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Potential of Residual Sulfur and Zinc Nutrition in Improving Powdery Mildew (*Erysiphe trifolii*) Disease Tolerance of Lentil (*Lens culunaris* L.)

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*Lentil (*Lens culunaris *L.) is one of the major sources of protein and the second most important legume crop of the Indo-Gangetic Plain (IGP) in India. Powdery mildew (*Erysiphe trifolii*) is one of the important fungal diseases of lentil that affects the entire plant and causes great reduction in yield and quality of seed. Mineral nutrition, especially with sulfur (S) and zinc (Zn), plays a great role in powdery mildew management. A research trial was conducted from 2008–2009 to 2010–2011 at ICAR Research Complex of Eastern Region, Patna, India, to ascertain the role of residual sulfur (S) and zinc (Zn) in powdery mildew management in lentil under a rice–lentil cropping system. A field experiment was conducted in randomized block design with three replications. Four levels of S and Zn were tested. Sulfur and Zn were applied directly to rice crop as basal application and the residual response of lentil was ascertained in the rice–lentil cropping system. Powdery mildew disease index was prepared and it was noticed that plots treated with 40 kg sulfur + 5 kg Zn had less powdery mildew disease index (5.5%). Significantly greater disease index (15.5%) was documented in the fields where both the nutrients were not applied. Maximum lentil seed yield (1147 kg ha^{-1}) was recorded with 30 kg residual S, whereas minimum seed yield (1015 Kg ha^{-1}) was noticed with no application of S in the previous crop in the cropping system.*

Keywords Cropping system, lentil, percent disease index, powdery mildew disease, residual sulfur, residual zinc, seed yield

Introduction

Pulses/grain legumes are a major source of vegetable protein for humans and an excellent source of feed and forage for livestock. Lentil (*Lens culunaris* L.) is not an exception and is the richest source of protein and carbohydrates among edible pulses and the second most important legume crop of the Indo-Gangetic Plains (IGP) in India (Singh, Meena, and Bharati 2011). Rice–lentil is a very important cropping system and second after the

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rice–wheat system in the Indo-Gangetic Plains. It has a major share of human diet and livestock feed. It is a primary constituent of native cropping sequences and can be used as an excellent soil fertility restorer (Ali et al. 2012; Reddy 2009; Ramakrishna, Gowda, and Johansen 2000). Use of minerals, especially sulfur (S), in plant disease management is widely used. The use of elemental S as dust and wettable powder is common. Nowadays, there is a need to establish and encourage the use of various manures and fertilizers to alleviate the paucity of all these mineral nutrients, especially zinc (Zn) and S. It is well established that Zn scarcity is the most extensive micronutrient disorder in rice-growing tracts in general and the lower track in particular. There is a need to increase usage of Zn along with other major nutrients to escalate the seed yield impressively (Singh and Singh 2008).

Lentil productivity is limited by several biophysical constraints. It experiences several diseases, which not only limits seed yield but also decreases its quality considerably. Important one are Ascochyta blight (*Ascochyta lentis*, Vassiljevki), anthracnose (*Colletotrichum truncatum*), Botrytis gray mold (*Botrytis cinerea* Pers. ex. Fr.), Fusarium root rot (*Fusarium* spp.), and Rhizoctonia root rot (*Rhizoctonia solani* Kühn) (Banniza et al. 2004; Bayaa and Erskine 1998; Morrall et al. 1972; Khare 1981). Lentil powdery mildew (*Erysiphe trifolii*) is reported across the world, including parts of Asia to South America, the Middle East, the Mediterranean region, East Africa, Eastern Europe, Russia, and more intermittently in North America (Agrawal and Prasad 1997). Although powdery mildew (*Erysiphe trifolii*) is still not considered as a major disease, it could be a serious limitation to some of the susceptible strains of lentil in parts of the globe, especially in India during the months of January and February (Anonymous 2002; Agrawal and Prasad 1997).

