried plant sample was taken and digested in 100 ml conical flask with 12 ml of di-acid mixture of (9:4) consisting of AR grade HNO_3 and $HClO_4$ respectively and digested material was filtered through What man No. 40 filter paper in 100 ml volumetric flask and the filtrate was diluted up to the mark by adding distilled water.

Development of colour

5 ml of aliquot from the colourless filtrate was taken in a 50 ml volumetric flask for determination, then 10 ml of ammonium molybdate - ammonium meta vanadate solution was added into each volumetric flask to develop yellow colour. The neck of the flask was washed with distilled water and diluted up to the required mark. The colour intensity was measured by spectrophotometer at 420 nm wavelength after mixing thoroughly and after setting the instruments to zero with blank as described by Jackson (1967). The amount of phosphorus was calculated in percentage on oven dry basis.

3.14.Estimation of micronutrients (Zn and Fe) in Soil samples:

Estimated by DTPA extraction method (Lindsay and Norvell 1978). 10gm soil was taken in 100 ml conical flask, 20 ml DTPA reagent was added and shaken for two hours .The extract was filtered (Whatman No.40) and micronutrient (Zn and Fe) estimated with the help of Atomic Absorption Spectrophotometer. Result was expressed in mg kg^{-1}

3.15. Estimation of micronutrients (Zn and Fe) in plant samples:

Zinc and Iron were determined with the help of atomic Absorption Spectrophotometer.

Extraction-

One gram oven dried plant samples was taken and digested in 100ml conical flask with 12 ml of di –acid (mixture) (9:4) consisting of AR grade HNO_3 and $HClO_4$ respectively and digested material was filtered through What man No. 40 filter paper in 100ml volumetric flask and filtrate was diluted up to the mark. Micronutrient (Zn and Fe) determined in the extract through AAS by using respective hallow cathode lamp using standards of respective micronutrients.

3.16 Statistical analysis

The data pertaining to various growth and yield parameters as well as values of economic return were subjected to analysis of variance prescribed for factorial randomized block Design by the method given by Panse and Sukhatme (1967). The "F" test was performed for judging the significance of the treatment mean squares. The significant differences between means were judged by using critical difference (C.D.) at 5% level of probability.

Table 3.6 :- Skeleton of analysis of variance

Source of variation	DF	SS	MSS	F cal	F tab	SEm!	CD 5%
Replication (R)	2						
Treatment (T)	11						
Error	22						
Total	35						

In case of "F" test was significant, standard error and critical differences were calculated by formula.

(1) $$S.Em \pm = \sqrt{\frac{EMS}{R \times S}}$$

$$C.D \text{ at } 5\% = S.Em \pm \sqrt{2} \times t_{(22\ df)} \text{ at } 5\%$$

Where:

t = Number of treatments

R = Number of replication

D.F. = Degree of freedom

S.Em± = Standard error of mean

C.D. = Critical difference

MSS = Mean Sum of squares

SS = Sum of square

EMS = Error mean square

CHAPTER IV

RESULTS

The data recorded during the course of investigation in field as well as laboratory work are compiled and statistically analyzed and mean values are presented in the form of results in this chapter. The data are discussed in the light of different treatments tested and are given in various tables and figures.

4.1. Effect of Zinc, Iron and Bio fertilizer application on Symbiotic traits of Lentil in Black Soils:

The data recorded on symbiotic traits including nodule number, nodule dry weight and total dry weight of plant at different stages of crop growth are described as under-

4.1.1 Nodule number of Lentil at different stages:

The data on root nodules plant^{-1} at different stages of crop (45,60 DAS and maturity) are shown in Table 4.1.1, fig:3 and appendix (III).The data indicates chronological decrease in root nodules plant^{-1} from 45 DAS to 60 DAS and at maturity stages. No. of root nodules plant^{-1} was found to be increased significantly by the application of different treatments over absolute control at different stages of crop growth. The highest root nodules (21.09, 17.02 and 12.10) was recorded under the treatment T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) followed by (19.23, 16.88 and 11.90) under T_{10} (RDF+soil app. of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) and (18.71, 16.50 and 11.86) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) at 45, 60 DAS and at maturity respectively. Further the treatment T_{12}(Customized fertilizer(CFG1)+SI with bfr LNm 43a) and T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) were also recorded significantly higher root nodules over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKSha^{-1}) at 45 and 60 days and at maturity . Minimum root nodules (14.12, 12.20 and 8.77) was observed under T_1 (absolute control) at all the stages viz.45,60DAS and at maturity.

Table 4.1.1 Effect of Zinc, Iron and Bio-fertilizer application on nodule number (NN pl $^{-1}$) in Lentil:

Treatments		NNpl $^{-1}$ 45DAS	NNpl $^{-1}$ 60DAS	NN pl $^{-1}$ Maturity
T_1	Absolute control	14.12	12.20	8.77
T_2	Seed inoculation with bio fertilizer LNm43 a (*Rhizobium + PGPR)*	15.16	13.60	8.78
T_3	RDF (20-17-16-20 kg NPKSha $^{-1}$)	17.74	15.20	9.62
T_4	RDF+ 0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	18.50	16.40	11.67
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	18.44	15.90	10.34
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	18.71	16.50	11.86
T_7	RDF+seed treatment 1g $ZnSO_4$kg $^{-1}$ seed+SI with bfr LNm 43a	18.23	15.68	11.02
T_8	RDF+seed treatment 1g $FeSO_4$kg $^{-1}$ seed+ SI with bfr LNm 43a	18.34	15.41	10.52
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	18.54	16.22	11.33
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha $^{-1}$ +SI with bfr LNm 43a	19.23	16.88	11.90
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	16.57	14.27	8.89
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	21.09	17.02	12.10
	CD at 5%	**1.47**	**1.607**	**1.393**

4.1.2 Nodule dry weight of Lentil at different stages:

The data on root nodule dry weight plant $^{-1}$ at different stages of crop (45,60 DAS and at maturity) are shown in Table4.1.2, fig:4 and appendix (III).The data indicates chronological decrease in root nodules dry weight plant $^{-1}$ from 45 DAS to 60 DAS and at maturity stages. Root nodules dry weight was found to be increased significantly by the application of different treatments over absolute control at different stages of crop growth. The highest root nodules dry weight (11.92,8.30 and 3.87 mg plant $^{-1}$) was recorded under the treatment T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) followed by (11.81, 8.14 and 3.76 mg plant $^{-1}$) under T_{10} (RDF+soil app of $ZnSO_4$ 25kg ha-1 +SI with bfr LNm 43a) and (11.62,8.11 and 3.70mg plant^{-1}) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) at 45, 60 DAS and at maturity respectively. Further the treatment T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) and T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) and T_6 (RDF +0.5% Zn & 0.1% Fe foliar app +SI with bfr LNm 43a) were also recorded significantly higher root nodules dry weight over the existing practice of fertilization i.e. T_3 (RDF 20-17-16-20 kg NPKSha^{-1}) at 45 and 60 days and at maturity . Minimum root nodules dry weight (8.53,4.17 and 1.52 mg) was observed under T_1 (absolute control) at all the stages .

Table 4.1.2 Effect of Zinc, Iron and Bio-fertilizer application on nodule dry weight (mg) plant^{-1} of Lentil in Black soil:

Treatments		45 DAS (mg pl^{-1})	60 DAS (mg pl^{-1})	Maturity (mg pl^{-1})
T_1	Absolute control	8.53	4.17	1.52
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	9.44	5.81	2.34
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	10.33	7.10	2.52
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	11.51	7.91	3.42
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	10.72	7.63	3.20
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	11.62	8.11	3.70
T_7	RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a	10.40	7.22	3.13
T_8	RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a	10.62	7.31	3.20
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	11.21	7.80	3.31
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	11.81	8.14	3.76
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	10.01	6.93	2.51
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	11.92	8.30	3.87
	CD at 5%	**1.09**	**0.9529**	**0.3586**

4.1.3 Dry weight plant $^{-1}$ of Lentil at different stages:

The results of data on dry weight plant^{-1} at different stages of crop (45,60DAS and maturity) are shown in Table 4.1.3, fig:5 and appendix (I).The data indicates chronological enhancement in dry weight plant^{-1} at different stages. Dry weight plant^{-1} was found to be increased significantly by the application of different treatments over absolute control at different stages of crop growth.

Table 4.1.3 Effect of Zinc, Iron and Bio fertilizer application on Dry weight g plant $^{-1}$ of Lentil at different stages of crop growth:

Treatments		45 DAS (g)	60 DAS (g)	Maturity (g)
T_1	Absolute control	0.81	2.68	2.90
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	1.23	2.82	3.12
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	1.44	3.30	3.73
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	2.33	3.95	4.44
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	1.90	3.71	3.92
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	2.63	4.30	4.90
T_7	RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a	1.72	3.40	3.81
T_8	RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a	1.82	3.60	3.93
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	2.22	3.83	4.13
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	2.83	4.81	5.51
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	1.33	2.92	3.30
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	2.41	4.12	4.71
	CD at 5%	**0.20**	**0.67**	**0.66**

The highest dry weight plant^{-1} (2.83 ,4.81 and 5.51 g) was recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by (2.63, 4.30 and 4.90 g) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) then (2.41, 4.12 and 4.71 g) under T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a) and (2.33, 3.95 and 4.44 g) under T_4(RDF + 0.5% Zn foliar application +seed inoculation with bfr LNm 43 a) at 45, 60 DAS and at maturity respectively. Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) and T_6(RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) T_{12}(Customized fertilizer(CFG1)+SI with bfr LNm 43a) and T_4(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a) were also recorded significantly higher dry weight plant^{-1} over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}) at 45 and 60 days and at maturity . Minimum dry weight plant^{-1} (0.81, 2.68 and 2.90 g) was observed under T_1 (absolute control) at all stages.

4.2 Effect of Zinc, Iron and Bio fertilizer application on Growth attributes of Lentil in Black Soils:

The data recorded on various growth attributes viz. plant height, branches, and root length at different stages of crop growth are described as under-

4.2.1 Plant height :

The data on plant height at different stages of crop (45,60 DAS and maturity) are shown in Table 4.2.1, fig:6 and appendix (I). The data indicates chronological enhancement in height at different stages. The plant height was found to be increased significantly by the application of different treatments over absolute control at different stages of crop growth. The highest plant height (17.01,26.68 and 35.22 cm) was recorded under the treatment T_{10} (RDF+Soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a followed by (16.90,27.83 and 37.15cm) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a thereafter (17.32, 28.19 and 37.03cm) in T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a and (16.38,27.31 and 36.35cm) in T_4(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a at 45,60DAS and at maturity respectively. Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25 kgha^{-1} +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) were also recorded significantly higher height over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKS ha^{-1}) at 45, 60 DAS and at maturity stages . Minimum plant height (14.60, 23.92, 33.31 cm) was observed under T_1(absolute control) at all stages

Table 4.2.1: Effect of Zinc, Iron and Bio fertilizer application on plant height plant^{-1} (cm) in Lentil in Black soil:

Treatments		Plant height at 45 DAS (cm)	Plant height at 60 DAS (cm)	Plant height at Maturity (cm)
T_1	Absolute control	14.60	23.92	33.31
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	14.77	24.80	33.34
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	16.47	26.30	34.51
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	16.38	27.31	36.35
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	16.49	26.61	35.75
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	16.90	27.83	37.15
T_7	RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a	16.91	26.44	35.23
T_8	RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a	17.16	26.53	36.19
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	17.25	26.97	35.86
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	17.39	28.87	37.29
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	17.01	26.68	35.22
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	17.32	28.19	37.03
	C.D. at 5%	**1.1708**	**1.7363**	**2.1049**

4.2.2: Branches plant^{-1} at different stages in Lentil:

The data on branches plant^{-1} at different stages of crop growth (45, 60 DAS and maturity) are shown in Table 4.2.2, fig:7 and appendix (I).The data indicates chronological enhancement in branches plant^{-1} at different stages. Branches plant^{-1} was found to be increased significantly by the application of different treatments over absolute control at different stages of crop growth. The highest branches plant^{-1} (2.75, 3.51 and 3.60) was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) followed by (2.31, 3.17 and 3.50) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) at 45, 60 DAS and at maturity respectively. Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) were also recorded significantly higher branches plant^{-1} over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKS ha^{-1}) at 45 ,60 DAS and at maturity. Minimum branches plant^{-1} (1.66, 2.21, and 2.53) was observed under T_1 absolute control at all stages.

Table 4.2.2: Effect of Zinc, Iron and Bio fertilizer application on No. of branches plant^{-1} at different stages in Lentil in Black soil :

Treatments		No. of branches plant^{-1} 45 DAS	No. of branches plant^{-1} 60 DAS	No. of branches plant^{-1} Maturity
T_1	Absolute control	1.66	2.21	2.53
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	1.68	2.42	2.80
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	2.08	2.74	2.97
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	2.28	3.07	3.30
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	2.22	3.06	3.10
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	2.31	3.17	3.50
T_7	RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a	2.32	2.99	3.00
T_8	RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a	2.35	3.05	3.07
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	2.39	3.12	3.20
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	2.75	3.51	3.60
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	2.29	2.86	2.83
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	2.43	3.16	3.43
	CD at 5%	**0.35**	**0.36**	**0.60**

4.2.3 : Root length(cm):

The data on root length plant^{-1} at different stages of crop growth (45, 60DAS and at maturity) are shown in Table 4.2.3, fig:8 and appendix (II). The data indicates chronological enhancement in root length plant^{-1} at different stages. Root length plant^{-1} was found to be increased significantly by the application of different treatments over absolute control at different stages of crop growth .The highest root length plant^{-1}(6.83, 10.50 and 16.60 cm) was recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) followed by (6.42, 10.40 and 16.33 cm) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) there after (6.31, 10.27 and 15.21) under T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a) at 45, 60 DAS and at maturity respectively. Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) and T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) were also recorded significantly higher root length plant^{-1} over the existing practice of fertilization i.e T_3 (RDF +20-17-16-20 kg NPKSha^{-1}) at 45 and 60 days and at maturity . Minimum root length plant^{-1}(4.92, 8.27 and 12.47 cm) was observed underT_1 (absolute control) at 45, 60 DAS at at maturity respectively.

Table 4.2.3 Effect of Zinc , Iron and bio fertilizer application on root length (cm) in Lentil in Black Soils:

Treatments		Root length plant^{-1} (cm) 45DAS	Root length plant^{-1} (cm) 60DAS	Root length plant^{-1} (cm) Maturity
T_1	Absolute control	4.92	8.27	12.47
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	5.13	8.43	15.18
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	5.40	8.83	15.29
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	6.20	10.13	15.64
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	5.72	10.03	15.52
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	6.42	10.40	16.33
T_7	RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a	5.60	9.63	15.31
T_8	RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a	5.71	9.90	15.36
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	5.82	10.07	15.55
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	6.83	10.50	16.60
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	5.21	8.63	15.63
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	6.31	10.27	15.21
	CD at 5%	**0.73**	**1.51**	**1.8469**

4.3. Effect of Zinc, Iron and Bio fertilizer application on Yield attributes in Lentil in Black soil :

The data recorded on various yield attributes viz. No of pods plant^{-1}, Seed yield plant^{-1}, and Seed Index at maturity stage are described as under-

4.3.1 No of Pods plant^{-1}:

The data on No of Pods plant^{-1} are shown in Table 4.3 fig:9 and appendix (IV). Pods plant^{-1} was found to be increased significantly by the application of different treatments over absolute control .The highest pods plant^{-1} (127.00) was recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by (115.60) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) then (114.13) under T_{12} (Customized fertilizer (CFG2)+SI with bfr LNm 43a). Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) and T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) were also recorded significantly higher pods plant^{-1} over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKSha^{-1}). Minimum dry pods plant^{-1}(66.62) was observed underT_1 (absolute control) .

4.3.2 Seed yield plant^{-1} :

The data on Seed yield plant^{-1} are shown in Table 4.3,fig:10 and appendix (IV) .The data indicates enhancement in seed yield plant^{-1} at different stages. Seed yield plant^{-1} was found to be increased significantly by the application of different treatments over absolute control .The highest seed yield plant^{-1} (4.61g) was recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by(4.53) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a), (4.45 g) under T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a) and (4.41g) under T_4 (RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a). Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) T_4 (RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a) were also recorded significantly higher seed yield plant^{-1} over the existing practice of fertilization

Table 4.3: Effect of Zinc , Iron and bio fertilizer application on Pods plant^{-1} , Seed yield plant^{-1} and seed index in Lentil in Black soil:

Treatments		No. of pods plant^{-1}	Seed yield plant^{-1} (g)	Seed index
T_1	Absolute control	66.62	3.08	2.27
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	82.30	3.43	2.42
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	93.72	3.66	2.45
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	113.51	4.41	2.77
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	100.70	4.19	2.76
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	115.60	4.53	2.87
T_7	RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a	94.53	3.71	2.73
T_8	RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a	97.90	4.07	2.74
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	101.22	4.25	2.76
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	127.00	4.61	3.00
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	86.30	3.47	2.42
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	114.13	4.45	2.78
	CD at 5%	**18.63**	**0.50**	**0.15**

i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}).Minimum Seed yield $plant^{-1}$(3.08g) was observed underT_1 (absolute control) at all stages .

4.3.3 Seed index:

The data on Seed index are shown in Table 4.3, fig:10 and appendix (IV .The seed index was found to be increased significantly by the application of different treatments over absolute control .The highest seed index was (3.00) recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by (2.87) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) then (2.78) under T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a) and (2.77) under T_4(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a). Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) and T_6(RDF +0.5% Zn & 0.1% Fe foliar app +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) and T_4 (RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a) were also recorded significanytly higher seed index $plant^{-1}$ over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKSha^{-1}).Minimum seed index (2.27) was observed under T_1 (absolute control).

4.4. Effect of Zinc, Iron and Bio fertilizer application on Seed, Straw, Biological yield and harvest index of Lentil in Black soil :

The data recorded on various yield attributes viz. seed yield $plot^{-1}$, straw yield $plot^{-1}$,seed yield kg ha^{-1} straw yield Kg ha^{-1},biological yield and harvest index are described as under

4.4.1a Seed yield (kg $plot^{-1}$)

The data on Seed yield kg $plot^{-1}$ are shown in Table 4.4.1a,fig:11 and appendix (V). Seed yield $plot^{-1}$ was found to be increased significantly by the application of different treatments over absolute control .The highest seed yield kg $plot^{-1}$ (1.66) was recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by (1.59) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) then (1.58) with T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) and T_{12}(Customized fertilizer(CFG1)+SI with bfr LNm 43a) were also recorded significantly higher seed yield $plot^{-1}$ over the existing practice of fertilization i.e

T_3 (RDF (20-17-16-20 kg NPKSha^{-1}). Minimum seed yield kg plot^{-1}(1.09) was observed underT_1 (absolute control).

Table 4.4.1: Effect of Zinc,Iron and bio fertilizer application on Seed yield (kg plot^{-1}) and Straw yield (kg plot^{-1}) in Lentil in Black soil:

Treatments		Seed yield (kg plot^{-1})	Straw yield (kg plot^{-1}
T_1	Absolute control	1.09	1.19
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	1.22	1.30
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	1.44	1.51
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	1.58	1.60
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	1.54	1.58
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	1.59	1.66
T_7	RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a	1.50	1.52
T_8	RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a	1.52	1.55
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	1.54	1.61
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	1.66	1.73
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	1.41	1.42
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	1.58	1.65
	CD at 5%	**0.14**	**0.14**

4.4.1b Straw yield (kg plot^{-1}) :

The data on Straw yield kg plot^{-1} are shown in Table 4.4.1,fig:11 and appendix (V). Straw yield plot^{-1} was found to be increased significantly by the application of different treatments over absolute control .The highest straw yield kg plot^{-1} (1.73) was recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25kg ha^{-1} + SI with bfr LNm 43a) followed by (1.66) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) then (1.65) under T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) and T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) were recorded significantly higher straw yield kg plot^{-1} over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKSha^{-1}). Minimum straw yield kg plot^{-1} (1.51) was observed under T_1 (absolute control) .

4.4.2a Grain yield (kg ha^{-1})

The data on Grain yield kg ha^{-1} are shown in Table 4.4.2,fig:12 and appendix (IV) . Grain yield kg ha^{-1} was found to be increased significantly by the application of different treatments over absolute control T_1 .The highest grain yield was (1540 kgha^{-1}) recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by (1480 kg ha^{-1}) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) there after (1470 kg ha^{-1}) under T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) and (1470 kg ha$^{-1)}$ under T_4 (RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a) . Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) were recorded significantly higher grain yield kg ha^{-1} over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKSha^{-1}).Minimum grain yield kg ha^{-1} was observed (1010kgha^{-1}) underT_1 (absolute control) .

