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Effect of foliar application of zinc on growth and seed yield of late-sown lentil (*Lens culinaris*)

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ABSTRACT

Field experiment was conducted to develop zinc management strategy for late sown lentil (*Lens culinaris* Medik) crop alone or in cropping system mode during 2008-09 and 2009-10. Four levels of Zn, viz. Zn_1control (0.0%), Zn_2(0.02%), Zn_3(0.04%), Zn_4(0.08%) were applied foliar twice, first at preflowering and second at post podding stage.Highest (42.2 cm) and lowest (32.8 cm) plant height at harvest was recorded with application of 0.08% Zn and in control treatment. Longest (12.1cm) and shortest (7.9cm) root was recorded in the plots treated with 0.08% Zn and control respectively. Zn treatment (0.04%) produced maximum lentil seed (1 238.6 kg/ha), whereas lowest (1 063.1 kg/ha) was recorded under control.Highest nitrogen concentration (1.98 per cent)and N uptake (55.7 kg/ha) was recorded in plots fertilized with Zn applied @0.08%. Gradual buildup of organic carbon, N, P and K and zinc content in the soil were also noticed. It is recommended that under late sown condition foliar feeding with 0.04 % Zn twice during preflowering and post podding stage will increase lentil seed yield by 16.2%.

Key words: Cropping system, Growth and development, Indo-Gangetic plains, Lentil, NPK content and uptake, Zinc

India is world's largest homeland of vegetarian population and world leader in pulses production and import to provide protein supplements (Ali and Gupta 2012).Lentil (*Lens culinaris* Medik.) is one of the most nutritious cool season food legumes and ranks next only to chickpea. It is grown throughout the northern and central India for grains. Besides its utilisation as a dal, whole or dehulled grains are also used in various other preparations.It is one of the prominent sources of vegetable protein in the Indo-Gangetic plain (IGP) region, essentially grown as a rainfed crop on the residual soil moisture of preceding crop (rice in-general) (Ali *et al.* 2012 and Joshi 1998). It was first grown in southwest Asia in 7000 BC (McVicar *et al*. 2010). At present, India, Canada, Turkey, Australia, Nepal, USA, Bangladesh and China are the world's top producers of lentil. In 2009, worldwide lentil production was 3 917 thousand tonnes on cultivated area of 3 700 thousand hectares (FAO 2011).In India lentil occupies 1.51 million ha area with a production of 0.95 million tonnes (Dixit *et al*. 2009).In the Indian IGP, lentil occupies 0.30 M ha, either alone or under rice-lentil sequential cropping system, being second most important cropping system after rice–wheat cropping system (Anonymous 2011). Indian IGP contributes 66% of Indian lentil production from 54.7% area. Lentil productivity in the Indian IGP is quite satisfactory (839 kg/ha) as compared to national average (697 kg/ha) though it faces several biophysical constraints (Anonymous, 2011 and Singh *et al.* 2011). Lentil sowing get delayed either due to late harvest of preceding long duration rice crop or due to heavy soil moisture in the field forcibly kept for lentil, because it is the only crop which can grow or left field fellow for year round (Joshi 1998, Reddy 2009 and Singh *et al.* 2011). Consequent upon delayed planting, early encounter with severe cold, growth and development of lentil crop gets hampered for considerable period. Subsequently plants get comparatively less time to complete lifecycle in hurry, by and large force maturity prevailed (Reddy 2009 and Ramakrishna *et al.* 2000).To improve the lentil seed production under late sown conditions of Indian IGP, critical examination of situation revealed that, interventions to boost vegetative growth during early and mid-phase of life to create base/source is the basic necessity that can be achieved by accelerated vegetative growth and finally unilateral translocation of photosynthate to sink during reproductive stage (Guilfoyle and Hagen 2001, and Pandey and Gautam 2009).

Zn deficiency is very common in IGP, in the rice growing tract in general and rice–wheat and rice–lentil cropping system

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in particular (Joshi 1998 and Ali *et al.* 2012). Zinc role is as multifaceted as the interface that reduces its availability. Physiologically its role in a plant is either as a metal constituent in enzymes or as a functional co-factor of number of enzymes reactions. In general zinc deficient plant show signs of low levels of auxins such as indole acetic acid (IAA). Investigation may provide sound footing that zinc is required for synthesis of tryptophan, which in turn is precursor for synthesis of IAA (Guilfoyle and Hagen 2001 and Liscum and Reed 2002).After flowering, high concentration of zinc in plant will enhance cell differentiation. Zinc plays a greater role during reproductive phase especially during fertilization. Remarkably pollen grain contains zinc in very high quantity. At the time of fertilization most of zinc is diverted to seed only (Jenik and Barton 2005, Pandey and Gautam 2009 and Reid *et al.* 2011). Foregone discussion outlined the role and importance of zinc in lentil crop production particularly under late sown conditions. Keeping in view the importance of zinc especially during sensitive phase may boost the performance of late sown lentil in the IGP region of India, with an objective to improve the lentil productivity and production by foliar supplementing of zinc to correlate and validate critical phase this field experiment was undertaken.