Powdery mildew disease is an obnoxious disease problem and poses a great threat for lentil production. It is now increasingly realized that powdery mildew disease is going to be a major limiting factor for diminishing area and production of lentil (Chitale, Tyagi, and Bhatnagar 1981; Beniwal et al. 1993). Powdery mildew (*Erysiphe trifolii*) is an important foliar fungal disease of lentil crop affecting all the aboveground parts of the plant including leaves, stems, and pods. The infected leaves drop down, leaving only terminal leaves on the stems and thereby severely affecting the assimilation of photosynthates, which leads to reduction in crop yield and quality of seed. It is worldwide pathogen of legumes, including pea and lentil (Attanayake et al. 2009).

At the start of disease, tiny spots of a fine powdery and white growth containing conidia and mycelium appear. These small spots spread rapidly and cover the whole surface of leaves, stems and pods in a very quick time (Bayaa and Erskine 1998; Beniwal et al. 1993). Later on, the leaflets become dry and curled, and under severe attack leaves shed prematurely. This condition not only causes significant decrease in seed harvest but also in its seed quality. Further, seeds harvested from infected plants and fields remain unable to attain normal size and remain small and shrivelled (Beniwal et al. 1993; Pande, Sharma, and Rao 2008). Recent indications demonstrated that *E. trifolii* also infects lentil. The anamorph stage is by and large responsible for spread of the disease; however, Chitale, Tyagi, and Bhatnagar (1981) reported that the teleomorph stage occurs especially in India and Sudan. Prevailing atmospheric and weather conditions are important and play a great role in its initiation and rapid spreading. Airborne spores were produced by powdery mildew fungi. The most favorable agroclimatic conditions are when the ambient temperature is moderate with high relatively humidity ($>50\%$). Further, a little high temperature coupled with modest relative humidity also favors the disease development (Pande, Sharma, and Rao 2008; Saxena and Khare 1998; Wicks, Hitch, and Emmett 2007). Powdery mildew (*Erysiphe* *trifolii*) fungal contamination happens when active spores come into contact with plant surfaces and germinate. The fungus pierces the surface (epidermal) cell wall. Cell wall firmness and intercellular space play crucial roles as the first line of resistance of the plant to reject the entry of the pathogen (Bayaa and Erskine 1998; Kaiser et al. 2000; Pande, Sharma, and Rao 2008).

Mineral nutrients are very important to develop strong cell walls and other tissues, which increase plants' resistence to these foreigner objects (Datnoff, Elmer, and Huber 2006; Bayaa and Erskine 1998). Spore germination is encouraged when compounds ooze out from the plant system. The quantity and constituent of the plant oozing is regulated through plant nourishment. Deficiency of these nutrients diminishes the quantity and superiority of the antifungal compounds of the plant system during the course and place of infection (Graham and Webb 1991). Under the circumstances of low levels of S and Zn nutrients in the plant system, the oozing compounds contain substances with greater amounts of sugars and amino acids. These substances not only encourage but also provide a favorable environment for the easier establishment of the fungus. Tikoo et al. (2005) reported that now powdery-mildew-resistant lentil genotypes are available. Because seed replacement rate is very limited in this part of globe, sustainable agronomic management practices could be one of the best alternatives for successful lentil production (Singh, Meena, and Bharati 2011).