4.4.2b Straw yield (kg ha^{-1})

The data on Straw yield kg ha^{-1} are shown in Table 4.4.2b, fig:12 and appendix (IV) .Straw yield kg ha^{1}was found to be increased significantly by the application of different treatments over absolute control T_1 .The highest straw yield kg ha^{-1} was (1610 kg ha^{-1}) recorded under the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by (1542 kg ha^{-1}) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) there after (1528 kg ha^{-1}) under T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a).Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) and T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) were also recorded significantly higher straw yield kg ha^{-1} over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKS ha^{-1}) .Minimum straw yield (1528 kg ha^{-1}) was observed under T_1 (absolute control) .

4.4.2c: Biological yield (kg ha^{-1}) –

The data on Biological yield kg ha^{-1} are shown in Table 4.4.2, fig:12 and appendix(IV).Biological yield was found to be increased significantly by the application of different treatments over absolute control (T_1).The highest biological yield (3150 kg ha^{-1}) was recorded under the treatment T_{10} (RDF+soil app. of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by (3022 kg ha^{-1}) under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) there after (2998kg ha^{-1}) T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a) and (2960 kgha^{-1}) under T_4 (RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a).Further the treatment T_{10} (RDF+soil app of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a),T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) were also recorded significantly higher biological yield over the existing practice of fertilization i.e T_3 (RDF (20-17-16-20 kg NPKSha^{-1}).Minimum biological yield was observed(2113 kg ha^{-1}) under T_1 (absolute control) .

4.4.2d Harvest index (%) :-

The data on Harvest index are shown in Table 4.4.2, fig:13 and appendix (IV).Harvest index was found to be increased significantly by the application of different treatments over absolute control T_1.The highest harvest index (49.66) was recorded under the treatment T_4 (RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a) followed by (49.51)under T_7 (RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr) there after (49.40) under T_8 (RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr).However these were statistically identical with T_{10},T_6 and T_{12}. Minimum harvest index was observed underT_1 (absolute control).

Table 4.4.2: Effect of Zinc , Iron and bio fertilizer application on Grain yield kg ha^{-1} ,Straw yield $kgha^{-1}$, Biological yield and Harvest index in Lentil in Black soil:

NO.	Treatments	Seed yield (Kg ha^{-1})	Straw Yield (Kg ha^{-1})	Biological Yield (Kg ha^{-1})	Harvest Index (%)
T_1	Absolute control	1010	1103	2113	47.80
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	1131	1210	2341	49.23
T_3	RDF (20-17-16-20 kg $NPKSha^{-1}$)	1366	1404	2770	48.31
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	1470	1490	2960	49.66
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	1430	1463	2893	49.11
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	1480	1542	3022	48.90
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	1390	1415	2805	49.51
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	1409	1443	2852	49.40
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	1432	1493	2925	48.95
T_{10}	RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a	1540	1610	3150	48.90
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	1310	1322	2632	49.22
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	1470	1528	2998	49.26
	CD at 5%	**169.3**	**131.6**	**176.4**	**0.92**

4.5.1 Effect of Zinc, Iron and Bio fertilizer application on N content in seed, straw & protein content in Lentil :

4.5.1a Nitrogen content(%) in lentil Seed:

The data on N content in seed are shown in Table 4.5.1,fig:14 and appendix(VI). The N content in seed was found significant by the application of different treatments over absolute control .The highest N content in seed (3.96) was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) then inT_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatment $T_{10,}$ recorded significantly higher N content over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}) .Minimum N content was observed under T_1 (absolute control) .

4.5.1b Nitrogen content(%) in lentil Straw:

N content in straw-: The data on N content in straw are shown in Table 4.5.1,fig;14 and appendix (VI). The N content in straw was found to be significant by the application of different treatments over absolute control, T_1 .The highest N content in straw was recorded under the treatment T_{10} (RDF+ soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatments T_6 to T_{12} recorded significantly higher N content over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}).However T_6 to T_{12} were statistically identical. Minimum N content was observed under T_1 (absolute control).

4.4.1c Protein content (%) in Seed:

Protein content-: The data on protein content in seed is shown in Table 4.5.1,fig:14.1 and appendix (VI). The Protein content in seed was found significant by the application of different treatments over absolute control .The highest Protein content in seed was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatmentT_{10} recorded significantly higher protein content over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$).Minimum Protein content was observed under T_1 (absolute control) .

Table 4.5.1: Effect of Zinc, Iron and Bio fertilizer application on N content in seed, straw & protein content in Lentil :

Treatments		N content Seed %	N content Straw %	Protein content in seed %
T_1	Absolute control	3.70	0.70	23.12
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	3.72	0.75	23.25
T_3	RDF (20-17-16-20 kg $NPKSha^{-1}$)	3.92	0.78	24.50
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	3.93	0.80	24.56
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	3.94	0.82	24.62
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	3.94	0.85	24.62
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	3.92	0.86	24.50
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	3.94	0.87	24.62
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	3.94	0.87	24.62
T_{10}	RDF+soil application of $ZnSO_4$ $25kgha^{-1}$ +SI with bfr LNm 43a	3.96	0.88	24.85
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	3.94	0.88	24.62
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	3.94	0.88	24.62
	CD at 5%	**0.02**	**0.05**	**0.125**

4.5.2: Effect of Zinc, Iron and Bio fertilizer application on Nitrogen uptake by seed , straw and total N uptake (kg ha^{-1}) in lentil:

4.5.2a N uptake in seed (kg ha^{-1}) :

The data on N uptake in seed are shown in Table 4.5.2 ,fig:15 and appendix (VI). The N uptake in seed was found to be significant by the application of different treatments over absolute control T_1 .The highest N uptake in seed (60.98 kg ha^{-1}) was recorded under the treatment T_{10}

(RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) , T_6(RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) and T_{12}(Customized fertilizer(CFG1)+SI with bfr LNm 43a) and T_4(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a) were also recorded significantly higher N uptake over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKS ha^{-1}) . Minimum N uptake was observed under T_1 (absolute control) .

4.5.2b N uptake in Lentil Straw

The data on N uptake in straw are shown in Table 4.5.2,fig:15 and appendix(VI). The N uptake in straw was found significant by the application of different treatments over absolute control .The highest N uptake in straw(14.17 kg ha^{-1}) was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatment T_{10} and T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) recorded significantly higher N uptake in straw over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}).Minimum N uptake (7.72 kg ha^{-1}) was observed under T_1 (absolute control).

4.5.2c Total N uptake Lentil (Seed+ Straw) kg ha^{-1}

The data on total N uptake in are shown in Table 4.5.2, fig:15 and appendix(VI) . The total N uptake was found significantly superior by the application of different treatments over absolute control,T_1 .The highest total N uptake (75.15 kg ha^{-1}) was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha-1 +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) and T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatments viz.T_4,T_6,T_8,T_9,T_{10},T_{12} recorded significantly higher total N uptake over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}). Minimum total N uptake was observed under T_1 (absolute control) .

Table 4.5.2: Effect of Zinc, Iron and Bio fertilizer application on Nitrogen uptake by seed ,straw and total N uptake(kg ha^{-1}) in lentil:

Treatments		N uptake In seeds (Kg ha^{-1})	N uptake In (straw Kg ha^{-1})	Total N uptake (Kg ha^{-1})
T_1	Absolute control	37.86	7.72	45.59
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	41.84	9.07	50.91
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	53.54	10.95	64.49
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	57.77	11.92	69.69
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	56.34	11.99	68.33
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	58.31	13.11	71.42
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	54.48	12.16	66.64
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	55.51	12.55	68.02
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	56.42	12.99	69.41
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	60.98	14.17	75.15
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	51.61	11.63	63.24
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	57.91	13.44	71.35
	CD at 5%	**3.01**	**1.88**	**4.09**

4.5.3: Effect of Zinc, Iron and Bio fertilizer application on Phosphorus content in Seed and Straw in Lentil:

4.5.3a P content in Lentil Seed:

The data on P content in seed are shown in Table 4.5.3,fig:16 and appendix(VII). The P content in seed was found significant by different treatments over absolute control T_1 . The highest P content in seed was recorded under the treatment T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) followed by T_{11} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) Further the treatment T_8,T_{12} and T_{11} recorded significantly higher P content over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}). Minimum P content was observed under T_1 (absolute control) .

Table 4.5.3: Effect of Zinc, Iron and Bio fertilizer application on Phosphorus content(%) in Seed and Straw in Lentil:

Treatments		P content Seed (%)	P content Seed (%)
T_1	Absolute control	0.36	0.23
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	0.39	0.25
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	0.42	0.27
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	0.42	0.26
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	0.43	0.27
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	0.43	0.27
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	0.43	0.26
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	0.44	0.27
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	0.43	0.27
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	0.43	0.26
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	0.44	0.28
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	0.44	0.30
	CD at 5%	**0.01**	**0.015**

4.5.3b P content in Lentil Straw:

The data on P content in straw are shown in Table 4.5.3,fig:16 and appendix(VII). The P content in straw was found significant due to application of different treatments over absolute control,T_1 .The highest P content in straw was recorded under the treatment T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a) followed by T_{11}(Customized fertilizer(CFG1)+SI with bfr LNm 43a). Further the treatment T_{12} recorded higher P content in straw over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}). Minimum P content in straw was observed under T_1 (absolute control)

4.5.4: Effect of Zinc, Iron and Bio fertilizer application on Phosphorus uptake by Seed , Straw and total P uptake kg ha^{-1} in Lentil:

4.5.4a P uptake in Seed(kg ha^{-1}):

The data on P uptake in seed are shown in Table 4.5.4, fig:17and appendix(VI). The P uptake in seed was found significant by the application of different treatments over absolute control .The highest P uptake in seed was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_{12} (Customized fertilizer(CFG_2)+SI with bfr LNm 43a). Minimum P uptake was observed under T_1 (absolute control) .

4.5.4b P uptake in Straw(kg ha^{-1}):

The data on P uptake in Straw are shown in Table 4.5.4,fig:17 and appendix (VI). The P uptake in straw was found significant by the application of different treatments over absolute control The highest P uptake in straw was recorded under the treatment T_{10} (RDF+ soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Minimum P uptake was observed under T_1 (absolute control) .

Table 4.5.4c Total(Seed+Straw) P uptake (kg ha^{-1}) in lentil:

The data on Total P uptake are shown in Table 4.5.4,fig;17 and appendix(VI). The total P uptake was found significant by the application of different treatments over absolute control .The highest total P uptake was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a)followed by underT_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a). Minimum total P uptake was observed under T_1 (absolute control) .

Table 4.5.4: Effect of Zinc, Iron and Bio-fertilizer application on Phosphorus uptake(kg ha^{-1}) in Seed and Straw in Lentil:

Treatments		P uptake seed (kg ha^{-1})	P uptake Straw (kg ha^{-1})	Total Seed+ Straw (kg ha^{-1})
T_1	Absolute control	3.63	2.54	6.17
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	4.41	3.02	7.43
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	5.73	3.65	9.38
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	6.17	3.87	10.04
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	6.14	3.95	10.09
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	6.36	4.16	10.52
T_7	RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a	5.98	3.68	9.66
T_8	RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a	6.20	3.90	10.10
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	6.16	4.03	10.19
T_{10}	RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a	6.77	4.34	11.11
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	5.76	3.70	9.46
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	6.46	4.58	11.04
	CD at 5%	**0.25**	**0.09**	**0.17**

4.6: Effect of Zinc, Iron and Bio fertilizer application on Zn and Fe scontent and uptake g ha^{-1} in Lentil :

4.6.1: Effect of Zinc, Iron and Bio fertilizer application on Zn and Fe content and uptake g ha^{-1} in Lentil :

4.6.1a Zn content in Seed:

The data on Zn content in seed are shown in Table 4.6.1,fig:18 and appendix(VIII). The Zn content in seed significantly influenced by the application of different treatments over absolute control,T_1 .The highest Zn content in seed was recorded under the treatment T_{10} (RDF+soil application of

$ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_9 (RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a). Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) and T_9 (RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43) recorded significantly higher Zn content over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$). Minimum Zn content was observed under T_1 (absolute control).

Table 4.6.1: Effect of Zinc, Iron and Bio fertilizer application on Zn (ppm) content in seed and straw Lentil in :

Treatments		Zn content seed (ppm)	Zn content Straw (ppm)
T_1	Absolute control	35.13	8.32
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	35.19	8.41
T_3	RDF (20-17-16-20 kg $NPKSha^{-1}$)	35.56	8.60
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	35.93	8.75
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	35.63	8.62
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	36.00	8.98
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	36.13	9.16
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	35.76	8.86
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	36.23	9.00
T_{10}	RDF+soil application of $ZnSO_4$ $25kgha^{-1}$ +SI with bfr LNm 43a	36.55	9.20
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	35.83	9.08
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	35.85	9.04
	CD at 5%	**0.61**	**0.32**

4.6.1b: Zn content in Straw:

The data on Zn content in straw are shown in Table 4.6.1,fig:18 and appendix (VIII). The Zn content in straw was found significant by the application of different treatments over absolute control .The highest Zn content in straw was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_9 (RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a).Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) and T_9 (RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43) recorded significantly higher Zn content over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$). Minimum Zn content was observed under T_1 (absolute control) .

4.6.2: Effect of Zinc, Iron and Bio fertilizer application on Zn uptake by seed , straw and total Zn uptake in lentil:

4.6.2a Zn uptake in Lentil Seed (g ha^{-1}):

The data on Zn uptake in seed are shown in Table 4.6.2,fig:19 and appendix(VIII). The Zn uptake in seed was found significant by the application of different treatments over absolute control,T_1 .The highest Zn uptake in seed was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then by T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatment T_{10},$T_{6,}$ T_{12} andT_4 also recorded significantly higher Zn uptake over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$). Minimum Zn uptake was observed under T_1 (absolute control) .

4.6.2b Zn uptake in Lentil Straw (g ha^{-1}):

The data on Zn uptake in straw are shown in Table 4.6.2,fig(19) and appendix(VIII). The Zn uptake in straw was found significant by the application of different treatments over absolute control .The highest Zn uptake in straw was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then in T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatment T_{10}, T_6 and T_{12} and T_4 recorded significantly higher Zn uptake in straw over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$) . Minimum Zn uptake was observed under T_1 (absolute control)

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Table 4.6.2: Effect of Zinc, Iron and Bio fertilizer application on Zinc uptake by seed , straw and total Zn uptake $kgha^{-1}$ in lentil:

S.NO	Treatments	Zn uptake Seed gha^{-1}	Zn uptake Straw gha^{-1}	Total Zn uptake Seed+Straw gha^{-1}
T_1	Absolute control	35.45	9.17	44.62
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	39.59	10.17	49.86
T_3	RDF (20-17-16-20 kg $NPKSha^{-1}$)	48.08	12.07	60.15
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	52.77	13.03	65.80
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	50.90	12.61	63.51
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	53.28	13.84	67.12
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	50.17	12.96	63.13
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	50.44	12.78	63.22
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	51.83	13.44	65.27
T_{10}	RDF+soil application of $ZnSO_4$ $25kgha^{-1}$ +SI with bfr LNm 43a	56.05	14.81	70.86
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	46.89	12.00	58.89
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	52.62	13.81	66.43
	CD at 5%	**1.55**	**0.41**	**1.65**

4.6.2c Total (Seed+ Straw) Zn uptake (g ha^{-1}) in Lentil

The data on total Zn uptake are shown in Table 4.6.2, fig:19 and appendix(VIII) . The total Zn uptake in Lentil was found significant by the application of different treatments over absolute control,T_1 .The highest total Zn uptake was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then in T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a), T_6(RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) and T_{12}(Customized fertilizer(CFG1)+SI with bfr LNm 43a) and T_4(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a) recorded significantly higher total Zn uptake over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}).Minimum total Zn uptake was observed under T_1 (absolute control) .

4.6.3: Effect of Zinc, Iron and Bio fertilizer application on Iron content seed and straw in lentil:

4.6.3a Fe content in Seed :

The data on Fe content in seed are shown in Table 4.6.3,fig:20 and appendix(IX). The Fe content in seed was found significant by the application of different treatments over absolute control. The highest Fe content in seed was recorded under the treatment T_8 (RDF+seed treatment 1g $FeSO_4$$kg^{-1}$ seed+ SI with bfr LNm 43a) followed by under T_9 (RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a).Further the treatment T_8 (RDF+seed treatment 1g $FeSO_4$ kg^{-1} seed+ SI with bfr LNm 43a) and T_9 (RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43) also recorded significantly higher Fe content over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}). Minimum Fe content was observed under T_1 (absolute control) .

4.6.3b Fe content in Straw:

The data on Fe content in straw are shown in Table 4.7.1,fig:20 and appendix (IX). The Fe content in straw was found significant by the application of different treatments over absolute control .The highest Fe content in straw was recorded under the treatment T_8 (RDF+seed treatment

1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) followed by under T_9 (RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) .Further the treatment T_8 (RDF+seed treatment 1g $FeSO_4$ kg^{-1} seed+ SI with bfr LNm 43a) and T_9 (RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43) recorded significantly higher Fe content over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$). Minimum Fe content was observed under T_1 (absolute control).

Table 4.6.3: Effect of Zinc, Iron and Bio fertilizer application on Iron content (ppm) seed and straw in lentil:

Treatments		Fe in Seed (ppm)	Fe in Straw (ppm)
T_1	Absolute control	56.67	222.8
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	56.92	222.9
T_3	RDF (20-17-16-20 kg $NPKSha^{-1}$)	57.74	224.4
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	58.22	225.2
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	58.75	225.4
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	58.48	225.3
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	57.76	224.5
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	59.11	225.8
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	58.79	225.5
T_{10}	RDF+soil application of $ZnSO_4$ $25kgha^{-1}$ +SI with bfr LNm 43a	57.89	224.2
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	57.87	224.7
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	57.90	224.6
	CD at 5%	**0.72**	**0.43**

4.6.4: Effect of Zinc, Iron and Bio fertilizer application on Iron uptake by Seed, Straw and total uptake(g ha^{-1}) in lentil:

4.6.4a Fe uptake in Lentil Seed (g ha^{-1})

The data on Fe uptake in seed are shown in Table 4.6.2,fig:21 and appendix (IX).The Fe uptake in seed influenced found significant by the application of different treatments over absolute control .The highest Fe uptake in seed was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). In general all the treatments which received Fe application (T_5,T_6,T_8,T_9) recorded significantly higher Fe uptake in straw recorded significantly higher Fe uptake over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$). Minimum Fe uptake was observed under T_1 (absolute control) .

4.6.4b Fe uptake in Lentil Straw(g ha^{-1})

The data on Zn uptake in straw are shown in Table 4.6.4,fig:21 and appendix (IX). The Fe uptake in straw was found significant by the application of different treatments over absolute control .The highest Fe uptaket in straw was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a). In general all the treatments which received Fe application (T_5,T_6,T_8,T_9) recorded significantly higher Fe uptake in straw over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$).Minimum Fe uptake was observed under T_1 (absolute control) .

4.6.4c Total (Seed+ Straw) Fe uptake(g ha^{-1}) in Lentil

The data on total Fe uptake are shown in Table 4.7.2, fig:21 and appendix(IX) . The total Fe uptake found significant by the application of different treatments over absolute control .The highest total Fe uptake recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) followed by under T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43) then T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a). In general all the treatments which received Fe application (T_5,T_6,T_8,T_9) recorded significantly higher total Fe uptake over the existing practice of fertilization i.e T_3(RDF 20-17-16-20 kg $NPKSha^{-1}$).Minimum Total Fe uptake was observed under T_1 (absolute control) .

Table 4.6.4: Effect of Zinc, Iron and Bio fertilizer application on Iron uptake by seed, straw and total uptake (gha^{-1}) in lentil:

Treatments		Fe Uptake Seed (gha^{-1})	Fe Uptake Straw (gha^{-1})	Total Fe Uptake Seed+ Straw (gha^{-1})
T_1	Absolute control	57.26	245.74	303.00
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	64.35	269.70	334.05
T_3	RDF (20-17-16-20 kg $NPKSha^{-1}$)	78.81	315.05	393.86
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	85.55	335.54	421.09
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	84.08	329.90	413.98
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	86.58	347.41	433.99
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	80.34	317.66	398.00
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	83.27	325.82	409.09
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	84.20	336.52	420.72
T_{10}	RDF+soil application of $ZnSO_4$ $25kgha^{-1}$ +SI with bfr LNm 43a	91.78	360.92	452.70
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	75.84	297.04	372.89
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	85.11	343.18	428.29
	CD at 5%	**1.81**	**11.9**	**11.3**

4.7: Effect of Zinc, Iron and Bio fertilizer application on available N ,P, Zn and Fe (kg ha^{-1}) in lentil after crop harvest:

4.7.1 Available nitrogen in soil:

The data on available N are shown in Table 4.7,fig:22 and appendix(X) . The available N was found significant by the application of different treatments over absolute control.The highest available N was recorded under the treatment T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) and minimum available N was observed under T_1 (absolute control).However available N under the treatments T_4 to T_{11} was to T_{12} recorded .