MATERIALS AND METHODS

To evolve zinc management scheme, a field experiment was conducted at ICAR Research Complex for Eastern Region, Patna during 2008-09 and 2009-10 in randomized block design (RBD) and replicated thrice. The experimental plot size was 10.0 m × 5.0 m. The surface soil up to 30 cm depth were sampled and analyzed for various physicochemical properties. The texture of soil of experimental field was clay loam having good texture with neutral mean pH (6.8). The chemical and physical characteristic of soil at experimental sites is depicted in Table 1.

The experiment consist of 4 treatments (concentration levels) of Zn namely (control) Zn_1 (0.0%), Zn_2(0.02%), Zn_3(0.04%), Zn_4(0.08%) as per presented in Table 2. Foliar applications were carried out at preflowering and post podding stages. Every time, light irrigations were provided two day before the treatment applied.The chosen agrochemical was none other than commercial grade zinc sulphate ($ZnSO_4.7H_2O$) which contains 21% Zn (active ingredient).Long duration (145 to 155 days) genotype Swarna Mansoori MTU-7029 was chosen for rice crop. Tested lentil genotype was Pant Lentil 406 (PL 406), recommended for North and Eastern zone, i e Indian IGP, where this field experiment was conducted, as well as its performance even under late sown condition along with its medium maturity (125-135 days) are few features faovoured its selection. Sowing of lentil was performed on 10 December during both occasions. Seeds were sown at 3 cm depth at 30 cm row distance. Nutrients particularly, nitrogen, phosphorus, potassium and sulphur were applied as basal dose as well as other agronomic management practice was as per recommended practices and was kept similar for all the treatments. One hand weeding after three weeks of sowing was performed to maintain optimum plant population. Two watering was done at pre flowering stage and post podding stage. Plant protection measures were taken care to manage the biotic stress if any.

Data on number and dry weight of nodules/plant were recorded 60 and 90 DAS by digging five plants from each plot. Five plants were sampled 90 DAS for measuring shoot dry weight. Dry weight of the nodules and shoots were recorded by drying samples in an oven at 60°C for 72 hours. Similarly, chlorophyll contents were taken at 90 DAS.Chlorophyll contents were determined in young leaves (3rd to 4th leaf from the top by the method described by Lichtenthaler and Wellburn (1983).At harvest five representative samples of each plot were collected and biometrical data were recorded and computed for plant height (cm), shoot dry weight (g/plant), root length (cm), root dry weight (g), productive branch/plant, pod/plant, seed yield (g/plant). Similarly 100 seed weight (g) were also computed. Biomass (kg/ha) and seed yield (kg/ha) were computed based on seed weight/plot and computed for ha. Seed yield (kg/ha) were adjusted to 12% moisture. Physical and chemical parameter of soils were recorded with reference to sand (%), silt (%), clay (%), pH, EC (dS/m), OC (%),NO_3 (ppm), available P(ppm) and exchangeable K (ppm) before sowing and after harvest crop. The soil samples were analyzed as per the procedure described by Ryan *et al.* 2001.Two-way analysis of variance (ANOVA) was performed for each trait for all seasons and the combined (Pooled) analysis over seasons after testing error variance homogeneity was carried out according to the procedure outlined by Gomez and Gomez (1984), using SPSS (version 16.0; SPSS Inc., Chicago, IL, USA) statistical package. Significant differences between

Table 1 Soil characteristic of experimental site

Value	Sand (%)	Silt (%)	Clay (%)	Soil pH	Soil carbon (%)	Bulk density (m m^3)	Electrical conductivity (dS/m)	NO_3 (ppm)	Available phosphorus (ppm)	Exchange-able potassium (ppm)	Zinc (ppm)
Initial	26.4	42.6	31.0	7.1	0.68	1.41	0.21	122.7	14.6	92.8	0.38
Status	Clay loam Soil			Normal	Normal	Normal	Normal	Low	High	Medium	Low

Table 2 Treatment layout

Treatment	Symbol used
Zinc (0.0%) (Control)	Zn_1
Zinc (0.02%)	Zn_2
Zinc (0.04%)	Zn_3
Zinc (0.08%)	Zn_4

the treatments were compared with the critical difference at (± 5%) probability by LSD.