Sulfur-containing fungicides are recommended as a foliar spray. Beniwal et al. (1993) reported that chemicals such as benomyl, tridemorph, aqueous S, karathane (dinocap), calixin, or sulfex (ferrous bisulfide) can be used as safe fungicides; however, some insecticides (quinalphos, tnazophos, phoxim) can also be used as alternatives and should be applied on foliage at 10- to 15-day intervals, which prove effective in suppressing powdery mildew growth in the lentil crop. It is argued that S suppresses pathogen existence by altering the abiotic environment as well as by modifying the biological environment, whereas S compounds present in root exudates and metabolites from residue decomposition affect pathogen virulence, plant resistance, and biological control. Sulfur can also be utilized to balance other nutrients and make the circumstances less encouraging for the disease-causing pathogen (Huber 2001). Information pertaining to the exact association of Zn nutrition with powdery mildew pathogen is diverse. Zinc is unswervingly lethal to many disease-causing agents/organisms. However, at the same time, there is lack of sufficient information to describe in what way Zn overpowers biotic stress, especially disease. Zinc is an essential constituent in certain compounds commonly used by bacteria and fungi. It is deadly to several disease-causing fungi (Graham and Webb 1991). Deficiency of Zn nutrition in the soil laid the foundation for the outflow of sugars on the leaves surface, which amplifies the severity of powdery mildew infections (Huber and Graham 1999; Graham and Webb 1991). However, application of Zn potentially can decrease the ruthlessness of such pathogens, obviously, because it is indispensable to the constancy of cell membranes. It is believed that Zn plays a crucial role in preventing outflow of necessary components from cell sap of the plant (Datnoff, Elmer, and Huber 2006; Huber and Graham 1999).

Though the interactions of mineral nutrition with disease are by and large based on events relatively closely associated with each other, these are (i) effects of nutrition on incidence or severity of a particular disease, (ii) differences in the mineral concentrations in healthy plants as compared to diseased plants, and (iii) circumstances influence the accessibility of a particular mineral nutrient with particular disease. These events can normally coexist for a specific mineral nutrient and disease interface. However, outcome of these interactions may differ based on agroclimatic situation, growth, stage of plant, and biological activity (Huber and Haneklaus 2007). Limited information is available on the influence of S and Zn nutrition on dynamics of powdery mildew (*Erysiphe trifolii*) disease of lentil. However, emphasis has been put forth for efficient and sustainable management of powdery mildew of lentil with the inclusion of agronomic, cultural, nutritional, and chemical aspects as well. In the light of significance of powdery mildew disease of lentil crop production in the Indo-Gangetic plains, the roles of residual S and Zn were ascertained to know the magnitude of powdery mildew disease management, if any.

Materials and Methods

Experimental Details and Treatments

A field trial was planned and executed from 2008–2009 to 2010–2011 at the research farm of the ICAR Research Complex for Eastern Region, Patna, India, in a complete randomized block design (CRBD) with three replications. The objective of this experimentation was to know the extent and pattern of effectiveness of residual S and Zn on powdery mildew of lentil grown in the eastern Indo-Gangetic Plains of India, mainly confined to Eastern Uttar Pradesh and Bihar, in rice–lentil cropping sequences.

Experimental Sites

The physical and chemical properties of experimental field were ascertained. Soil texture was classified as silty clay loam. Soil reaction was neutral with mean pH value of 6.8. Inherent soil fertility status was also analysed, and organic carbon content was 0.68%. Nutrient status was calculated on a hectare basis. In the case of major nutrients, nitrogen (N), phosphorus (P), and potassium (K), it was noticed that available N was 244.7 kg, whereas available P stood at 28.6 kg, and exchangeable K was 185.8 kg. Similarly, the status of S and Zn was 8.3 kg and 0.8 kg. The individual experimental plot size was kept at 10.0 × 5.0 m for this study. The surface soil up to 30 cm deep was sampled and collected from the experimental field, air dried, mixed, and passed through 2-mm sieves, and analyzed for various physical and chemical properties.

Treatments

Four levels of S [S_1 (0 kg), S_2 (20 kg), S_3 (30 kg), and S_4 (40 kg)] and four levels of Zn [Zn_1 (0 kg), Zn_2 (4 kg), Zn_3 (5 kg), and Zn_4 (6 kg)] were applied in combination to rice crop and their residual effect on lentil was investigated.