4.7.2 Available phosphorus in soil:

The data on available P after crop harvest are shown in Table 4.8,fig:23 and appendix (X) . The available P was found significant by the application of different treatments over absolute control ,T_1.The available P after crop harvest was normally found statstically identical under treatments T_3 to T_{12} but these were superior over T_1 absolute control. Minimum available P was observed under T_1 (absolute control) .

4.7.3 Available Zn in soil:

The data on available Zn are shown in Table 4.8,fig:24 and appendix(X). The available Zn was found significant by the application of different treatments over absolute control .The highest available Zn was recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) . Further the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) recorded significantly higher available Zn over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}) .Minimum available Zn was observed under T_1 (absolute control)

.**4.7.4 Available Fe in soil:**

The data on available Fe are shown in Table 4.7, fig:25 and appendix (X). The available Fe was found significant by the application of different treatments over absolute control .The highest available Fe was recorded under the treatment T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) followed by T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) . Further the treatment T_{12} (Customized fertilizer(CFG1)+SI with bfr LNm 43a) and T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm

Table 4.7: Effect of Zinc, Iron and Bio fertilizer application on available N ,P, Zn and Fe ($kgha^{-1}$) in Lentil after crop harvest:

Treatments		Available N($kgha^{-1}$)	Available P($kgha^{-1}$)	Available Zn($kgha^{-1}$)	Available Fe($kgha^{-1}$)
T_1	Absolute control	201.58	13.30	0.46	10.48
T_2	Seed inoculation with bio fertilizer LNm 43 a(*Rhizobium+PGPR)*	218.76	13.62	0.46	10.69
T_3	RDF (20-17-16-20 kg NPKSha^{-1})	216.90	15.17	0.46	10.53
T_4	RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43 a	215.15	14.82	0.47	10.58
T_5	RDF+0.1% Fe foliar application +SI with bfr LNm 43a	214.48	14.80	0.46	10.53
T_6	RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a	217.30	14.17	0.47	10.62
T_7	RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a	218.52	14.80	0.47	10.77
T_8	RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a	216.59	14.62	0.46	10.75
T_9	RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a	217.40	14.73	0.47	10.78
T_{10}	RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a	218.50	15.27	0.49	10.78
T_{11}	Customized fertilizer(CFG1)+SI with bfr LNm 43a	218.80	15.10	0.46	10.76
T_{12}	Customized fertilizer(CFG2)+SI with bfr LNm 43a	223.50	15.72	0.48	10.78
	CD at 5%	**3.04**	**1.15**	**0.019**	**0.21**

43a) were recorded significantly higher available Fe over the existing practice of fertilization i.e T_3 (RDF 20-17-16-20 kg NPKSha^{-1}) . Minimum available Fe was observed under T_1 (absolute control) .

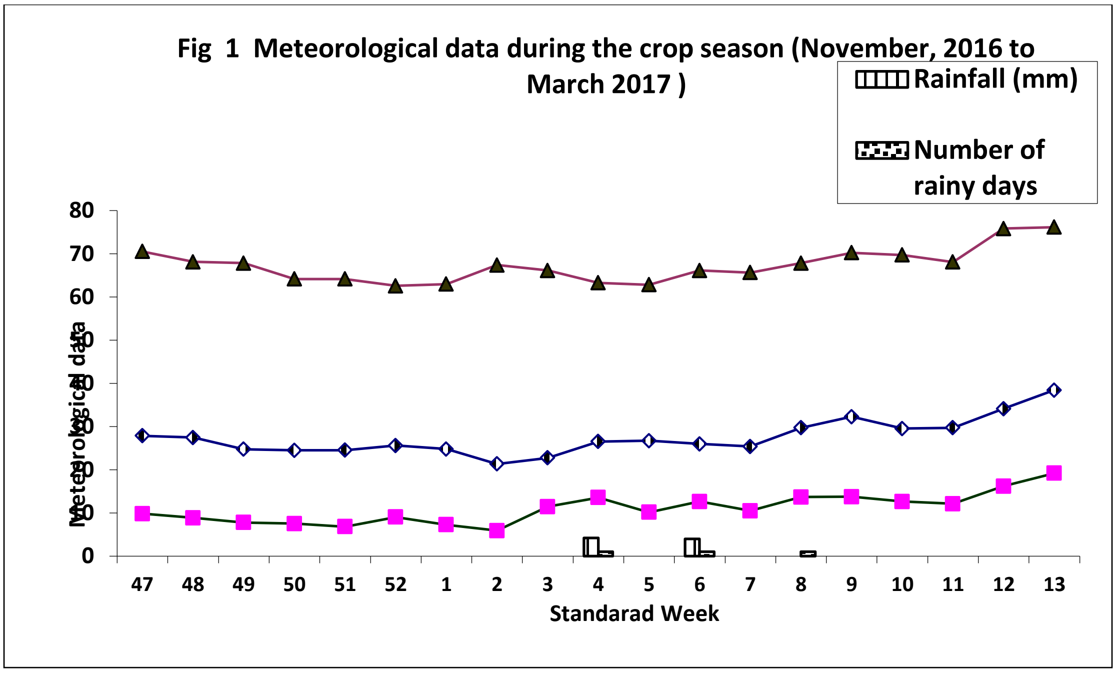
Fig 1 Meteorological data during the crop season (November, 2016 to March 2017)
Rainfall (mm)
Number of rainy days
Meteorological data
80
70
60
50
40
30
20
10
0
47
48
49
50
51
52
1
2
3
4
5
6
7
8
9
10
11
12
13
Standarad Week

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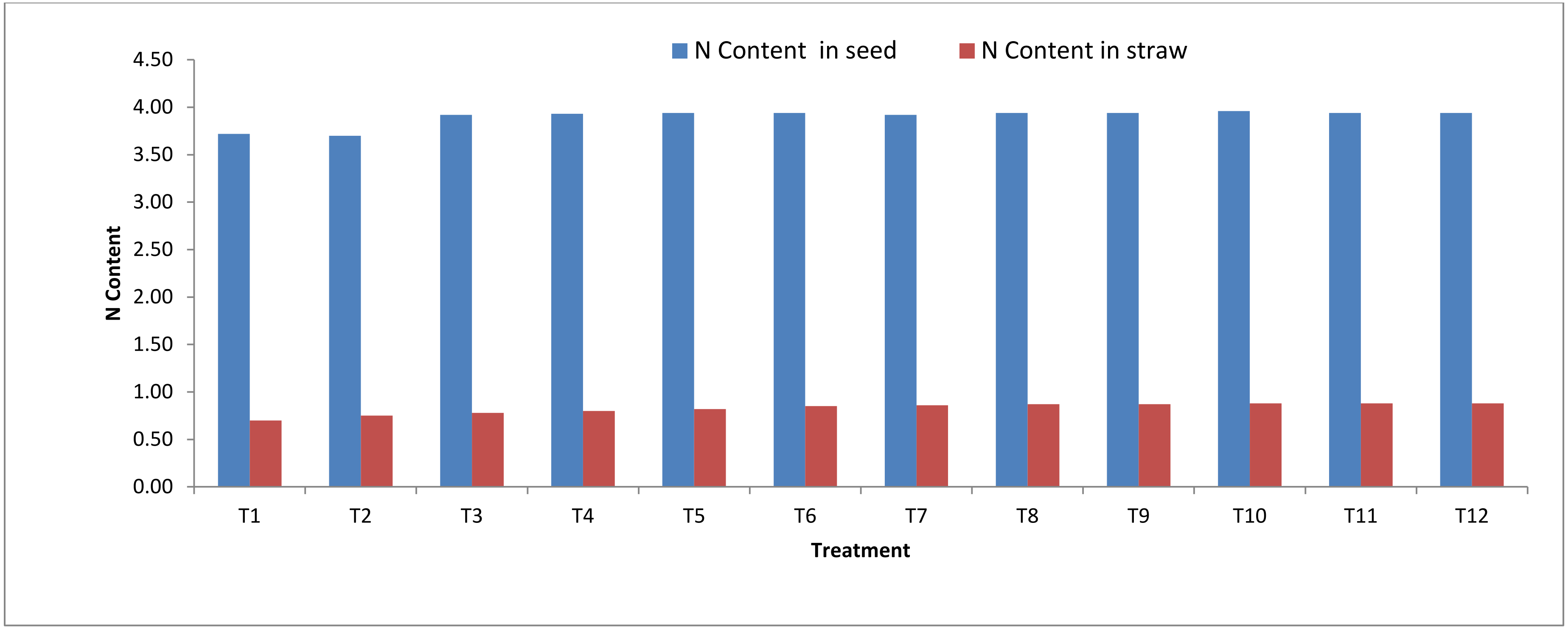
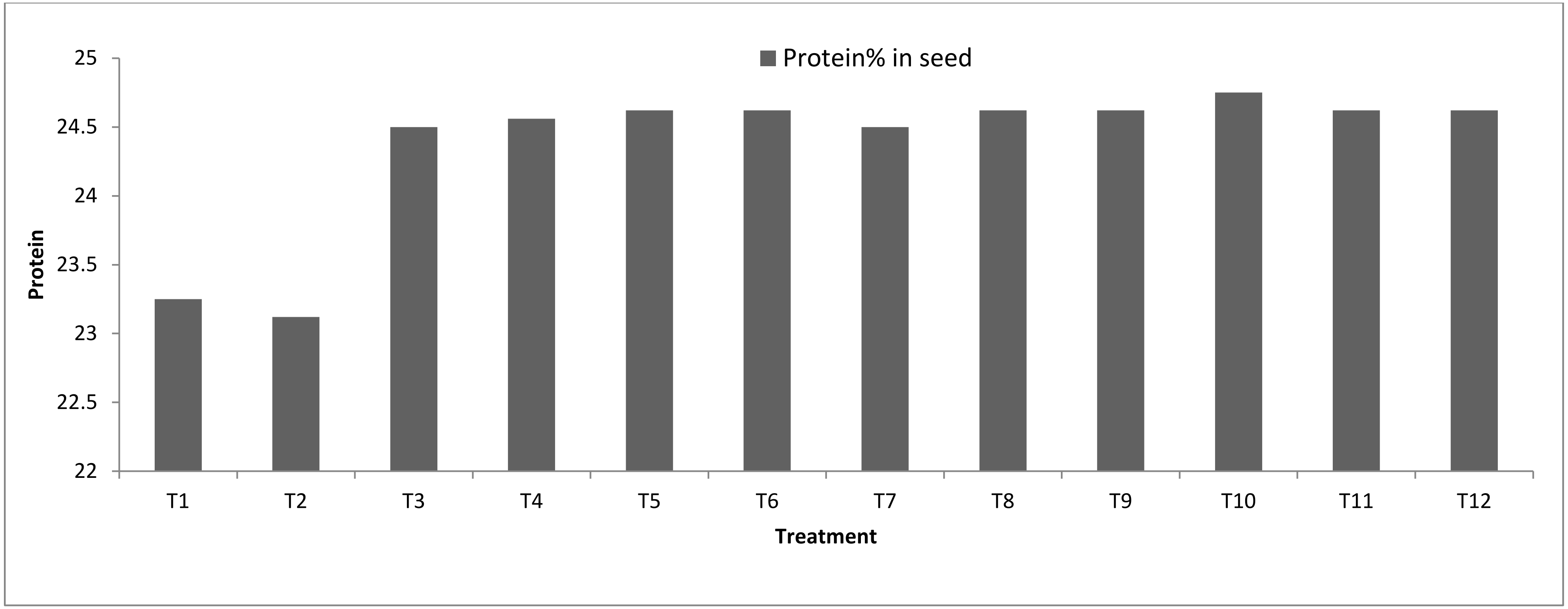
Effect of Zinc, Iron and Bio fertilizer application on N content in seed & straw in Lentil



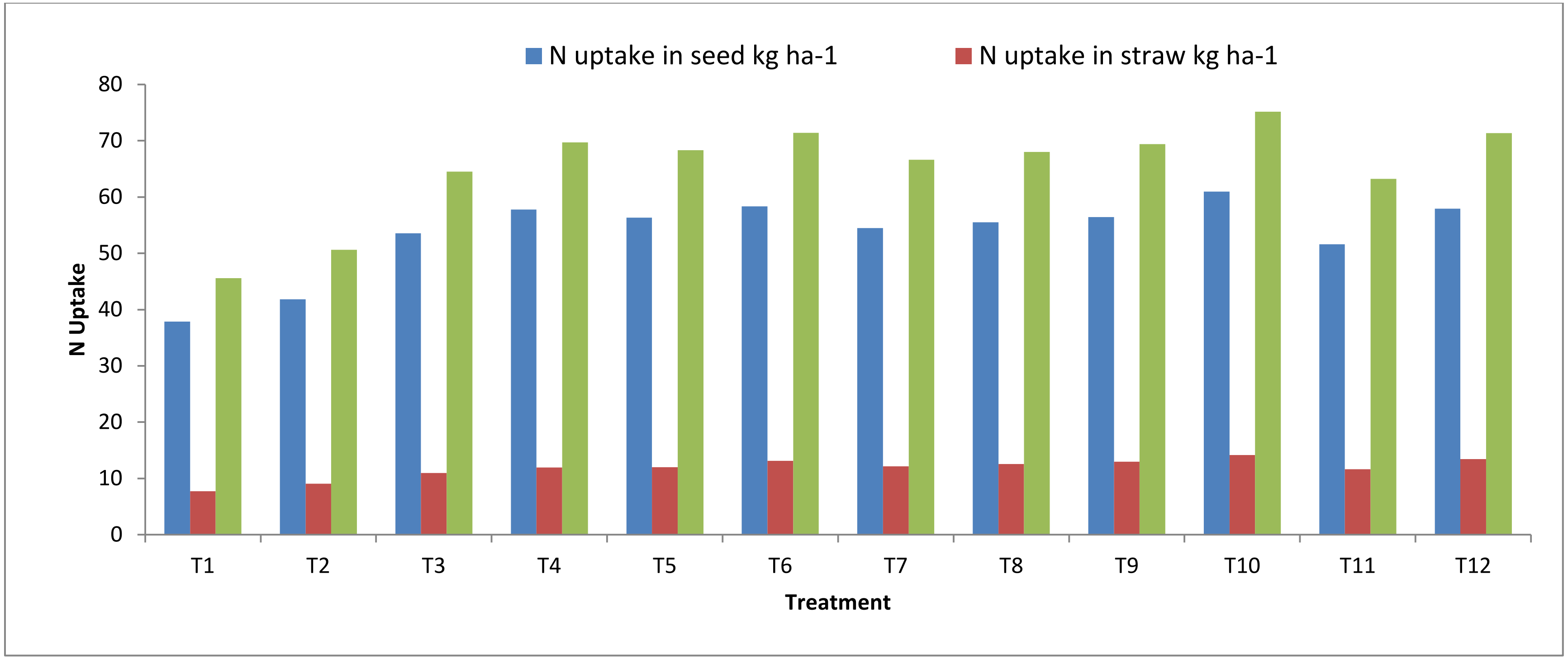
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:14.1 Effect of Zinc, Iron and Bio fertilizer application on Protein content in seed in Lentil :



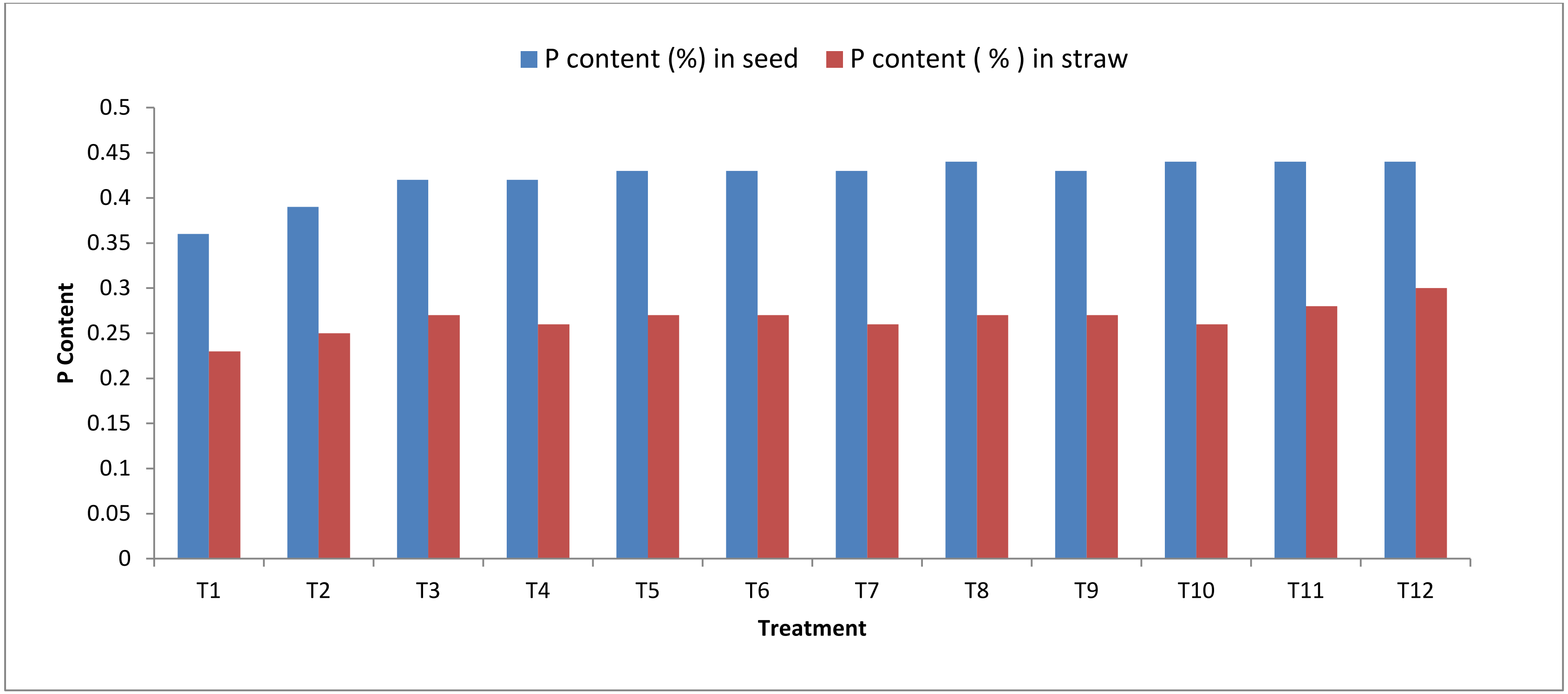
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:15 Effect of Zinc, Iron and Bio fertilizer application on N uptake in seed , straw & total uptake (kg ha^{-1}) in Lentil :



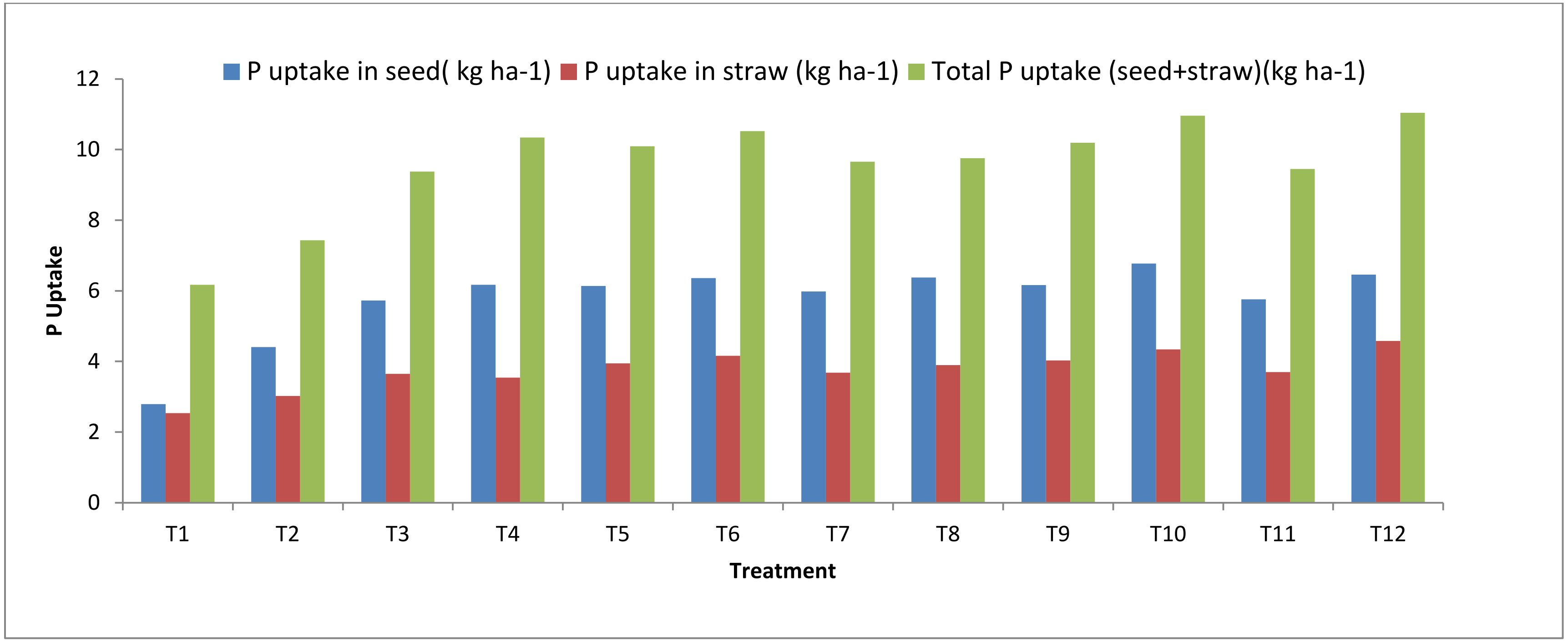
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:16 Effect of Zinc, Iron and Bio fertilizer application on P (%) content in seed & straw in Lentil:



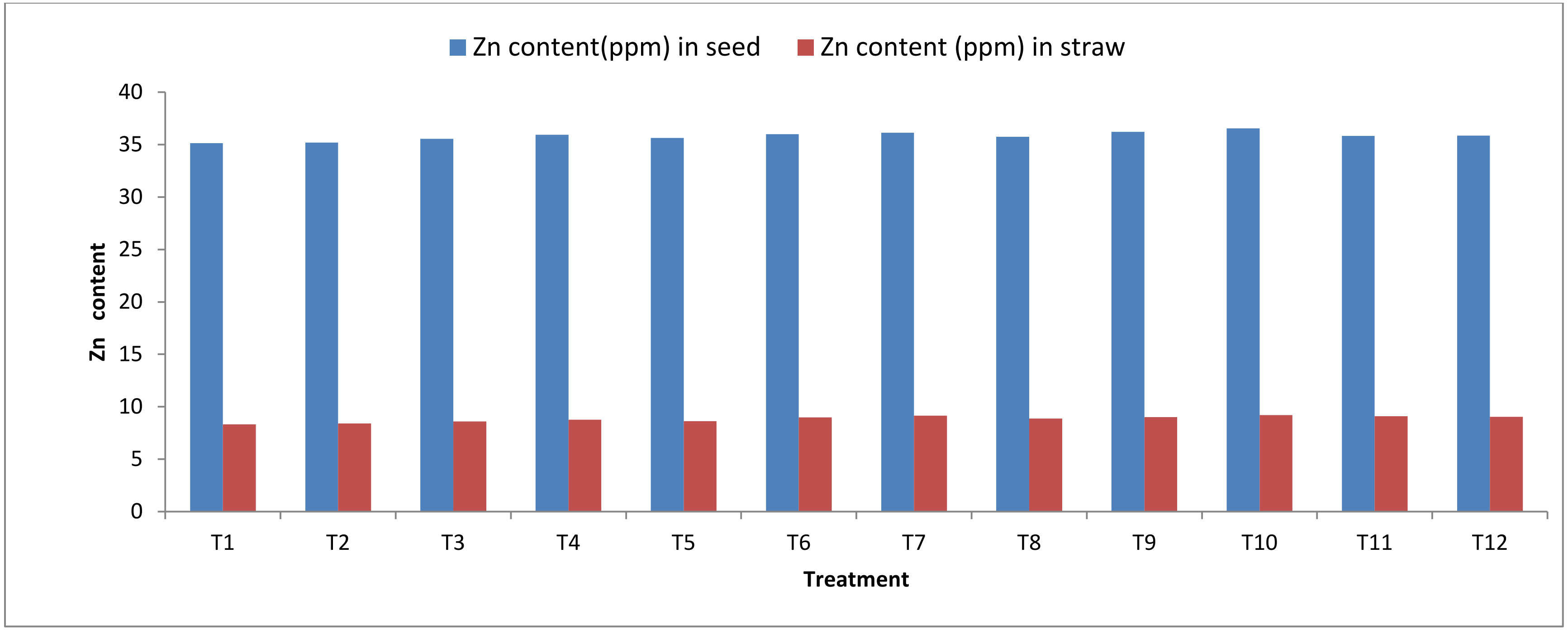
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:17 Effect of Zinc, Iron and Bio fertilizer application on P uptake in seed($kgha^{-1}$) , straw ($kgha^{-1}$) & total uptake ($kgha^{-1}$) in Lentil :



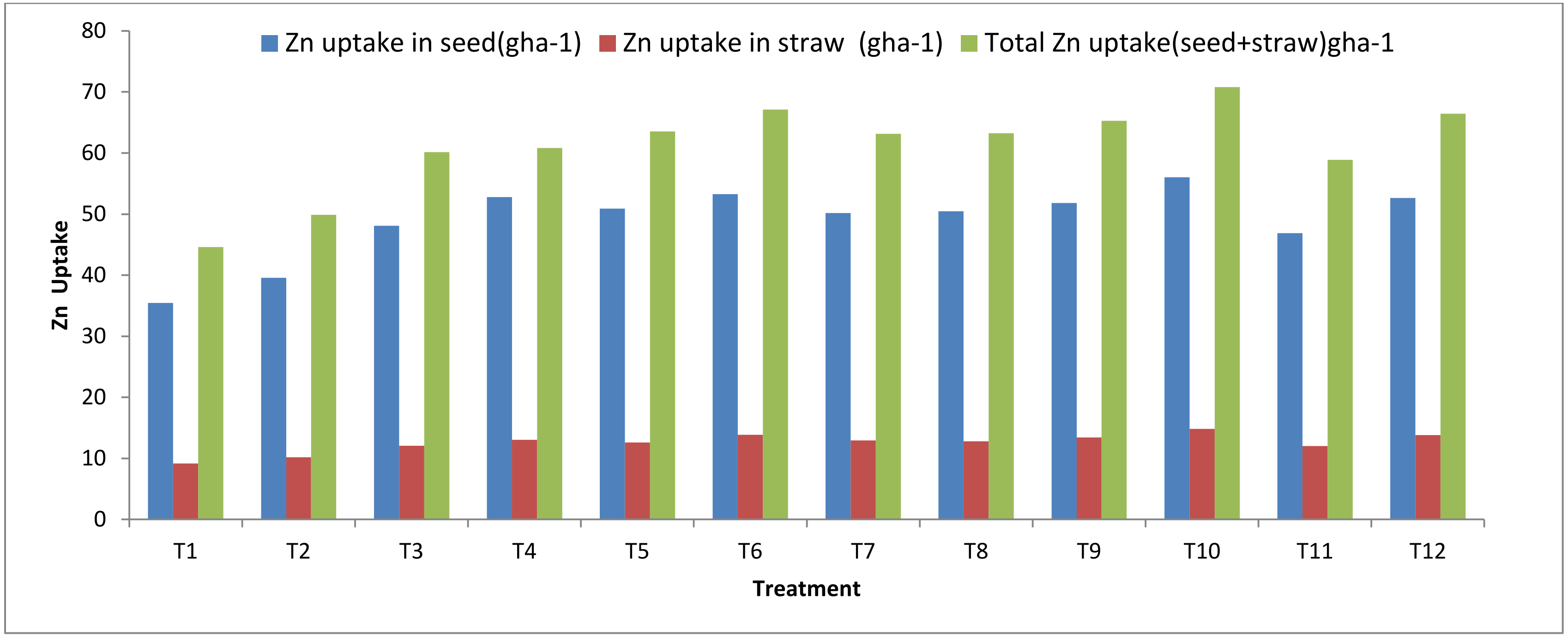
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25$kgha^{-1}$ +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:18 Effect of Zinc, Iron and Bio fertilizer application on Zn content (ppm) in seed & straw in Lentil :



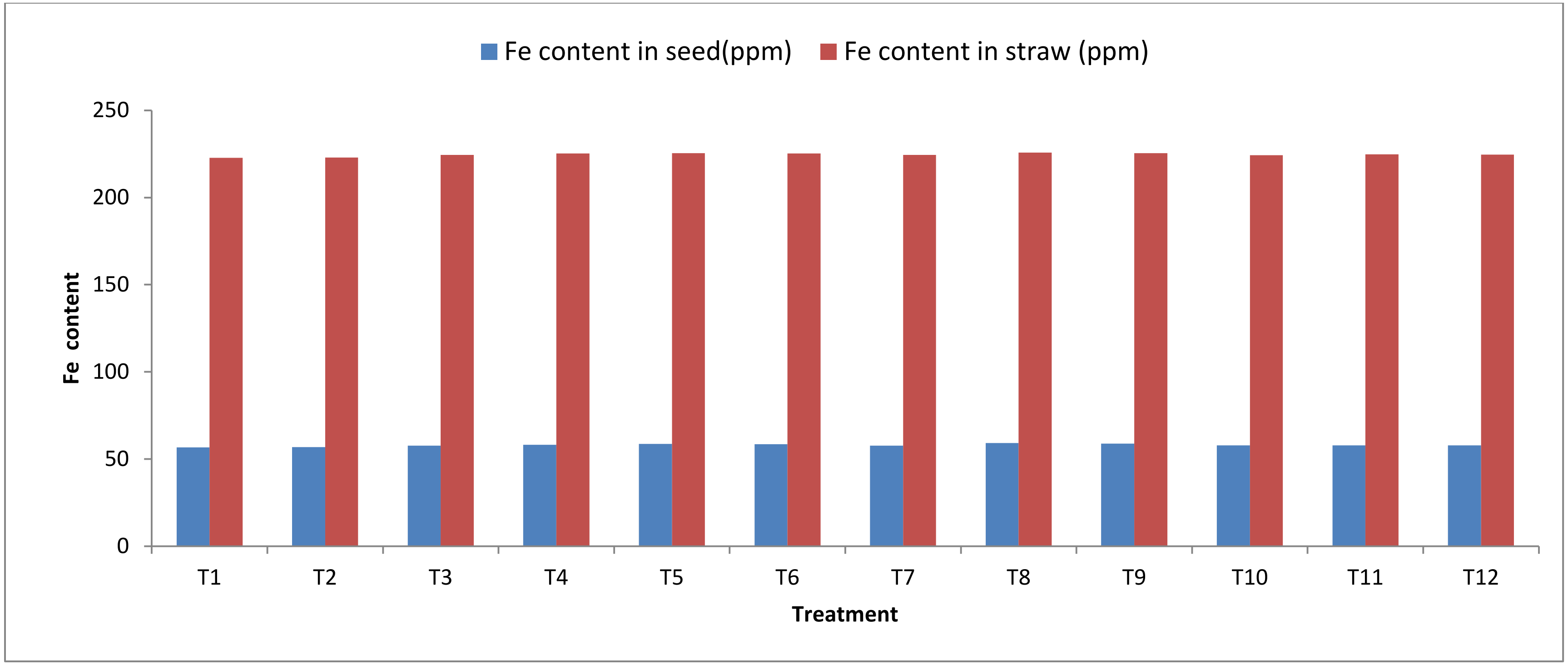
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:19 Effect of Zinc, Iron and Bio fertilizer application on Zn uptake in seed(g ha^{-1}) , straw(g ha^{-1}) & total uptake (g ha^{-1}) in Lentil :



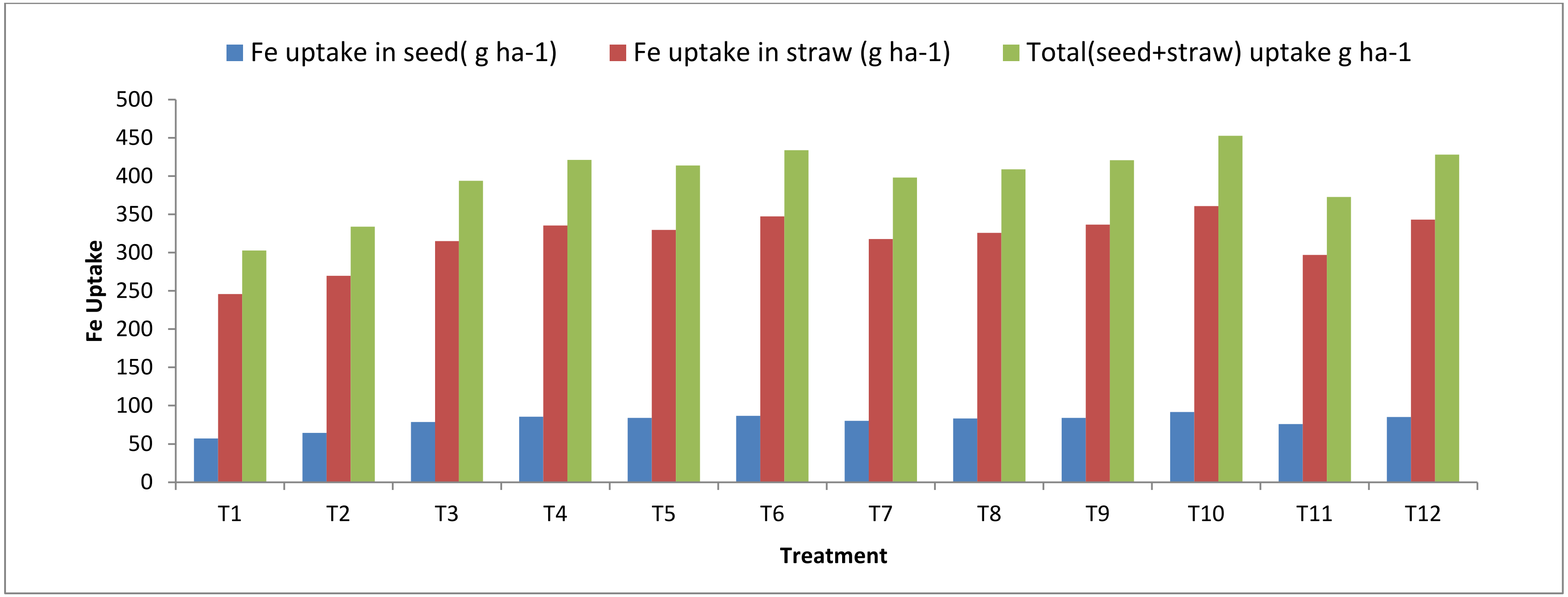
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig: 20 Effect of Zinc, Iron and Bio fertilizer application on Fe (ppm) content in seed & straw in Lentil :



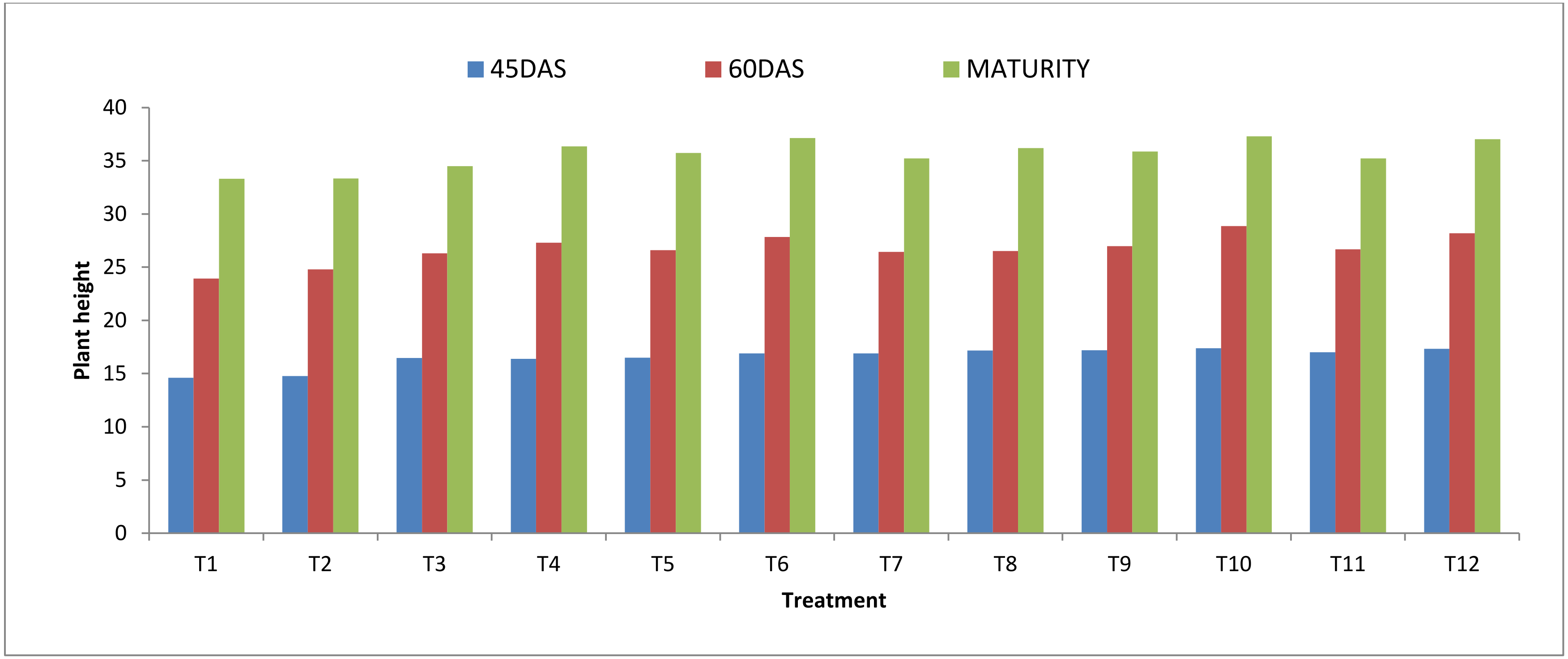
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:21 Response of Zinc, Iron and Bio fertilizer application on Fe uptake in seed (g ha^{-1}) ,straw (g ha^{-1}) and total uptake (g ha^{-1}) in Lentil:



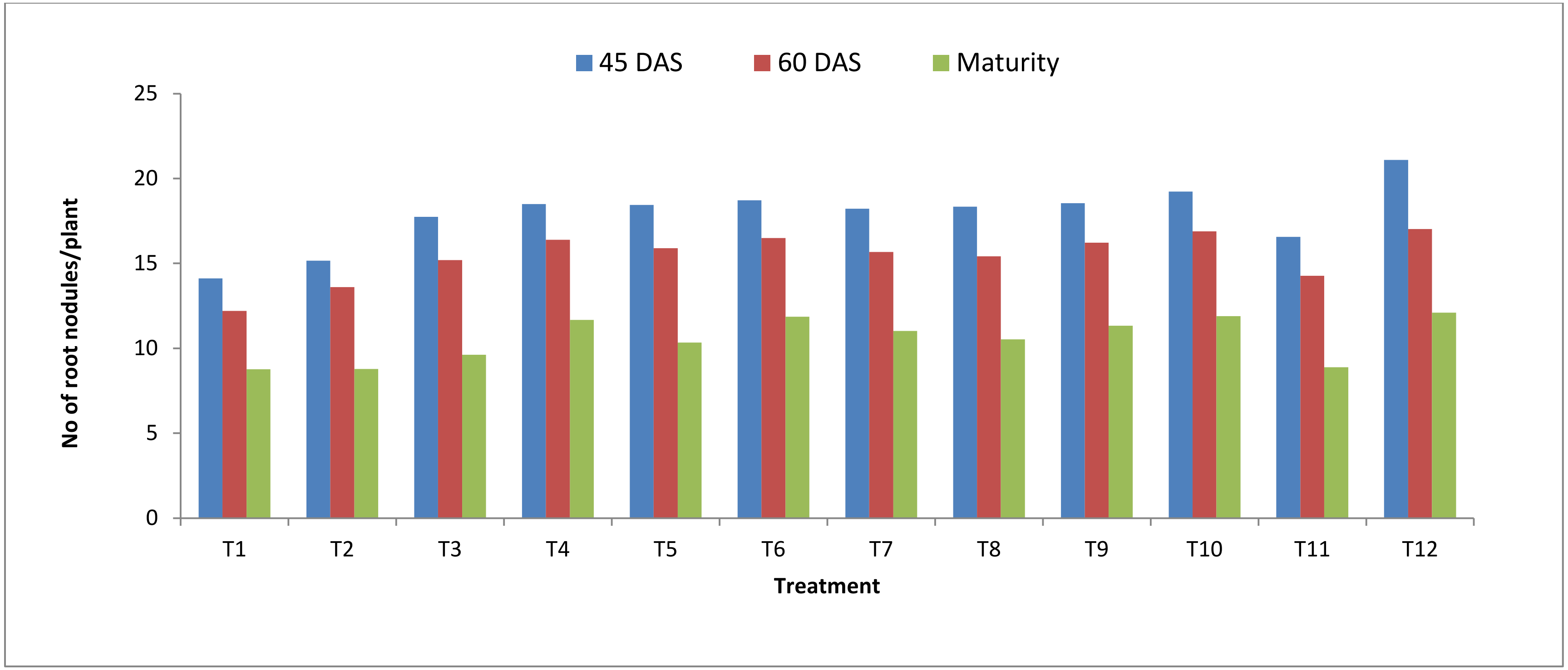
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:6 Effect of Zinc, Iron and Bio fertilizer application on Plant height plant^{-1}(cm) in Lentil in Black soils.