RESULTS AND DISCUSSION

To ascertain the extent and pattern of effective availability of Zn minerals applied foliar to the lentil crop.Data presented in Table 3 suggests that there is presence of significant response of Zn nutrient in terms of growth and development of lentil. It is observed that the plant height of lentil is significantly influenced by different levels of application of Zn. Maximum (42.2 cm) and minimum (32.8 cm) plant height was recorded at harvest, with that of 0.08% and control (0%) foliar application of Zn (Table 3) (Ali *et al.* 2012 and Singh *et al.* 2011). Lentil root length at harvest also follows the same fashion, longest (12.1 cm) and shortest (7.9 cm) root was recorded with 0.08 and control application respectively. Root dry weight did not fail to copy the pattern of response, as it was previously seen in case of root length. Highest root dry weight (2.45 g/plant) was noticed with 0.08% foliar application of Zn (Pandey and Gautam 2009). Nodules/plant was recorded at two stages at 30 days interval starting with 60 DAS (Table 3). With increase in Zn concentration and advancement of growth stage, nodule count increased significantly (Reid *et al.* 2011 and Van and Hartley 2000). Maximum (21.8 nodules at 90 DAS) and minimum (10.6 nodules at 60 DAS) were recorded with application of Zn_4 (0.08%) and control respectively. Nodule dry weight (mg/plant) had shown alike trend as it was noticed in case of nodules count. Nodule dry weight increased with the time passes and also influenced with incremental doses of Zn. Maximum (41.3 mg/plant at 90 DAS) and minimum (27.3 mg/plant at 60 DAS) were recorded with application of Zn_4(0.08%) and Zn_1(0.0%) respectively (Reid *et al.* 2011 and Singh *et al.* 2011). Chlorophyll contents were taken at 90 DAS, significant increase with increase in Zn concentration were recorded up to highest concentration, though, maximum increased in terms of per cent was noticed in case of Zn_2 over Zn_1 (Pandey and Gautam 2009).

Shoot dry weight (g/plant) was recorded to increase with increasing concentration of foliar applied Zn mineral (Table 4). Minimum (3.23 g/plant) and maximum (4.37 g/plant) was recorded with application of Zn_1 (0.0%) and Zn_4 (0.08%) respectively (Van and Hartley 2000, Singh *et al.* 2011, Somani 2008 and McVicar *et al*. 2010). Number of productive branches/plant is one of the primary yield contributing traits get influenced with both the tested nutrients. Productive branches/plant had been recorded minimum (14.4) with no application of zinc, whereas maximum (16.3) was obtained in case of Zn_3 (0.04%) (Singh *et al.* 2011 and Somani 2008). Similarly, pods/plant were recorded maximum (63.8) in plots fertilized foliar with Zn_4 (0.08%) and minimum (45.9) with no application of zinc treatment (Pandey and

Table 3 Effects of foliar application of zinc on growth and development of lentil

Treatment	At harvest			Nodules/plant (no)		Nodule dry weight (mg/plant)		Chlorophyll content
	Plant height (cm)	Root length (cm)	Root dry weight (g/plant)	60 DAS	90 DAS	60 DAS	90 DAS	at 90 DAS (mg/g fresh weight of leaves)
Control Zn_1(0.0%)	32.8	7.9	1.87	10.6	14.9	27.3	30.9	1.962
Zn_2 (0.02%)	38.7	10.2	2.01	12.7	15.2	31.9	33.4	2.329
Zn_3 (0.04%)	39.8	11.4	2.12	15.9	18.3	34.2	36.5	2.542
Zn_4 (0.08%)	42.2	12.1	2.34	17.4	21.8	37.1	41.3	2.654
CD (P=0.05)	2.8	1.42	2.45	1.6	2.1	2.4	3.3	0.127

Table 4 Effect s of foliar application of zinc on yield attributes and seed yield of lentil

Treatment	Shoot dry weight (g/plant)	Branches/ plant	Pods/ plant	Biomass (kg/ha)	Seed yield (kg/ha)	Harvest index	1000 grain wt (g)
Control Zn_1 (0.0%)	3.23	14.4	45.9	2 537.5	1 063.1	0.40	24.7
Zn_2 (0.02%)	3.67	15.9	54.2	2 825.6	1 171.2	0.39	24.7
Zn_3 (0.04%)	4.11	16.3	58.0	2 902.6	1 238.6	0.39	24.8
Zn_4 (0.08%)	4.37	16.2	63.8	2 942.1	1 208.6	0.38	25.0
CD (P=0.05)	0.18	1.9	8.6	87.5	35.2	NS	NS

Gautam 2009).Total above ground biomass was also gets influenced significantly with applied zinc. Maximum (2 942.1 kg/ha) and minimum (2 537.5 kg/ha) was recorded with the (0.08%) plot and (0.0%) zinc (Table 4) (Pandey and Gautam 2009 and Ramakrishna *et al.* 2000). Highest lentil seed yield (1 238.6 kg/ha) was recorded with (0.04%) Zn treatment, whereas lowest yield (1 015 kg/ha) was noticed with no application of (0.0%) Zn. 1 000-grain weight (g) was not influenced by of the levels of Zn as it is genetic characters and in general not influenced by management practices (Singh *et al.* 2011). Harvest Index is also not influenced by any of the given treatment and this might be due to character, highly associated with genetic makeup of the crop (Singh *et al.* 2011 and Thiyagarajan *et al.* 2003).