Crop Management

Based on the actual rice–lentil cropping system, the lentil crop was sown just after harvest of preceding rice. Long-duration genotype Swarna Mansoori MTU-7029 was chosen for rice crop and transplanted on 15 July during the rainy seasons and harvested during last week of November in both years. Seedbed with medium tilth was prepared every year of lentil sowing. Sowing of lentil was performed on 10 December during both occasions. Seeds were sown at 3 cm deep in rows set 30-cm apart. Nutrients, particularly N, P, K, S, and Zn, were applied as basal doses. Other agronomic management practices were done as per recommended practices and were similar for all the treatments. Hand weeding 3 weeks after sowing was performed once to maintain the optimum plant population. Watering was done twice, at preflowering stage and postpodding stage. Plant protection measures were taken care to manage the biotic stress, if any.

Biometrical Observation and Data Recording

Biometrical data were recorded for plant height (cm), productive branch plant^{-1}, pod plant^{-1}, pod length (cm), grains pod$^{-1,}$ seed yield (g plant^{-1}), lentil seed yield (kg ha^{-1}), and 1000-seed weight (g), which was estimated based on seed weight per plot adjusted to 12% moisture.

Disease Assessment

Plants were carefully examined and powdery mildew disease severity was recorded from upper, middle, and lower leaves on the basis of leaf area covered by the infection. To quantify disease severity, disease intensity was calculated following a 0–5 scale (Mayee and Datar 1998; Townsend and Heuberger 1943) with slight modifications (Table 1). Ten representative plants were randomly selected from every plot and disease intensity rating was carried out accordingly.

The intensity of powdery mildew disease in all plots were measured by the formula as employed by Wheeler (1969):

$$\text{Per cent disease index} = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves observed} \times \text{Maximum rating}} \times 100$$

Statistical Analysis

Comparison of different responses of residual S and Zn nutrition on powdery mildew disease index (%) in lentil and seed yield was carried out using two-way analysis of variance (ANOVA) techniques (Steel and Torrie 1980). The statistical model considered was $y_{ijk} = \mu + \rho_i + \alpha_j + \beta_k + (\alpha\beta)_{jk} + \varepsilon_{ijk}$ where yijk is the response of a particular trait (i.e., powdery mildew disease index), seed yield of lentil in the ith replica with jth level of S and kth level of Zn, μ is the general response, ρi is the ith replica effect, αj is the effect of jth level of S, βk is the effect of kth level of Zn, $(\alpha\beta)$jk is the interaction effect, and εijk is the error term of the model assumed to be normally and independently distributed with zero mean and constant variance σ2. The least significant differences (LSD) at the 5% level of

Table 1
Disease rating scale

No.	Description	Numerical rating (scale)
1.	No visual infection area/ symptoms on leaf	0
2.	1–5% leaf area affected	1
3.	6–20% leaf area affected	2
4.	21–40% leaf area affected	3
5.	41–70% leaf area affected	4
6.	71–100% leaf area affected	5

significance were obtained where the null hypothesis for the factor effect (S, Zn, and their interaction) is rejected (Gomez and Gomez 1984).

The association among plant characteristics of lentil were identified using product moment correlation (ρ) and its significance was identified at 5% level from the correlation table given by Snedicor and Cochran (1967).

Results

Lentil is an important component in vegetarian diets to supplement protein and the second most important legume crop in the Indo-Gangetic Plains, where it is mainly grown under unfavorable conditions. It is being attacked by several disease and pests including powdery mildew. During experimentation, residual impacts of S and Zn, which was directly applied to rice, were observed on the dynamics of powdery mildew disease (Graham and Webb 1991; Datnoff, Elmer, and Huber 2006; Huber and Graham 1999; Vishwa, Singh, and Gurha 2004). Disease scoring was carried out during all 3 years, and for the sake of convenience pooled data analysis was performed and presented in table form. Integration of all possible mechanisms to manage powdery mildew of lentil is also advocated by researchers including Muehlbauer et al. (1995); Singh, Meena, and Bharati (2011), and Vishwa, Singh, and Gurha (2004).