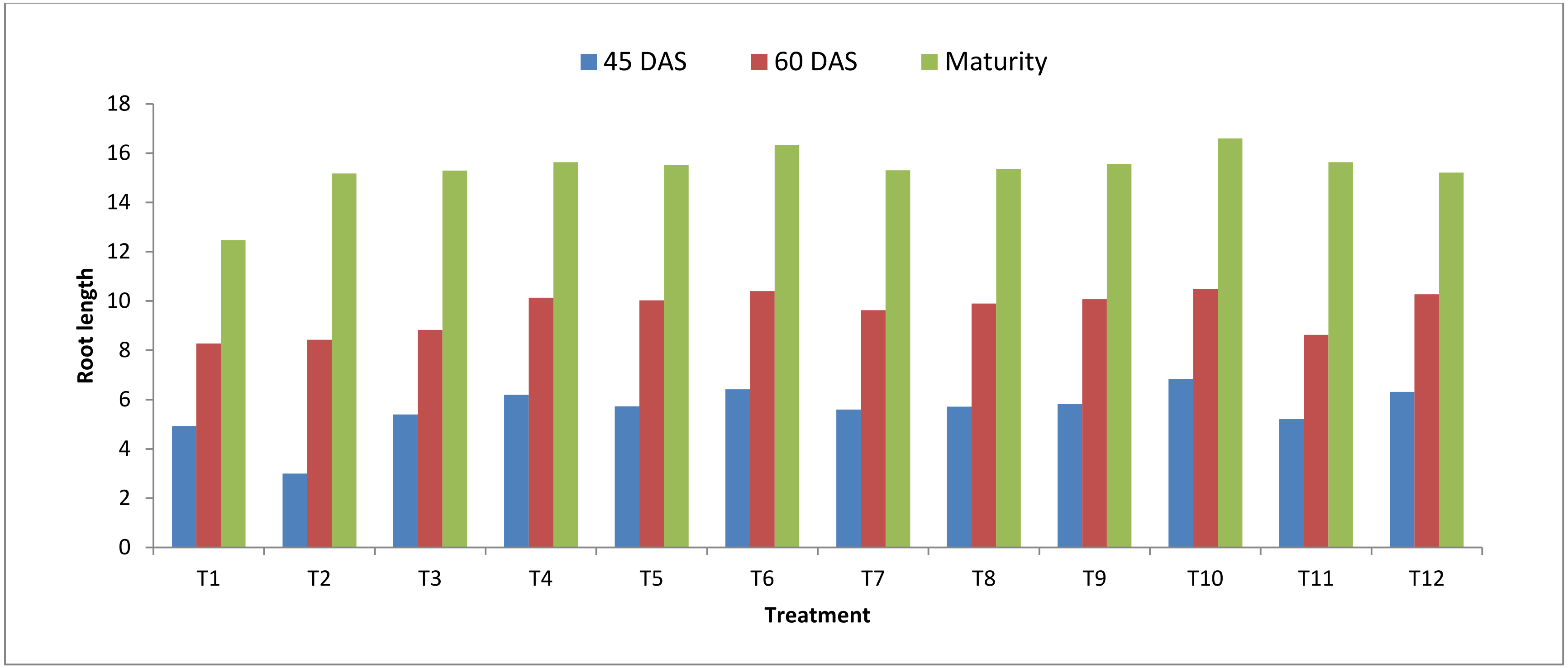
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:3 Effect of Zinc, Iron and Bio- fertilizer application on No. of root nodules plant^{-1} in Lentil in Black soils:



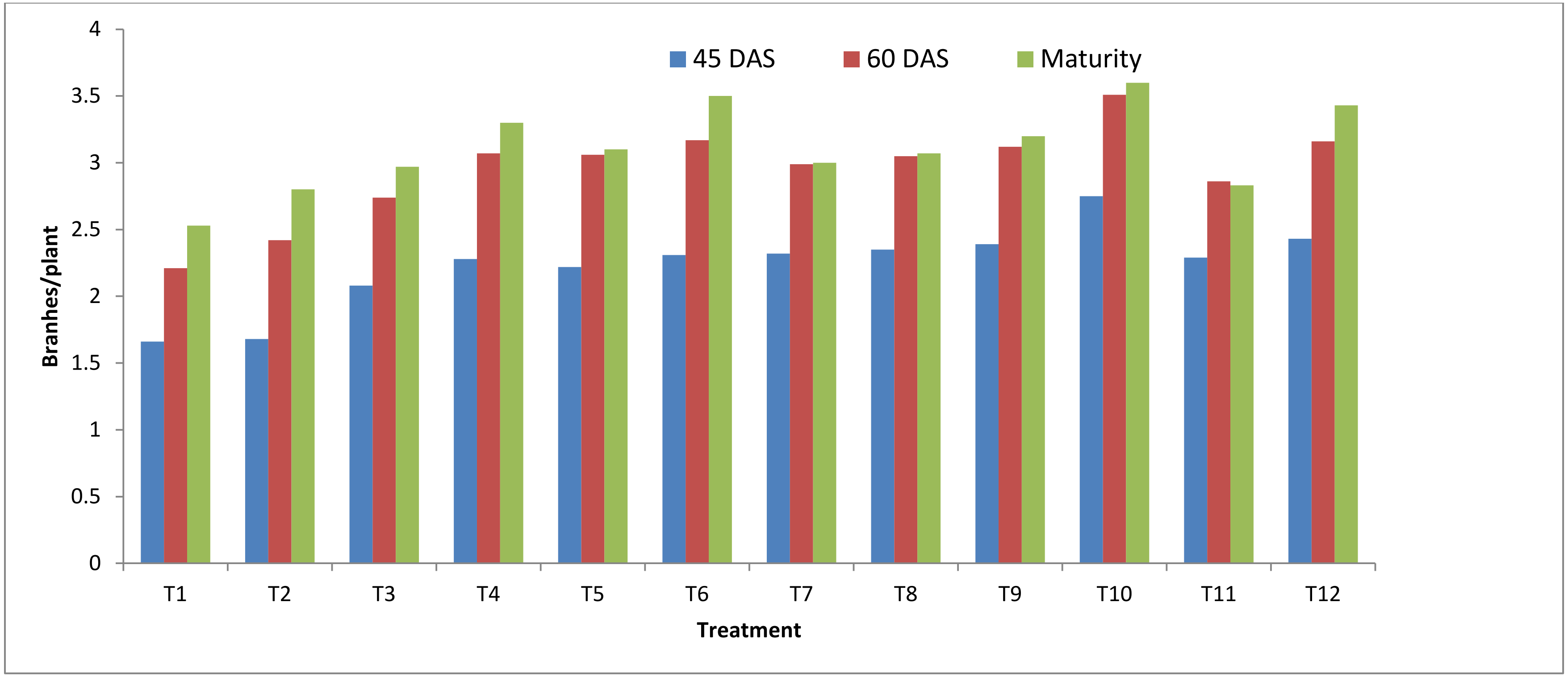
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig: 8 Effect of Zinc , Iron and Bio fertilizer application on root length plant^{-1} (cm) in Lentil in Black soils:



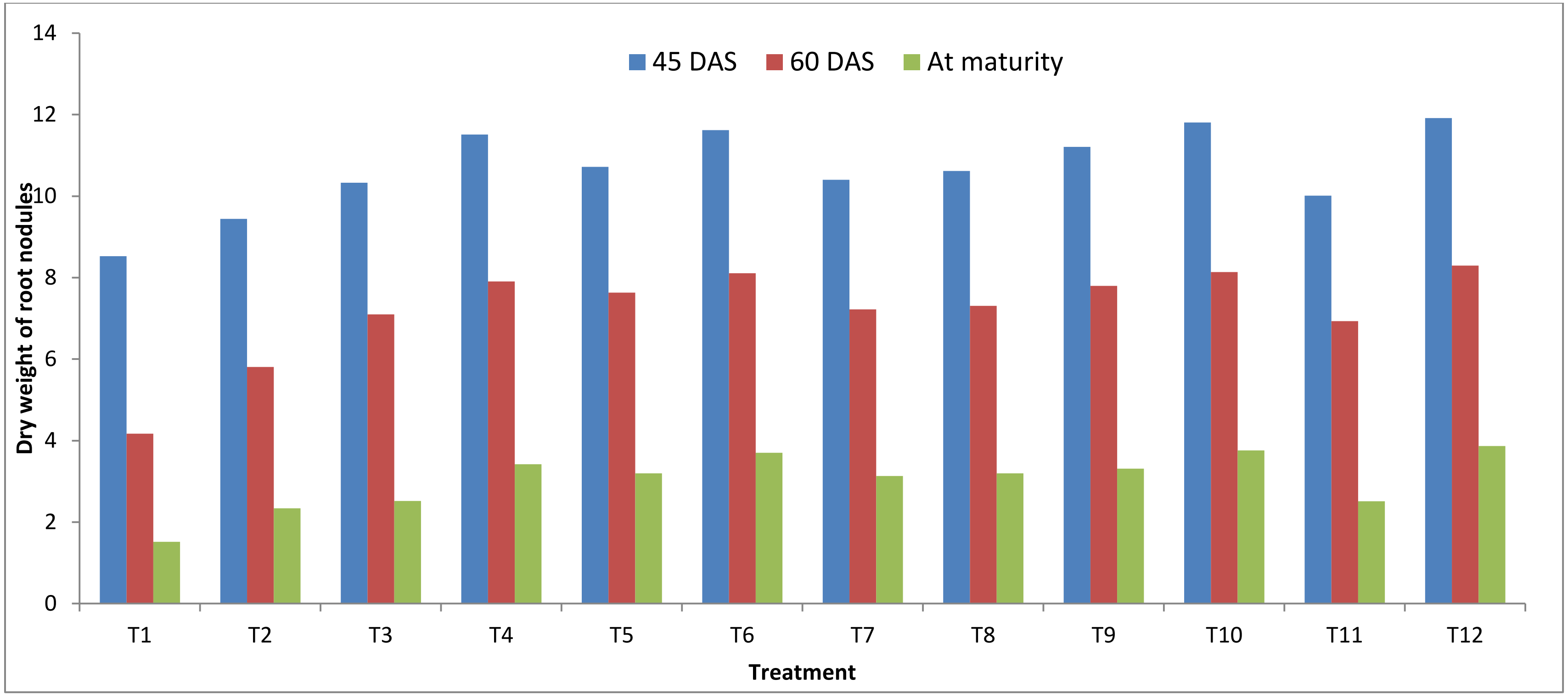
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig: 7 Effect of Zinc , Iron and Bio fertilizer application on Branches plant^{-1} in Lentil in Black soils:



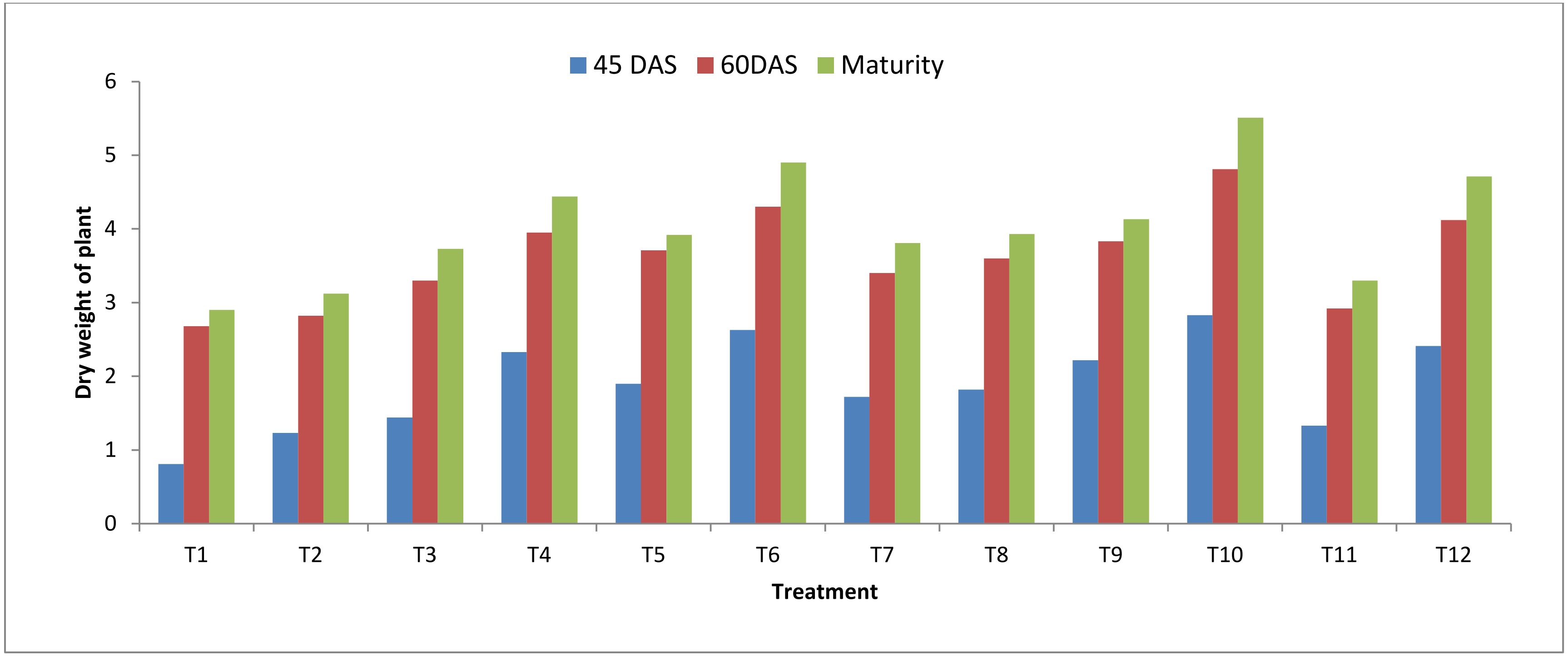
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:4 Effect of Zinc, Iron and Bio fertilizer application on Dry weight of root nodules plant^{-1}(mg) in Lentil in Black soils.



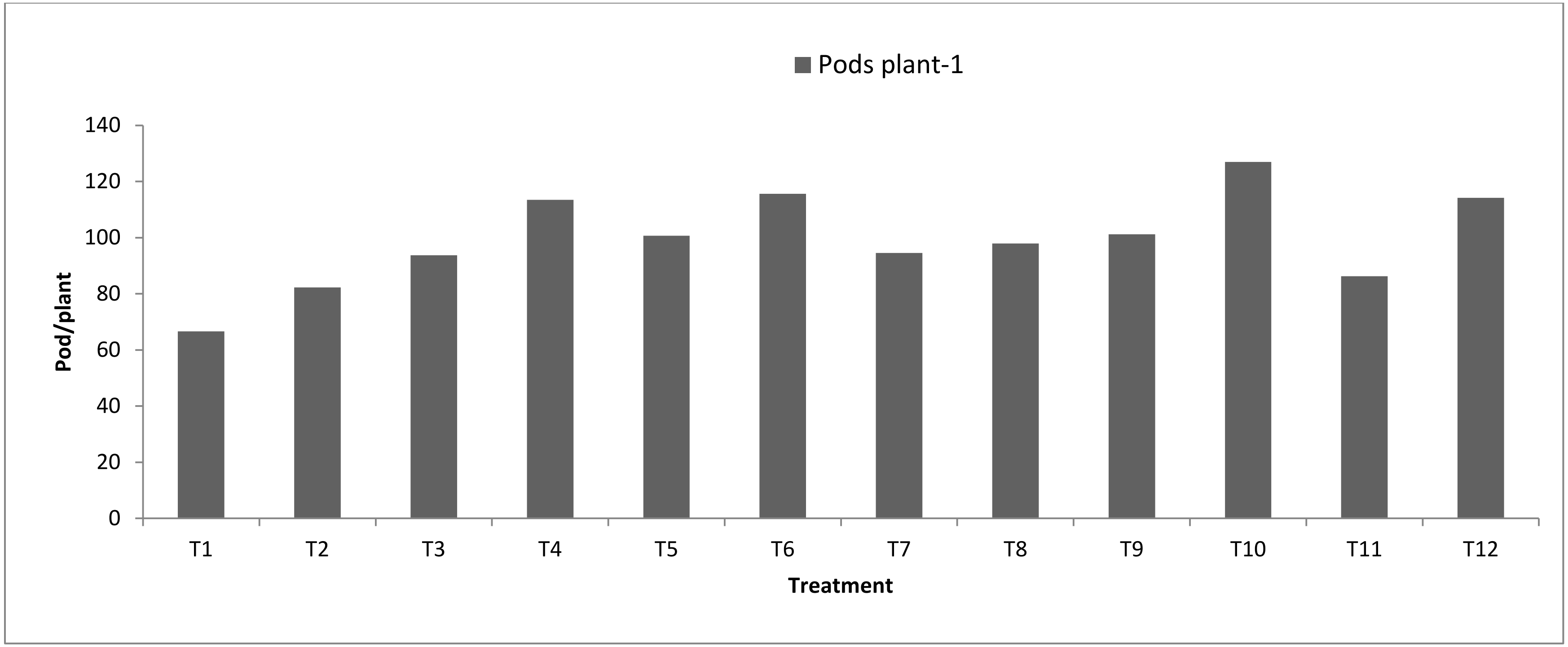
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:5 Effect of Zinc, Iron and Bio fertilizer application on Dry weight plant^{-1} (g) in Lentil in Black soils.