To know the effect of foliar zinc application on NPK concentration (%) and uptake (kg/ha) in lentil, whole plant samples were analysed for above purpose. Data presented in Table 5, indicates that concentration and uptake of nitrogen, phosphorus and potassium due to foliar application of zinc, influenced significantly. Highest concentration (1.98%) of nitrogen in lentil was recorded in plots fertilized with Zn_4 (0.08%) application. The lowest concentration (1.83%) of nitrogen was noticed in case of lentil plots treated with no application of Zn_1 (0.0%). Similar trend was noticed in case of uptake too (Table 5). Highest N uptake 55.7 kg/ha was recorded with Zn_4 (0.08%) application, corresponding minimum was noticed 50.1 kg/ha Zn_1 (0.0%) (Somani 2008 and Thiyagarajan *et al.* 2003). Likewise response was also obtained in case of phosphorus and potassium concentrations. Highest (0.71%) and lowest (0.57%) P concentration in lentil recorded with Zn_4 (0.08%) application and Zn_1 (0.0%) application. Corresponding maximum uptake of P (20.7 kg/ha) recorded with Zn_2 (0.02%). This is clear-cut indication of antagonistic relation of P and Zn (Salvagiotti *et al.* 2008 Thiyagarajan *et al.* 2003). K concentration in lentil had been influenced by all the level of zinc. However, it was noticed that no clear-cut trend was established with both the treatments (Singh *et al.* 2001 and Sahaa *et al.* 2007). Maximum K uptake (269/ha) was recorded in the plot supplemented with Zn_2 (0.02%) (Sahaa *et al.* 2007).

Perusal of data presented in Table 6 revealed that the initial value for pH and EC was recorded normal, however organic carbon (%) and K was in medium in category. However, phosphorus is the only mineral which content was recorded and classified as high (28.6 kg/ha). Moreover, zinc content was recorded below benchmark (critical) level. At the end of three years crop cycle, pH and EC was recorded normal. There are gradual build-up of organic carbon (%), N, P and K due to foliar application of zinc; however significant build-up was noticed in case of zinc content in the soil of experimental plots and it cross the critical limits and categorized as normal (Ali *et al*. 2012 and Salvagiotti *et al.* 2008). This data show that every parameter was improved with the application of the minerals, this not only improving overall productivity of cropping system but also improving fertility status of soils as well (Ali *et al*. 2012, Sahaa *et al.* 2007 and Somani 2008).

It was concluded that foliar application of zinc not only improves lentil productivity but soil fertility status was also improved due to balanced nutrition. Foliar application of zinc (0.04%) not only proves most beneficial but economical too for lentil production under Indo-Gangetic condition of Bihar.

Table 5 Effects of foliar application of zinc on NPK content (%) and uptake (kg/ha) in lentil

Treatment	N		P		K	
	Content	Uptake	Content	Uptake	Content	Uptake
Control Zn_1 (0.0%)	1.83	50.1	0.71	19.3	0.93	25.3
Zn_2 (0.02%)	1.84	51.9	0.73	20.7	0.95	26.9
Zn_3 (0.04%)	1.92	53.8	0.66	18.5	0.76	21.3
Zn_4 (0.08%)	1.98	55.7	0.57	16.2	0.94	26.7
CD (P=0.05)	0.1	4.9	0.07	3.1	0.06	3.6

Table 6 Effects of foliar application of zinc on soil fertility status

Treatment	pH	EC (ds/m)	OC (%)	NO_3 (ppm)	P (ppm)	K (ppm)	Zn (ppm)
Control Zn_1 (0.0%)	6.84	0.19	0.71	254.3	15.3	92.9	0.81
Zn_2 (0.02%)	6.84	0.19	0.74	271.4	16.5	93.3	0.95
Zn_3 (0.04%)	6.83	0.20	0.76	289.4	16.9	96.3	0.97
Zn_4 (0.08%)	6.84	0.20	0.76	291.4	17.1	97.5	1.1
Status (F)	Normal	Normal	Medium	Low	High	Medium	Normal
CD (P=0.05)	NS	NS	NS	27.6	1.3	NS	0.6

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