Changes in Powdery Mildew of Lentil with Residual Sulfur and Zinc Nutrition

*Powdery Mildew (*Erysiphe trifolii*) Disease Tolerance.* Influence of residual S and Zn on the dynamic (extent and pattern) of powdery mildew of lentil is presented in Table 2 and Figure 1. Results indicated that residual S and Zn influence disease severity individually as well as in combination. Individually in the case of S it was observed that least (7.5%) and greatest (12.3%) incidences of powdery mildew were recorded with applications of S_4 (40 kg) and S_1 (0 kg), respectively (Huber 2001; Wicks, Hitch, and Emmett 2007). Similar results were also obtained while working on powdery mildew management on various crops by Beniwal et al. (1993), Huber (1991), Saxena and Khare (1998), Singh, Meena, and Bharati (2011), and Wicks, Hitch, and Emmett (2007). In the case of residual Zn treatments, it was noted that minimum (8.1%) and maximum (11.9%) incidence was recorded with the application of Zn_4 (6 kg) and Zn_1 (0 kg), respectively (Graham and Webb 1991; Singh, Meena, and Bharati 2011; Datnoff, Elmer, and Huber 2006; and Vishwa, Singh, and Gurha 2004). Data presented in Table 3 revealed that interaction effect of both nutrients was significantly effective in the reduction of powdery mildew disease severity. Corresponding least (5.5%) and most (15.5%) incidences were documented in the

Table 2
Response of residual sulfur and zinc nutrition on powdery mildew disease index (%) in lentil

Main effect S alone				Main effect Zn alone			
S1	S2	S3	S4	Zn1	Zn2	Zn3	Zn4
12.3	11.0	9.3	7.5	11.9	10.5	9.5	8.1
	LSD at 5% = 3.2				LSD at 5% = 3.2		

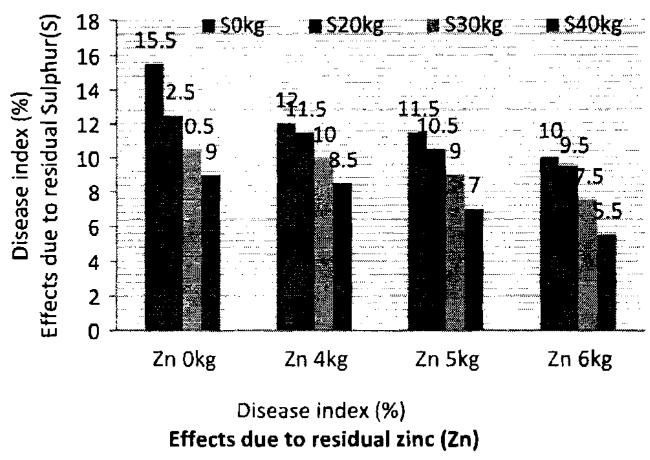

Figure 1. Response of powdery mildew in lentil affected by residual sulfur and zinc nutrition.

Table 3
Interaction effects of residual sulfur and zinc nutrition on powdery mildew disease index (%) in lentil

Treatment	S_1 (0 kg)	S_2 (20 kg)	S_3 (30 kg)	S_4 (40 kg)
Zn_1 (0 kg)	15.5	12.5	10.5	9.0
Zn_2 (4 kg)	12	11.5	10.0	8.5
Zn_3 (5 kg)	11.5	10.5	9.0	7.0
Zn_4 (6 kg)	10	9.5	7.5	5.5

LSD (±5%) S × Zn = 5.3

plots having (1) residual S (40 kg) and Zn (6 kg) and (2) S (0 kg) and Zn (0 kg), respectively (Datnoff, Elmer, and Huber 2006; Graham and Webb 1991; Huber and Haneklaus 2007).