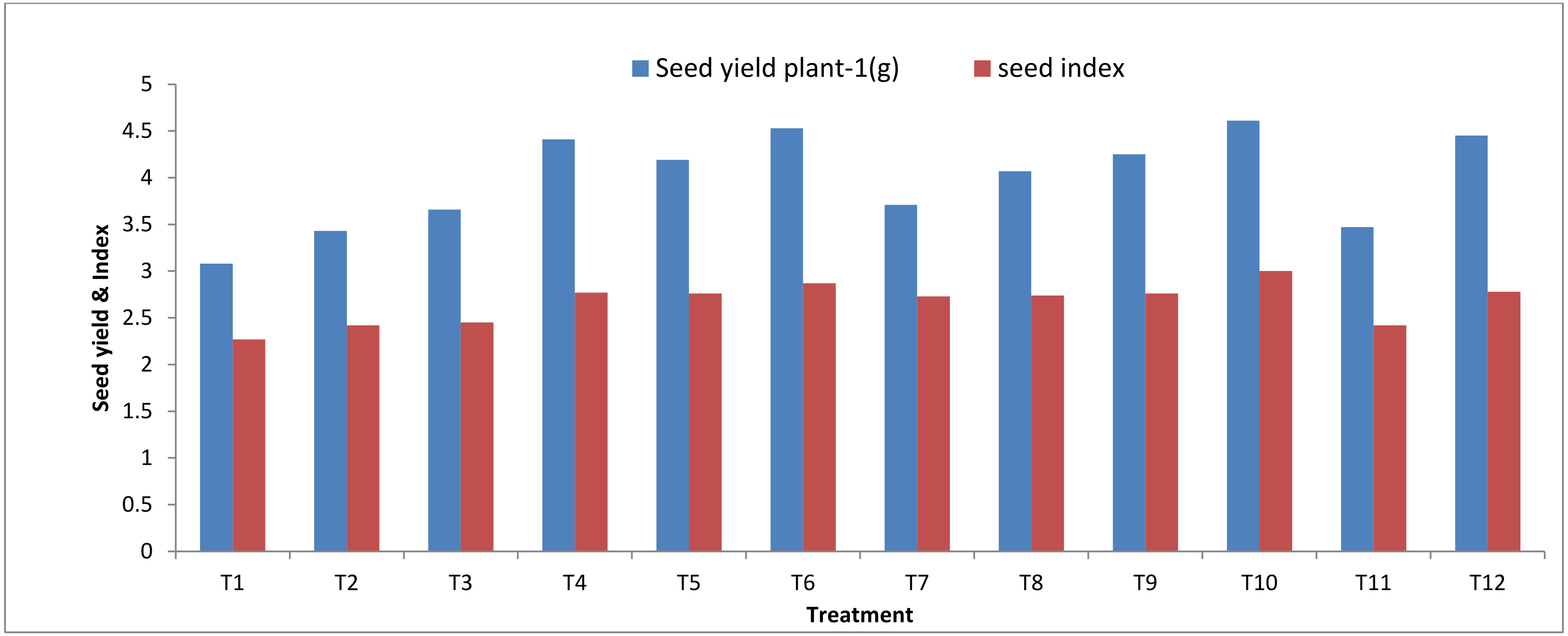
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:9 Effect of Zinc, Iron and Bio fertilizer application on No. of Pods plant^{-1} in Lentil in Black soils:



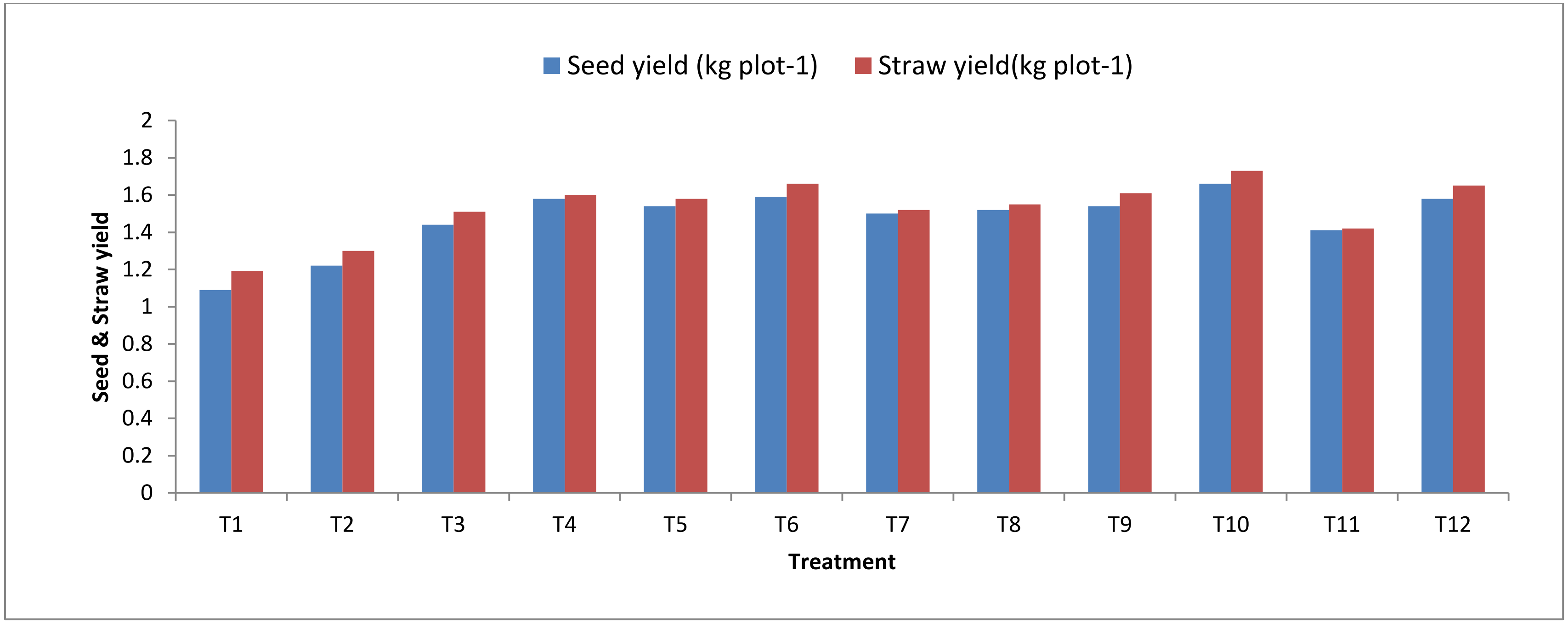
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:10 Effect of Zinc, Iron and Bio fertilizer application on seed yield plant^{-1} (g) and Seed index plant^{-1} in Lentil in Black soils:



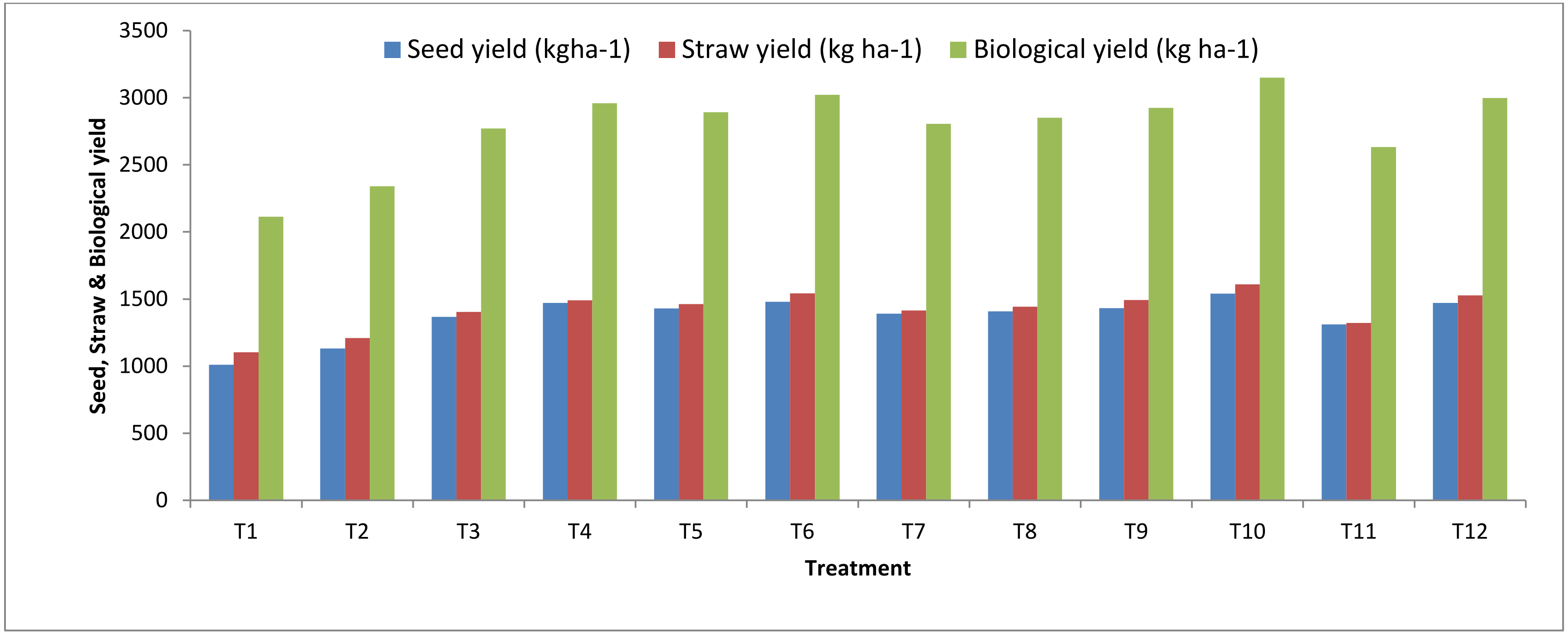
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:11 Effect of Zinc, Iron and Bio- fertilizer application on Seed yield (kg plot^{-1}) and Straw yield (kg plot^{-1}) in Lentil in Black soils:



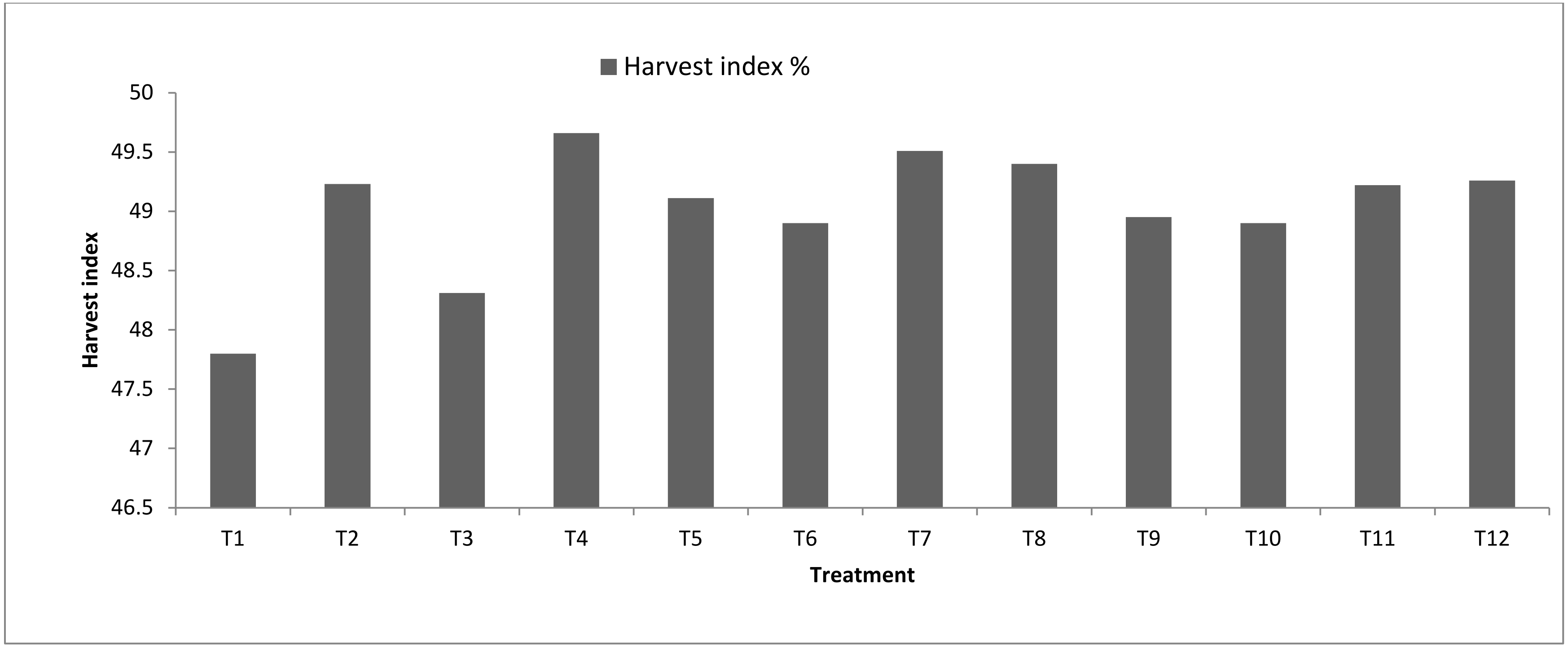
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:12 Effect of Zinc, Iron and Bio- fertilizer application on Seed yield (kg ha^{-1}), Straw yield (kg ha^{-1}) and Biological yield (kg ha^{-1}) in Lentil in Black soils:



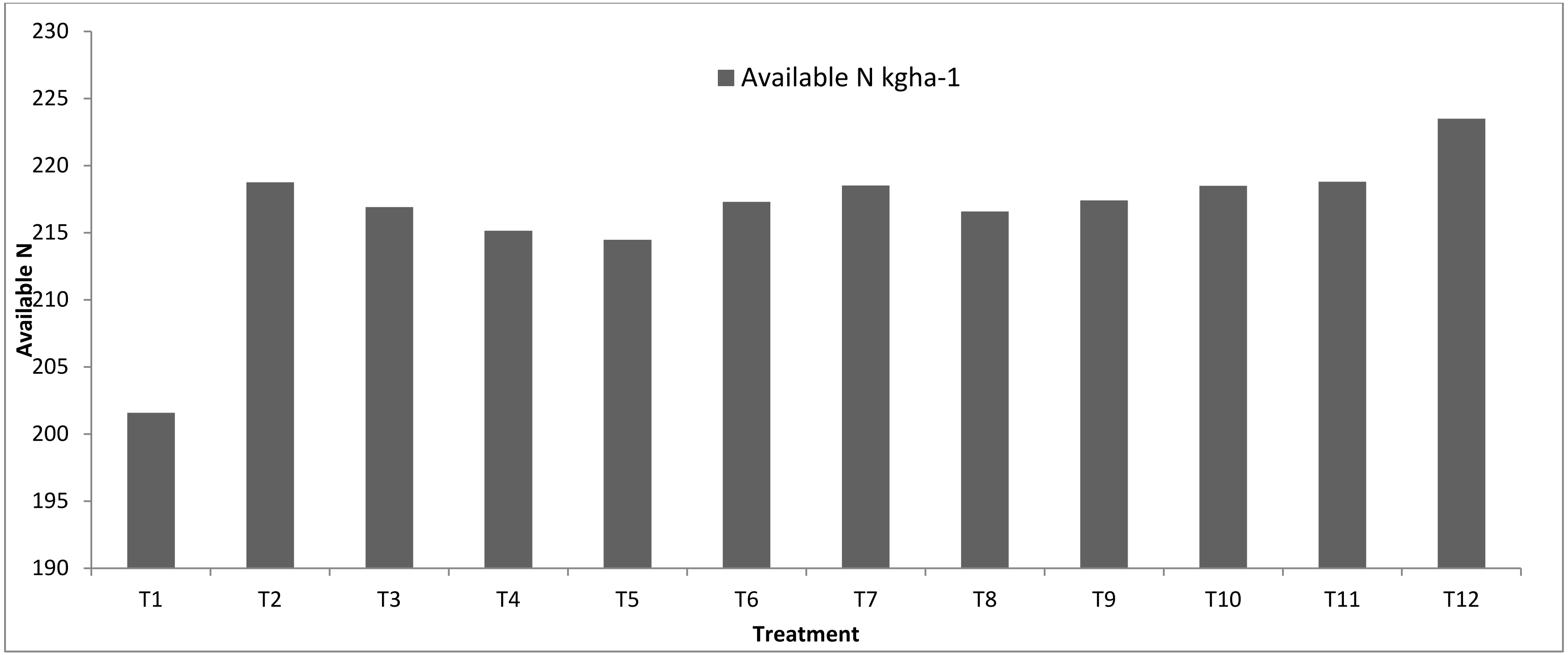
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:13 Effect of Zinc , Iron and Bio- fertilizer application on harvest index (%) in Lentil in Black soils:



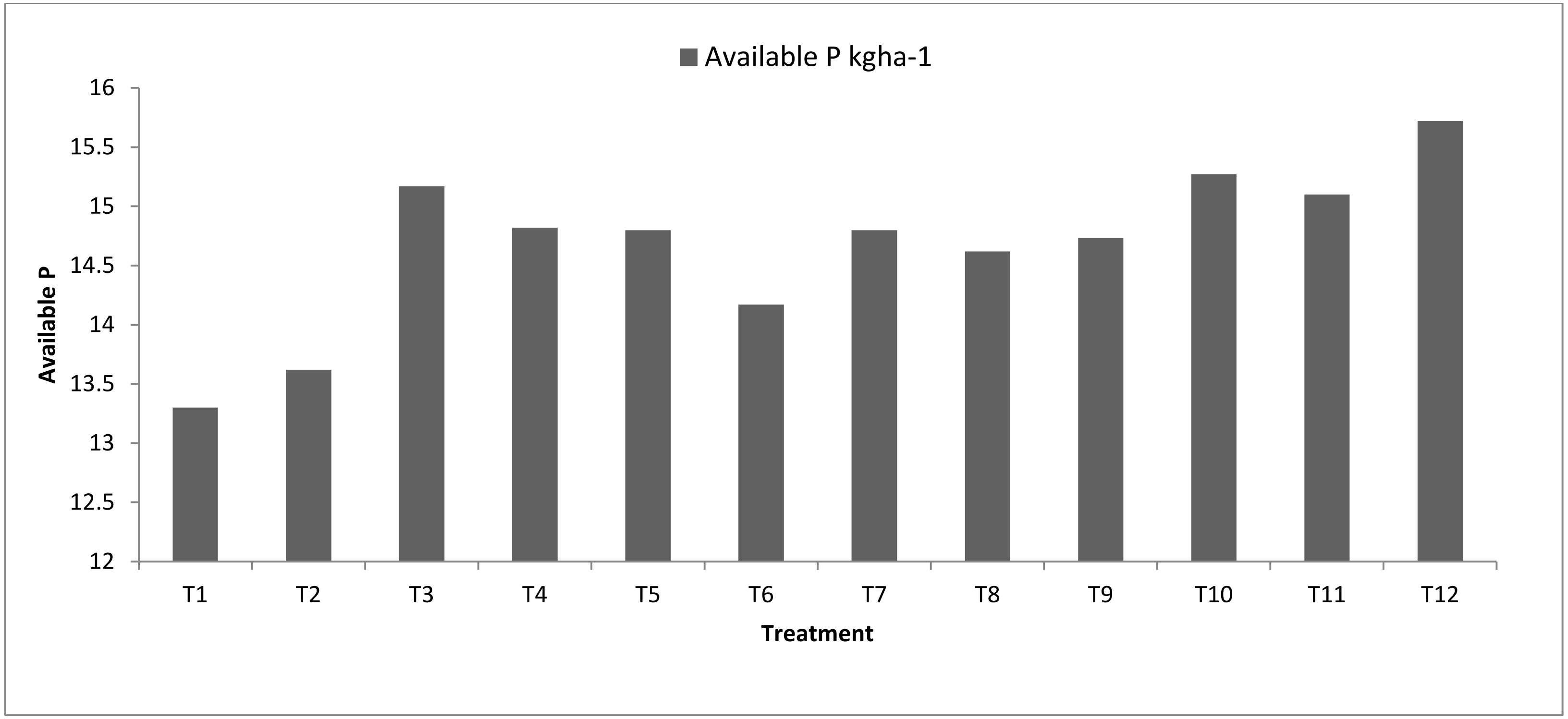
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:22 Effect of Zinc , Iron and Bio- fertilizer application on available N kg ha^{-1} in soil after harvest of lentil:



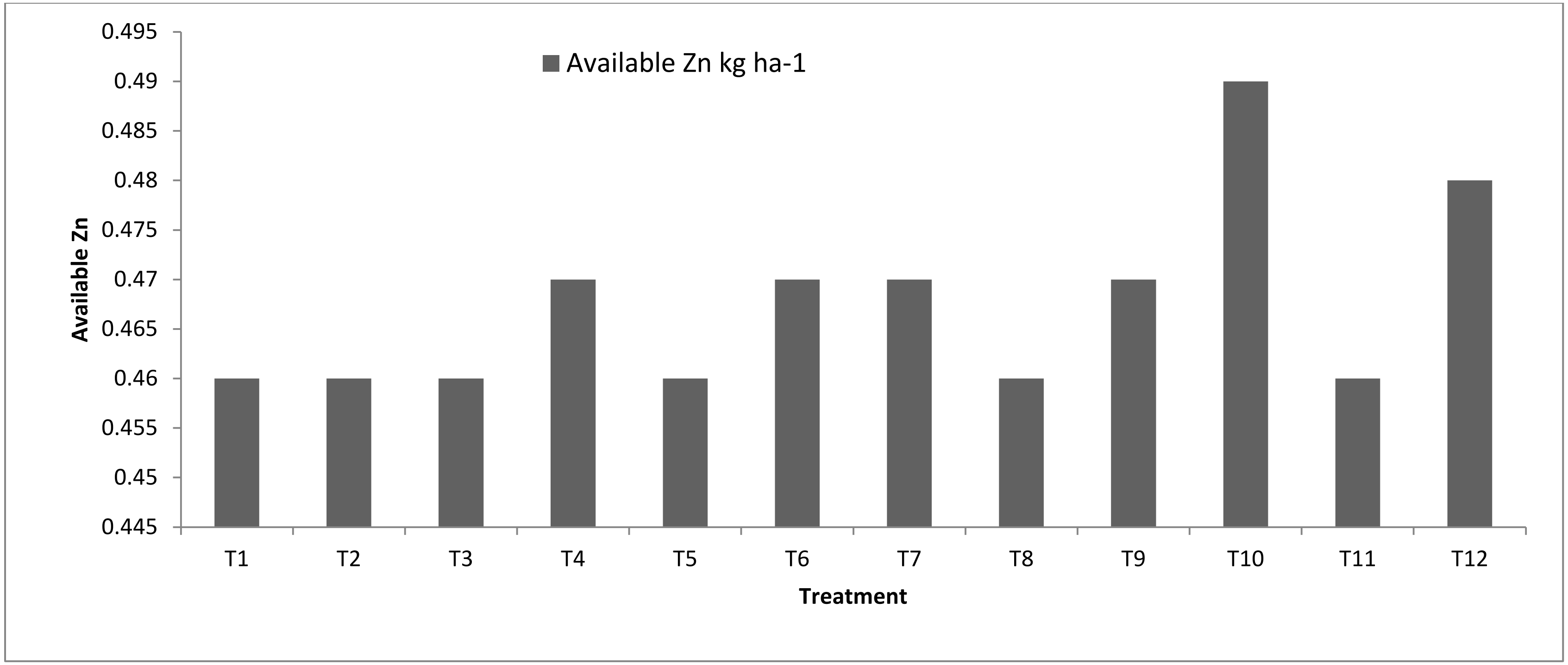
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig:23 Effect of Zinc , Iron and Bio- fertilizer application on available P kg ha^{-1} in soil after harvest of lentil:



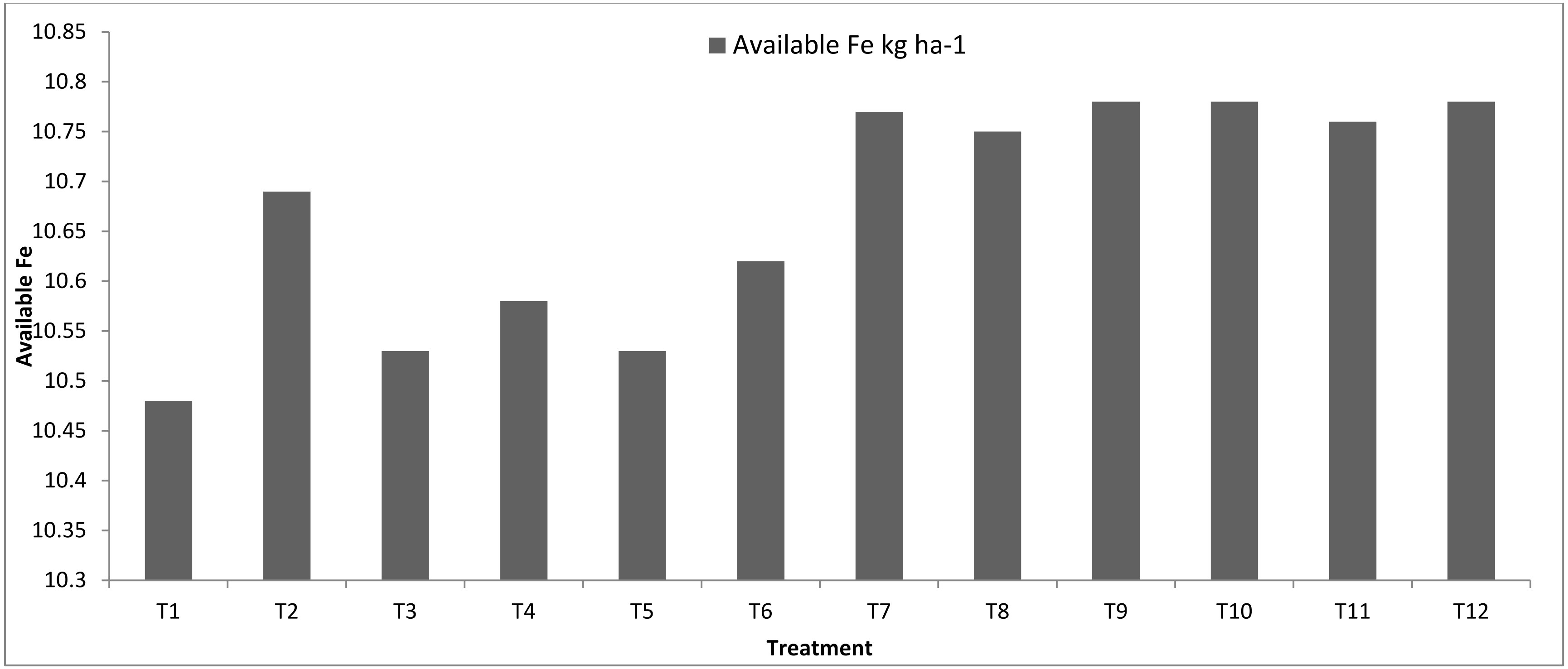
T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig: 24 Effect of Zinc , Iron and Bio- fertilizer application on available Zn kg ha^{-1} in soil after harvest of lentil:



T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR) ,***T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4kg^{-1}$ seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4kg^{-1}$ seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

Fig: 25 Effect of Zinc , Iron and Bio- fertilizer application on available Fe kg ha^{-1} in soil after harvest of lentil:



T1 Absolute control ,**T2**(Seed inoculation with bio fertilizer LNm43 a(*Rhizobium+PGPR)* ,**T3** RDF (20-17-16-20 kg NPKSha^{-1}) ,**T4**(RDF+0.5%Zn foliar application +seed inoculation with bfr LNm 43a),**T5** (RDF+0.1% Fe foliar application +SI with bfr LNm 43a) ,**T6**(RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) ,**T7**(RDF+seed treatment 1g $ZnSO_4$kg^{-1} seed+SI with bfr LNm 43a) ,**T8**(RDF+seed treatment 1g $FeSO_4$kg^{-1} seed+ SI with bfr LNm 43a) ,**T9**(RDF+seed treatment 1g $ZnSO_4$ & 1g $FeSO_4$ seed +SI with bfr LNm 43a) ,**T10**(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) ,**T11**(Customized fertilizer(CFG1)+SI with bfr LNm 43a) ,**T12**(Customized fertilizer(CFG2)+SI with bfr LNm 43a)

CHAPTER V
DISCUSSION

The result recorded during the course of investigation as reported in the previous chapter are discussed here. In order to find out the possible explanation, the present results are explained and discussed in this chapter with the support of available previous research evidences.

5.1. Effect of Zinc, Iron and Bio fertilizer application on Symbiotic traits of Lentil in Black Soils-

Symbiotic traits including nodule number, nodule dry weight, total plant dry weight recorded at 45,60 DAS and at maturity indicates that nodule number and nodule dry weight decreased from 45 DAS to 60 DAS and at maturity.This might be due to the fact that nodule start forming at 20-25 DAS and remained in full functioning up to flowering thereafter senescence start and due to nodule degeneration at later stage its number and also weight drops. As regards the effect of various treatments significantly higher nodulation was recorded in all those treatment which received bio fertilizer inoculation over the treatment of absolute control T_1. This might be ascribed to the effect of inoculation with effective strains of bio fertilizers containing *Rhizobium* .Better nodulation in T_{12} Customized fertilizer application and in T_{10} over T_3 might be ascribed to effect of available molybdenum in composition of customized fertilizer and also better availability of Zn with soil application. Molybdenum is essential for nitrogenase enzyme which is essential for BNF through *Rhizobium* and its activity in the nodular tissues. Zinc is essential for several metabolic and biochemical reactions in roots and plant as a whole. These micronutrients might have favored better plant vigor and as such enable plants to bear more nodules with better weight. Dry weight plant^{-1} indicates chronological enhancement at different stages of crop (45,60DAS and maturity).This might be ascribed to the growth of crop with accumulation of photosynthates which resulted in enhancement of dry weight plant^{-1} as the stage of growth advances. Application of all the treatments showed significant increase in dry weight of plant over absolute control .This might be due to bio fertilizer inoculation and addition of Zn and Fe through foliar spray and seed application and also through soil application of Zn . Zn and Fe are essential nutrients in several biochemical reaction in plant metabolism ,their increased availability under various treatments supported plant growth along with RDF and bio fertilizers inoculation. Soil application of Zn T_{10} (RDF+soil app of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) might have facilitated the crop, its availability from seedling stage up to maturity and hence the response is better and significant over T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$) the existing practice of fertilization.T_{12} also showed better performance which might be due to balance supply of nutrients including molybdenum which enhances BNF through nitrogenase activity. Favorable effect of micronutrients viz. Mo, Fe and Zn on nodulation in legumes have also been reported by Jain *et.al*.(1995), Chandra and Pareek (2002), , Nasser *et.al*.,(2008) , Gupta and Gangwar ,(2012) and Gupta and Sahu (2012) .

5.1.2 Effect of Zinc, Iron and bio fertilizer application on growth attributes of lentil in Black soil :

Crop growth attributes viz. plant height , number of branches, dry weight of plants are the important growth attributes which contribute to yield of Lentil .These parameters showed significant enhancement due to micronutrients (Zn) and (Fe) and with balance nutrition with customized fertilizer application in Lentil .Significantly superior effect of T_{10}, T_6 and T_{12} on growth attributes over absolute control T_1 and also over T_3, the existing practice of fertilization, might be ascribed to the better and constant availability of Zn to crop in T_{10}(RDF+soil app of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) and Zn & Fe in T_6 (RDF +0.5% Zn &0.1% Fe foliar app +SI with bfr LNm 43a) and of balance nutrients including molybdenum in T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) . Zn found deficient in soil under experiment.Zn is the necessary cofactor in enzymes, formation of plant growth hormones, formation of chlorophyll and construction of seed ,carbohydrate and starch. Fe is the key factor of oxidation-reduction process and also favors chlorophyll development . Customized fertilizer(CFG_2) contains N,P,K,S,Zn,Fe,B & Mo. Molybdenum is essential in Biological nitrogen fixation in legumes through activation of N_2-fixing enzyme nitrogenase. Hence all these factors independently /jointly might have contributed to better nodulation N_2-fixation ,P availability resulting in better growth parameters. The beneficial effects of micronutrients in legume/pulses crops on Growth attributes have also reported by Kumar *et al*.,(2009), Kobraee *et.al*.,(2011) and Gupta and Gangwar ,(2012).

5.1.3 Effect of Zinc , Iron and bio fertilizer application on Yield attributes of lentil in Black soil:

Various yield attributing characters viz. number of pods per plant , seed yield per plant , seed index, seed yield(kg $plot^{-1}$) and straw yield(kg plot-1)significantly varied due to various treatments .The highest number of pods per plant , seed yield per plant and seed index was found under T_{10}(RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) followed by withT_6 (RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) and T_{12}(Customized fertilizer(CFG2)+SI with bfr LNm 43a) .This enhancement in yield attributes in T_{10} might be due to adequate supply of Zn throughout the crop growth period by its application in soil before sowing of crop .Bio fertilizer application also contributed N,P and growth promoters. Similarly treatment T_6 also received Zn and Fe as foliar application along with bio fertilizer application which makes Zn and Fe and also N,P and growth promoters available to crop plants which resulted in better yield attributes. Zn and Fe are essential nutrient for plant metabolism and several enzymatic activities. Under T_{12}- customized fertilizer application (N, P, K, Zn, Fe, S, B & Mo) , Mo might have favor BNF through nitrogenase activity, B favors pollination in crop Zn and Fe enzymatic activity and plants metabolism which resulted in improvement in growth and yield attribute in lentil. The favorable effect of Zn ,Fe ,Mo and B in promoting yield attributes in legumes was also reported by Pathak *et.al* (2003) Singh *et al*. ,(2006) , Gupta and Sahu (2012) and Sagar *et al*.(2015) .

5.1.4 Effect of Zinc , Iron and bio fertilizer application on Seed yield and Straw yield of lentil in Black soil:

Favorable effects of promising treatments on yield attributes significantly increased the seed and straw yield of lentil as there is positive correlation of seed yield with growth and yield attributes .Out of applied twelve treatments T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) resulted highest yield (1540 kg ha^{-1}) over rest of the treatments. The increase in seed yield owing to this treatments might be due to the fact that N ,P and Zn plays an important role in synthesis of chlorophyll amino acid , while bio-fertilizers

,viz. *Rhizobium* increases the root nodulation which fixes more atmospheric nitrogen, PGPR are capable of promoting plant growth and yield of lentil .Other treatments viz.T_6 (RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) –foliar spray of Zn and Fe + Seed inoculation with bio fertilizer and T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) consisting of N,P,K,Zn, Fe, S, B & Mo also resulted higher seed and straw yield over rest of the treatments .The significant increase in seed and straw yield due to these nutrient management treatments might be attributed to similar increases in vegetative growth characters viz. plant height ,nodulation , branches plant^{-1} ,pods plant^{-1} and better N, P, Mo, Zn and Fe supply and their contribution in various metabolic processes in plant. The positive effect of Mo , Zn ,Fe and bio-fertilizer on grain and straw yield of lentil/other pulses have also been reported elsewhere, Azad *et. al.*(1991), Khanna *et.al.*(2006), Gupta and Gangwar (2012), Kanase *et at*.(2006) and Gupta et al.(2015).

As regards biological yield T_{10} recorded highest value followed by T_6 and T_{12} . This might be ascribed to enhanced growth straw and grain yield due to positive effect of Zn, Zn &Fe and balance nutrition in customized fertilizer application respectively .All these factors resulted in better biological yield under these treatments. Highest harvest index was recorded with T_4 followed by with T_7 and T_8. However these treatments were statistically identical with T_{10},T_{12} and T_6 . This might be ascribed to better seed yield due to positive effect of micronutrients (Zn,Fe and Mo,B) under these treatments as against T_1.Favourable effect of micronutrients viz.Zn,Fe and Mo on biological yield and harvest index was also reported by other researchers in legumes,Krishnareddy *et.al*.(1996),Ahmed *et.al*.(1999)and Singh *et.al.* (1999).

5.2 Major nutrients content in Seed and Straw :

5.2.1 Nitrogen content and uptake in seed and straw and protein content:

Significant and highest N content in seed and straw and crude protein content in seed were recorded in the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25 kg ha^{-1} +SI with bfr LNm 43a) followed by in T_6 (RDF +0.5% Zn &0.1% Fe foliar application +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) which might be due to enhanced N_2-fixation by bio- fertlizer inoculation together with better supply of Zn ,Fe and other nutrients (customized fertilizer (CFG_2) N, P,K,S,Zn ,Fe ,B &Mo) under these treatments. Nitrogen is the component of many important organic compounds ranging from proteins to nucleic acids .P role in plants is in energy transfer and protein metabolism ,Zn is the essential component of several dehydrogenases and peptidases ,Fe is also support for N_2 – fixation and photosynthesis and Mo required for the normal assimilation of N in plants an essential component of nitrate reductase as well as nitrogenase (N – fixation enzyme) which contribute higher nitrogen to seed and straw and crude protein content. The results of similar kind were also reported by other researchers Hossain and Suman (2005) and Gupta and Sahu (2012).

5.2.2 Phosphorus content and uptake in seed and straw and protein content

Highest P content in seed and straw of lentil was found under the treatment T_{12} (Customized fertilizer(CFG2)+SI with bfr LNm 43a) followed by inT_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a). Balance nutrient combination might have favored the growth and P assimilation in plants under customized fertlizer (T_{12})application resulting in better P content.In T_{10} overall favorable growth starting from initial stage to grand growth period of crop due to basal application of $ZnSO_{4,}$ the complementary assimilation of other nutrients including phosphorous was also there which resulted in better P content under this treatment. Bio fertilizer inoculation also favors availability of P. The result of similar kind have also been reported by Hossain and Suman(2005),Mukherjee and Rai(2007)& Gupta and Sahu (2012)

5.3 Minor nutrients content in Seed and Straw :

5.3.1 Zn content and uptake in seed and straw :

Significant and higher value of Zn content and uptake in seed as well as in straw were recorded under the treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a) .This might be due to regular availability of zinc throughout the growth span of crop because of its basal application as Zinc sulphate 25 kg $ha^{-1.}$ Better Zinc content and uptake in seed as well as in straw and also its total uptake in lentil was found in all those treatments wherever Zn was applied either as seed application of as foliar spray. The results of similar kind have also been reported by Wani *et.al*.(2008) ,Thavarajah *et.al*.(2009) and Gupta and Sahu (2012).

5.3.2 Fe content and uptake in seed and straw :

Fe content in seed and straw was significantly influenced by various treatments. In general significant and higher values of Fe content in seed as well as in straw and its uptake recorded under the treatment which received Fe application either as foliar, seed or with customized application of fertilizer (T_5,T_6,T_8,T_9 and Customized fertilizer application).This might be due to ready availability of this nutrient to root zone of crop by its application under these treatments as compared to those treatments where it was not applied. This results of similar kind have also been reported by Thavarajah *et.al*.(2009), Podder *et.al.*(2017) and Gupta and Sahu (2012).

5.4 Nutrient status after crop harvest:

5.4.1 Nutrients (N, P, Zn and Fe) status after crop harvest :

Available N, P, after crop harvest (T_{12}) found significantly better under all the treatments wherever RDF was given along with Zn and Fe treatments either as foliar, seed or soil application along with bio fertilizers inoculation (T_3 to T_{12}) as against absolute control $T_{1.}$ This might be due to better availability of these nutrients by addition of N,P through RDF and also through BNF and Plant growth promoting substances produced by PGPR used under T_3 to T_{12} as compared to T absolute control. The combination of Zn, Fe and also customized fertilizer along with bio fertilizers facilitated more availability of N,P in soil and also more uptake by crop.Results of similar kind have also been reported by Nasser *et.al.*(2008).

Zn content after harvest (T_{10}) was found better in all those treatments wherever it was applied as treatment with maximum value under T_{10} (RDF+soil application of $ZnSO_4$ 25kgha^{-1} +SI with bfr LNm 43a).This might be due to the basal application of Zn as $ZnSO_4$ 25 kg ha^{-1} which contributed to better supply of Zn to crop and also its higher balance in soil after crop harvest. Absolute control receives no fertilizer and also no inoculation hence minimum Zn content after crop harvest.Fe content was normally higher under the treatments which receives RDF and Fe along with bio fertilizer application T_7,T_8,T_9 T_{11} and T_{12} as against absolute control,T_1.This might be due to its increased availability with the supplementation of these nutrients in soil. Increase in Zn and Fe content in soil by its application in soil has also been reported by Jat *et.al*(2015)

CHAPTER VI
SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

A field experiment was conducted to study " Response of Lentil (*Lens culinaris Medikus*) to Zinc ,Iron and Bio fertilizer Application in Black soils" during the rabi season of 2016-17 at the research farm of R.A.K. College of Agriculture ,Sehore .The experiment was laid out in a randomized block design with three replications and twelve treatments. T_1 –Absolute control,T_2 - Seed inoculation with biofertilizer (bfr) LNm 43a(*Rhizobium* +*PGPR*),T_3 –RDF+ SI with bfr LNm 43a,T_4- RDF + 0.5%Zn foliar application +SI with bfr LNm 43a,T_5- RDF+0.1% Fe foliar application +SI with bfr LNm43a,T_6- RDF+0.5% Zn & 0.1% Fe foliar Application + SI with bfr LNm 43a,T_7- RDF+ Seed treatment 1g $ZnSO_4 kg^{-1}$ Seed + SI with bfr LNm 43a,T_8- RDF+Seed treatment 1g $FeSO_4 kg^{-1}$ Seed + SI with bfr LNm 43a,T_9- RDF+Seed treatment 1g $FeSO_4 kg^{-1}$ Seed + SI with bfr LNm 43a,T_{10}- RDF+ Soil application of $ZnSO_4$ 25 $kgha^{-1}$ + SI with bfr LNm 43a,T_{11}- Customized fertilizer (CFG_1- CFG_1 : 5.5- 4.6- 4.5- 8.3- 1.4- 0.0- 0.08 -0.0 kg (N ,P, K ,S, Zn, Fe, B & Mo) + SI with bfr LNm 43a,T_{12}- Customized fertilizer (CFG_2 CFG_2 : 5.5- 4.6- 4.5- 8.3- 1.4- 0.8 0.08-0.034 kg (N, P, K ,S, Zn, Fe, B & Mo) + SI with bfr LNm 43a.The soil of the experiment field was medium black Vertisol with pH 7.8 ,low in organic carbon and available nitrogen , medium in available phosphorus ,low in Zn but normal in Fe. The Lentil variety RVL-11-6 was sown on 09/11/2016 and harvested on 06/03/2017 .

Symbiotic traits, Growth and yield attributing characters to support seed and straw yields were studied. N, P, Zn and Fe content in seed and straw and their uptake by lentil crop and also N, P, Zn and Fe in soil after harvest of crop were also studied.

6.1 The important results of the present investigation are summarized as follows :

1. Number of root nodules and root nodules dry weight were found better under the treatments which received bio fertilizers inoculation and also supplementation of Fe, Zn (especially T_{10})and in customized fertilizer application +SI with bfr LNm 43a, T_{12} with composition of (N,P,K,S, Zn, Fe, B &Mo:5.5-4.6-4.5-8.3-1.4-0.8-0.08-0.034 kg).
2. Number of pods plant^{-1} ,seed yield plant^{-1} ,seed index, seed yield kg plot^{-1} and seed & straw yield kg ha^{-1}were significant with most of the treatments

.Treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) and T_{12} (Customized fertilizer(CFG_2)+SI with bfr LNm 43a) were significantly superior over T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$) in most of the studied parameters. However as regards seed yield T_{10} alone recorded significantly superior yield over T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$), the existing recommended practice of fertilization in Lentil.