Improving Lentil Performance. Results depicted in Table 4 indicated that there is significant residual response of both nutrients (S and Zn) in terms of growth, development, yield, and yield attributes of lentil crop. It was recorded that the plant height of lentil was significantly influenced by different levels of residual S and Zn. At harvest maximum plant height (42.2 cm) and corresponding minimum (32.8 cm) were recorded with 0 kg and 40 kg residual S (Table 4). Number of productive branches per plant is one of the primary yield-contributing traits of lentil crop. Results revealed that productive branches also influenced positively with both the tested nutrients (Beniwal et al. 1993; Singh and Singh 2008; Singh, Meena, and Bharati 2011; Tikoo et al. 2005). Minimum (13.9) productive branches per plant have been recorded in the plots with no application of Zn in previous rice crop, whereas maximum (16.3) was obtained in case of 30 kg residual S. Similarly, maximum (63.8) pod plant^{-1} was obtained with 40 kg residual S and corresponding minimum (45.9) was obtained with no application of Zn. Dry matter, or aboveground biomass, also is influenced significantly with the residual effects of both applied nutrients. Similar results were also obtained by other workers on the same crop, while working at their respective places (Kaiser et al. 2000; Muehlbauer et al. 1995; Singh and Singh 2008). Maximum

Table 4

Response of residual sulfur and zinc nutrition on growth and yield of lentil

Treatment	S_1 (0 kg)	S_2 (20 kg)	S_3 (30 kg)	S_4 (40 kg)	Zn_1 (0 kg)	Zn_2 (4 kg)	Zn_3 (5 kg)	Zn_4 (6 kg)	LSD (±5%)
Plant height (cm)	32.8	38.7	39.8	42.2	34.7	38.8	40.7	39.5	2.8
Branches/plant	14.4	15.9	16.3	16.2	13.9	14.7	15.4	16.1	1.9
Pod/plant	45.9	54.2	58	63.8	47.9	53.2	59.3	62.9	8.6
Biomass (kg/ha)	2537.5	2825.6	2902.6	2942.1	2723.7	2833.3	2800.0	2637.5	87.5
Seed yield (kg/ha)	1015	1102	1132	1118	1035	1105	1120	1108	35.2
Harvest index	0.40	0.39	0.39	0.38	0.38	0.39	0.40	0.41	NS
1000 grain wt (g)	24.7	24.7	24.8	25.0	24.7	24.7	24.9	24.9	NS

(2942.1 kg ha^{-1}) and minimum biomass yield (2537.5 kg ha^{-1}) was noted with the 40 kg and 0 kg ha^{-1} residual S application (Table 4). The greatest lentil seed yield (1147 kg ha^{-1}) was recorded with 30 kg residual S, whereas lowest yield (1015 Kg ha^{-1}) was noticed with no residual/application of S (Table 5). Interaction effects of both the nutrients on lentil seed yield (Table 6) clearly show that the greatest seed yield (1243 kg ha^{-1}) was noticed with collective dose of 30 kg S and 6 kg Zn, However, the lowest lentil seed output (960 kg ha^{-1}) was obtained in the case of no application of treatments (Table 7). Thousand-grain weight (g) was not influenced by of the levels of treatments because of its genetic character and in general was not influenced by management practices. Harvest index was also not influenced by any of the given treatments. This can be due to the nature of characteristics closely associated with heredity of the crop (Singh and Singh 2008; Singh, Meena, and Bharati 2011; and Tikoo et al. 2005). Under Indo-Gangetic conditions of Bihar, application of S + Zn at 40 kg and 5 kg per hectare is most ideal, not only for a rice–lentil cropping system, but also because it provides better agronomical option to manage powdery mildew incidence in lentil (Beniwal et al. 1993; Huber 1980; Huber and Haneklaus 2007; Singh and Singh 2008; Singh, Meena, and Bharati 2011; Tikoo et al. 2005).