3. The N,P, Zn and Fe and Protein content in seed and straw and their uptake were found significantly higher in treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a), over T_3 (RDF 20-17-16-20 kg $NPKSha^{-1}$) for most of the treatment. Further other treatments consisted of Zn and Fe application as foliar and as seed treatment along with bio fertlizers inoculation and also customizer fertilizer application with composition(N,P,K,S, Zn, Fe, B &Mo:5.5-4.6-4.5-8.3-1.4-0.8-0.08-0.034 kg) also showed better uptake of nutrients over absolute control.
4. Balance of N,P after harvest of crop was found better when RDF was used along with bio fertilizers seed inoculation (T_3 to T_{12}) as against absolute control,T_1.
5. Zn and Fe content in soil was found better wherever these nutrients were used along with RDF + bio fertilizers inoculation as against absolute control. Zn in soil after harvest was found maximum in T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) .

6.2 Conclusion :

For obtaining higher yields of Lentil and sustaining soil fertility the use of Recommended dose of fertilizer viz. NPKS 20:17:20:20 +$ZnSO_4$ application @25kg ha^{-1} +SI with bfr LNm 43a (consisting of *Rhizobium+PGPR)* can be advocated in black soils of M.P. Under present investigation treatment T_{10} (RDF+soil application of $ZnSO_4$ 25kg ha^{-1} +SI with bfr LNm 43a) was found effective in enhancing symbiotic traits ,growth attributes ,grain & straw yield, nutrient uptake and also better available nutrients in soil.Thus Farmer can use this balance nutrition treatments for obtaining higher productivity and profit from lentil crop.

6.3 Suggestions for further work-

Field experiment for one more year may be conducted to reach to a valid conclusion and further recommendation.

BIBLIOGRAPHY

Ahmed,-M-A; Zaky,-N-M; El-Gazzar,-M-M (1999). Response of lentil to zinc, manganese under different levels of phosphorus fertilizers. *Annals of Agricultural Science Moshtohor*. **37**(1): 41-64

AOAC (1984).Official *Methods of Analysis of Analytical chemists* (W.Hartwitz,Ed). 14th Ed. AOAC Washington DC, U.S.A

Arya, R.L., Varshney J.G. and Kumar Lalit (2007). Effect of integrated nutrient application in chickpea+mustard intercropping system in the semi-arid tropics of North India. *Comm. Soil Sci. Pl. Anal*. **38** (1/2): 229-240.

Azad, A.S. Gill, A.S. and Dhaliwal , H.S. (1991). Response of phosphorus and *Rhizobium* culture on grain yield of lentil. *Lens Newsletter* **18** (12): 14-19 .

Bahure, G.K., I.A.B. Mirza, R.T. Bankar, A.N. Puri and M.K. Sirsath. 2016. Effect of foliar application of zinc, iron and magnesium on growth, yield and quality of soybean (Glycine max (L.) Merrill). *Asian Journal of Multidisciplinary Studies.* **4** *(3): 19-22.*

Bandhyopadhyay , S and Puste , A.M. (2002). Effect of integrated nutrient management on productivity and residual soil fertility status under different rice(Oryza sativa)-pulse cropping systems in rained lateritic belt of West Bengal. *Indian Journal of Agronomy* .**47**(1) 33-40

Bhanavase, D.B., Jadhav, B.R., Kshirsagar, C.R. and Patil, P.L. (1994). Studies on chlorophyll, nodulation, nitrogen fixation, soybean yield and their correlation as influenced by micronutrient. *Madras Agriculture Journal*, **81**:325-328.

Bouis H.(2002).Plant breeding: a new tool for fighting micronutrient malnutrition. *Journal of Nutrition* ,**132**:491S-494S

Chandra,R. and Pareek, N.(2002). Effect of inoculation of different strains of *Rhizobium leguminosarum Bv.vaciae* on nodulation and yield of lentil genotypes. *Legume Research* , **26** (4):292-295.

Dubey, S. K., Tripathi, S. K. and Singh, B. (2013). Effect of sulphur and zinc levels on growth, yield and quality of mustard [*Brassica juncea* (L.) Czern & Coss.*]. A Journal of Crop Science and Technology,* **2**: 2319-3395.

FAOSTAT (2016). www.agriculturestatistics.org

Gupta, S.C (2004).Response of gram (*Cicer arietinum* L.) to types and methods of microbial inoculation. *Indian J. of Agric. Sci*. **74**(2): 73-75.

Gupta, K.(2012).Role of phosphorus and zinc in enhancing growth, yield and quality of fennel crop (Foeniculum vulgare Mill.) in irrigated condition of North West Rajasthan. Ph.D. Thesis, SKRAU, Bikaner.

Gupta S.C. and Gangwar , S .(2012).Effect of molybdenum, iron and microbial inoculants on symbiotic traits, nutrient uptake and yield of chickpea. *Journal of Food legumes*.**25** (1): 45-49.

Gupta,S.C., Kumar, Sanjeev and Khandwe R (2011).Effect of biofertilizers and foliar spray of urea on symbiotic traits , nitrogen uptake and productivity of chickpea *. Journal of Food legumes* **24**(2) 155-157.

Gupta,S.C. and Sahu, S.(2012).Response of Chickpea to micronutrients and biofertilizers in vertisols. *Legume Research* **35** (3):248-251.

Harish K.(2012).Analysis of stability for iron and zinc concentration and molecular diversity in elite lines of Lentil (*Lens culinaris*) M.Sc. Thesis ,Indian Agricultural Research institute , New Delhi ,India.

Hossain ,M.M and Suman ,M (2005).Effect of bio fertilizer and nitrogenous fertilizer on growth ,yield and N- uptake of lentil (*Lens culinaris Medik*).*International J.Sust.Agril.Tech*.**1** (6):76-81.

Hussain, S., Maqsood, M., & Miller, L. (2011). Bio available zinc in grains of bread wheat varieties of Pakistan. *Cereal Research Communications*, **40**(1), 62-73.

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

Jain,R.C.Tiwari R.J.and Nema D.P.(1995).Integrated nutrient management for lentil under rain fed conditions in Madhya Pradesh. *Lens Newsletter***.22** (1-2) 13-15

Jat, G., Sharma, K. K. and Choudhary, R. (2015). Effect of FYM and mineral nutrients on yield, content and uptake of nutrients in mustard. *Annals of Agricultural Research*, **34**: 236-240.

Kanase, A.A., Mendhe, S.N, Khawale, V.S, Jarande, N.N. and Mendhe, J. (2006). Effect of integrated nutrient management and weed biomass addition on growth and yield of soybean. *J. Soils Crops*. **16** (1): 236-239.

Khanna, Veena, Sharma, Poonam and Sekhon, H.S. (2006). Effect of *Rhizobium* inoculation and *PGPR* on nodulation and grain yield in lentil (*Lens culinaris* L.).*Environ. Ecol.* **24** : 224-226.

Kobraee S , Shamsi K. and Rasekhi B (2011)..Effect of micronutrients application on yield and yield components of Soybean .*Annals Biol. Res*. **2**(2) : 476-482 .

Koeing, R.A. and Johnson, C.R. (1942) Calorimetric determination of biological material. Industrial and Engineering chemistry (Analytical Edition)**14**:155-164.

Krishnareddy, V. and Ahlawat I. p. S. (1996). Growth and Yield Response of Lentil Cultivars to Phosphorus, Zinc and Biofertilizers, Central Tobacco Research Institute, Rajahmundry, Andhra Pradesh â533 105, *India Agronomy & Crop Science* 177, 49-59,

Kumar, R.P; Singh, O.N, Singh, Yogeshwar, Sachchidanand Dwivedi and Singh, J.P. (2009). Effect of integrated nutrient management on growth, yield, nutrient uptake and ecnomics of french bean (*Phaseolus vulgaris*). *Indian J. Agril. Sci*. **79** (2): 122-128.

Kumar, S.H.A. and Uppar, D. S. (2007). Influence of integrated nutrient management on seed yield and quality of mothbean [*Vigna aconitifolia* (Jacq.) Marchel]. *Karnataka J. Agril. Sci*. **20** (2): 394-396.

Kumar, Satish and Kumar, Rakesh (2006).Effect of farm yard manure, phosphorus levels and biofertilizer on productivity of lentil. *Crop Research*-Hisar. **31**(3): 370-372.

Kumawat, R.N., Rathore, P.S. and Pareek, N, (2006). Response of mungbean to S and Fe nutrition grown on calcareous soil of Western Rajasthan. *IndIan Journal of Pulses Research*. **19** (2): 228-230.

Lindsay,W.L. and Norvell W.A. (1978).Development of DTPA micronutrient soil test for Zn ,Fe , Mn & Cu .*Soil Sci.Soc.America J*. **42**:421-428.

Lodha ,M.L. ,Prasanna B.M. and Pal R.K. (2005). Alleviating ‘hidden hunger’ through better harvest . *Indian Farming* **.54**(12):20-23

Mahriya, A.K. (1997). Response of cowpea to phosphorus on iron on growth and quality of cowpea [*Vigna unguiculata* (L.) Walp.] *Annals of Agriculture Biology Research*, **4**:203-05.

Mavarkar, N. S. Sridhara, S. and Naik, T. B. (2008).Effect of methods of zinc application on growth and yield of cowpea under rainfed conditions. *Research on Crops*; . **9** (2):290-292

Mousavi, S. R., Galavi, M., and Rezaei, M.(2013).Zinc (Zn) importance for crop production-a review. *International Journal of Agronomy and Plant Production*, **4**(1):64-68.

Mukherjee,P.K. and Rai,R.K.(2000).Effect of vesicular arbuscular mycorrhizae and phosphate –solubilizing bacteria on growth, yield and phosphorus uptake by wheat (*Triticum aestivum*) and chickpea (*Cicer arietinum*). *Indian J.Agron*.**45** (3):602-607.

Nasser,R.R; Fuller, M.P; Jellings,.A.J (2008). Effect of elevated and nitrogen levels on lentil growth and nodulation.*Agronomy for Sustainable Development.* **28**(2): 175-180.

Olsen, S.R., Cole, C.V. Watanabe F.S. and Dean ,L.A. (1954) .Estimating of available phosphorus in soil by extraction with sodium bicarbonate *USDA Circular*, 939.

Panes,V.G.and Sukhatme, P.V.(1967).Statistical methods for Agricultural workers, 3rd edition, ICAR, New Delhi 70--99.

Pathak, Styajite, Namdeo,K.N. Chakravarti, V.K. and Tiwari, R.K. (2003). Effect of bio-fertilizers, diammonium phosphate and zinc sulphate on growth and yield of chickpea .*Crop Research*, **26** (10): 42 – 46.

Piper, C S. (1967). Soil and plant analysis. *Uni.of Adelaide,* Australia. Hans Publishers, Bombay.

Podder Rajib, Tara’an Bunyamin and Vanderberg Albert (2017).Iron fortification of Lentil (*Lens culinaris Medik*.) to address Iron. Nutrients. **9**(8):863

Ravi, S., Channal, H. T., Hebsur, N. S., Patil, B. N. and Dharmatti, P. R.(2008). Effect of sulphur, zinc and iron nutrition on growth, yield, nutrient uptake and quality of sunflower (*Carthamus tinctorius* L.). *Karnataka Journal of Agriculture Science*, **21**:382-385.

Sagar, Alka, Ansari, Jammaluddin, Sharma C.P. and Azlee Fatima (2015).Interactive effect of bio-fertilizers (Rhizobium, PSB and VAM) in lentil (*Lens culinaris* L.) *Res. Environ. Life Sci*. **8**(4) 613-614.

Selim, M. M.; Bahar, A.; Kabesh, M. O. (2002). Utilization of bio fortified system for enhancing lentil yield and quality in reclaimed sandy soil. *Bulletin of the National Research Centre* (Cairo). **27**: 4, 521-531.

Sharma, B.C. and Sharma, S.C. (2004). Integrated nutrient management in lentil. *Adv. Pl. Sci*. **17** (1): 195-197.

Singh Yasbir ,Prasad Rajendra and Singh Ummed (2016). Micronutrient Fertilizers for Zinc and Iron Enrichment in Major Food crops: A Practicable Strategy, *Biofortification of Food Crops* pp 229-236.

Singh, G.,Sekhon, H.S. and Sharma, P. (2006).Effect of *Rhizobium*, phosphorus and potash on nodulation and productivity of lentil (Lens *culinaris Medik*.). *J Plant Sci. Res.* **22**: 239-241

Singh, Guriqbal, Sekhon, H.S. and Sharma, Poonam (2001).Effect of *Rhizobium*, vesicular arbuscular mycorrhiza and phosphorus on the growth and yield of lentil (*Lens culinaris*) and fieldpea (*Pisum sativum*). *Environ. Ecol*. **19** (1): 40- 42.

Singh, O.B. , Sharma ,H.B. and Singh , V.K. (1999).Effect of nitrogen , phosphorus and *Rhizobium* culture on yield and yield attributes of lentil under dry land conditions . *Indian Journal of Pulse Research*. **12** (2) 260-262.

Singh, S. P., Pal, M. S. and Dube, S. N. (2010).Yield, quality and nutrient uptake of mustard (Brassica juncea) with organic and inorganic fertilization. *Current Advances in Agricultural Sciences*, **2**:87-90.

Singh, S.B., Singh, O.N., Singh, S.K., Yadav, S.S. and Rajput, P.K. (2007). Effect of fertility levels, PSB and vermi-compost on growth, yield and quality of large seeded lentil. *J. Food Legumes*. **20** (1): 52-54.

Singh,Y.P; Chauhan,C.P.S and Gupta,R.K (2000).Effect of sulphur, phosphorus and inoculation on growth, yield and sulphur utilization by lentil (*Lens culinaris*). *Indian Journal of Agricultural Sciences.;* **70**(7): 491-493.

Solomons N.W. (2003).Zinc Deficiency In Caballero B (ed) Encyclopedia of Food Sci. and Nutrition, 2nd edn. Elsevier ,England

Subbiah, B.V. and G.L. Asija (1956). A rapid method for the estimation of available nitrogen in soil. *Current Sci. (***25**): 259-260.

Thavarajah, D., P. Thavarajah, A. Sarker and A. Vandenberg. (2009). Lentils (*Lens culinaris Medikus* subspecies *culinaris*): A whole food for increased iron and zinc intake. *J. Agric. Food Chem*. **57**: 5413-5419.

Tickoo J.L., Sharma B., Mishra S.K and Dikshit H.K (2005). Lentil (*Lens culinaris*) in India : Present status and future perspectives. *Indian Journal Agric. Sci*. **75** (9): 539-67

Togay N ; Togay, Y.; Erman M. and Çig F. (2015). Effect of Fe (iron) and Mo (molybdenum) application on the yield and yield parameters of lentil (*Lens culinaris* Medik.) *Legume Research*. **38** (3) 2015: 358-362

Tripathi, H. C., Pathak, R. K., Kumar, A. and Dimree, S.(2011). Effect of sulphur and zinc on yield attributes, yield and nutrient uptake in chickpea (*Cicer arietinum* L.) *Annals of Plant and Soil Research*, **13:**134-136.

UNSCN,(2004).5th Report on the world nutrition situation. Nutrition for improved development outcomes .United Nations System Standing Committee on Nutrition , Geneva

Vasanthi, D. and Subramanian S.2004).Effect of vermicompost on nutrient uptake and protein content in black gram (*Cicer arietinum*). *Legume Research,* **27** (4): 293 –295.

Walkley, A. and Black C.A. (1934).Estimation of soil organic carbon by the chromic acid titration method. *Soil Sci.* **37** (1): 29-38.

Wani,-P-A; Khan,-M-S; Almas-Zaidi (2008).Impact of zinc-tolerant plant growth-promoting rhizobacteria on lentil grown in zinc-amended soil *Agronomy-for-Sustainable-Development,* **28**(3): 449-455

Appendix – I : s Mean sum of square of plant height and no. of branches per plant at different successive stages of growth.

S.V.	D.F.	Plant height(cm)			Branches per plant (No.)		
		45 DAS	60 DAS	At maturity	45 DAS	60 DAS	At maturity
Rep.	2	0.492	0.235	0.014	0.119	0.059	0.077
Treat.	11	2.622	5.524	5.486	0.279	0.370	0.295
Error	22	0.478	1.052	1.546	0.045	0.047	0.126

* Significant at 5% level

Appendix – II : Mean sum of square of root length and dry weight per plant at different successive stages of growth.

S.V.	D.F.	Root length (cm)			Dry weight per plant (g)		
		45 DAS	60 DAS	At maturity	45 DAS	60 DAS	At maturity
Rep.	2	0.117	0.520	0.577	0.009	0.065	0.049
Treat.	11	0.997	2.001	3.036	1.133	1.213	1.744
Error	22	0.191	0.799	1.190	0.014	0.158	0.153

* Significant at 5% level

Appendix – III : : Mean sum of square of number and dry weight of root nodules per plant at different successive stages of growth.

S.V.	D.F.	No. of root nodules			Dry weight of root nodules (mg)		
		45 DAS	60 DAS	At maturity	45 DAS	60 DAS	At maturity
Rep.	2	0.059	0.666	0.444	2.388	0.209	0.129
Treat.	11	10.250	6.222	4.913	5.023	4.144	1.443
Error	22	0.764	0.902	0.677	4.066	0.317	0.045

* Significant at 5% level

Appendix – IV : Mean sum of square of yield and yield attributing characters.

S.V.	D.F.	Pods Plant^{-1} (No.)	Seed index (g)	Seed yield Plant^{-1} (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Rep.	2	164.202	0.022	0.008	285.361	73271808	0.346
Treat.	11	829.654	0.146	0.761	70950.444	73136581.33	0.807
Error	22	121.124	0.009	0.087	10000.846	72450741.67	0.302

* Significant at 5% level

Appendix – V : Mean sum of square of seed yield and straw yield kg $plot^{-1}$ characters.

S.V.	D.F.	Seed yield kg $plot^{-1}$	Straw yield kg $plot^{-1}$
Rep.	2	0.004	0.001
Treat.	11	0.082	0.072
Error	22	0.007	0.008

* Significant at 5% level

Appendix – VI : Mean sum of square of N–content (%) and N–uptake (kg ha^{-1}) in seed and straw.

S.V.	D.F.	N–content in seed (%)	N–content in straw (%)	N – uptake in seed (kg ha^{-1})	N – uptake in straw (kg ha^{-1})	Total N - uptake seed+ straw (kg ha^{-1})
Rep.	2	0.00007	0.0011	3.684	3.257	9.977
Treat.	11	0.02358	0.0105	142.470	10.104	227.712
Error	22	0.00019	0.0010	3.180	1.239	5.854

* Significant at 5% level

Appendix – VII: Mean sum of square of P – content (%) and P – uptake (kg ha^{-1}) in seed and straw.

S.V.	D.F.	P – content in seed(%)	P – content in straw(%)	P – uptake in seed (kg ha^{-1})	P – uptake in straw (kg ha^{-1})	Total P - uptake seed+ straw (kg ha^{-1})
Rep.	2	0.00002	0.00002	0.701	0.004	0.146
Treat.	11	0.00169	0.00080	3.656	0.928	6.134
Error	22	0.00012	0.00008	0.220	0.022	0.250

* Significant at 5% level

Appendix – VIII: Mean sum of square of Zn– content (%) and Zn– uptake (gha^{-1}) in seed and straw.

S.V..	D.F.	Zn–content in seed (%)	Zn – content in straw (%)	Zn–uptake in seed (g ha^{-1})	Zn – uptake in straw (g ha^{-1})	Total Zn - uptake seed +straw(g ha^{-1})
Rep.	2	0.239	0.061	2.207	0.061	0.107
Treat.	11	0.496	0.258	105.793	7.423	167.676
Error	22	0.131	0.035	0.837	0.059	0.951

* Significant at 5% level

Appendix – IX : Mean sum of square of Fe – content (%) and S – uptake (gha^{-1}) in seed and straw.

S.V..	D.F.	Fe–content in seed (%)	Fe–content in straw (%)	Fe – uptake in seed (g ha^{-1})	Fe – uptake in straw (g ha^{-1})	Total Fe - uptake seed +straw(g ha^{-1})
Rep.	2	0.075	0.172	0.001	0.010	0.130
Treat.	11	1.581	2.877	290.223	3324.894	5561.516
Error	22	0.507	0.064	1.149	0.497	0.578

* Significant at 5% level

Appendix –X : Mean sum of square of available N,P,K and S in soil after crop harvesting (kg ha^{-1}).

S.V.	D.F.	Available N in soil after harvest of crop ($kgha^{-1}$)	Available P in soil after harvest of crop ($kgha^{-1}$)	Available Zn in soil after harvest of crop ($kgha^{-1}$)	Available Fe in soil after harvest of crop ($kgha^{-1}$)
Rep.	2	0.014	0.135	0.00031	0.010
Treat.	11	81.180	1.110	0.00033	0.037
Error	22	3.228	0.462	0.00012	0.016

* Significant at 5% levels

VITA

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