A correlation study was also carried out to establish the relationship among the parameters recorded during the experimentation. Data presented in Table 6 show that performance of lentil in terms of seed yield is significantly correlated with the plant height, branches per plant, pods per plant, and biomass. Similarly, biomass is significantly correlated with plant height. Pods per plant was significantly correlated with plant height branch per plant and 1000-grain weight. The association of branch per plant with plant height and pods per plant was also observed. Thousand-grain weight showed significant correlation

Table 5
Response of residual sulfur and zinc nutrition on seed yield (kg/ha) of lentil

Main effect S alone				Main effect Zn alone			
S1	S2	S3	S4	Zn1	Zn2	Zn3	Zn4
1015	1102	1132	1118	1035	1105	1120	1108
	LSD at 5% = 35.2				LSD at 5% = 35.2		

Table 6
Correlation coefficient of different parameters associated with lentil performance

Parameter	Plant height (cm)	Branches/plant	Pod/plant	Biomass	Seed yield	Harvest index	1000-grain wt
Plant height (cm)	1.000	0.801*	0.925*	0.769*	0.951*	−0.053	0.751*
Branches/plant	0.801*	1.000	0.855*	0.517	0.824*	0.176	0.650
Pod/plant	0.925*	0.855*	1.000	0.523	0.852*	0.168	0.886*
Biomass	0.769*	0.517	0.523	1.000	0.751*	−0.615	0.354
Seed yield	0.951*	0.824*	0.852*	0.751*	1.000	0.046	0.579
Harvest index	−0.053	0.176	0.168	−0.615	0.046	1.000	0.115
1000-grain wt	0.751*	0.650	0.886*	0.354	0.579	0.115	1.000

*Significant at the level of 5%.

Table 7
Interaction effects of residual sulfur and zinc nutrition on on lentil seed yield (kg/ha)

Treatment	S_1 (0 kg)	S_2 (20 kg)	S_3 (30 kg)	S_4 (40 kg)
Zn_1 (0 kg)	960	1003	1073	1103
Zn_2 (4 kg)	1038	1138	1118	1125
Zn_3 (5 kg)	1070	1125	1153	1131
Zn_4 (6 kg)	992	1143	1183	1112
LSD (±5%) S × Zn = 69.3				

with plant height and pods per plant. Plant height was closely associated with all the parameters except harvest index. A nonsignificant correlation was established with harvest index and grain yield.

Discussion

Efficient management of S and Zn to manage disease and boost crop resistance is crucial, as greater S and Zn rates not only improve powdery mildew management of lentil but also its production and productivity, which prove the roles of S and Zn in nutrient and disease interactions as well (Graham and Webb 1991). Although the interaction of mineral nutrition with disease are by and large based on events that are relatively closely associated with each other, these are (i) effects of nutrition on incidence or severity of a particular diseases, (ii) differences in the mineral concentrations in healthy plants as compared to diseased plants, and (iii) circumstances influence the accessibility of a particular mineral nutrient with particular disease (Ali et al. 2012; Kaiser et al. 2000; Beniwal et al. 1993). Based on this discussion, it seems that residual influences of S and Zn have crucial and positive effects on lentil powdery mildew disease management. Twofold remuneration was realized with regards to improvement in lentil seed production as well as improved disease resistance due to supplementation of both the nutrients.

Balanced nutrition management plays a significant part in defining plant resistance power or weakness to biotic stress, especially diseases. Marked effects of micronutrients on the performance and associated traits/parameters were also established by correlation study. A highly nutrient-starved plant is in general more vulnerable to disease as compared to optimally fertilized plants (Huber 1980; Huber and Haneklaus 2007; Datnoff, Elmer, and Huber 2006; Tikoo et al. 2005).

Micronutrients are directly involved in physiological and biochemical activities of plant defenses including several cell components, enzymes, activators or inhibitors, and regulators of metabolism (Huber and Haneklaus 2007; Tikoo et al. 2005). The intricate relationship between nutritional status of plant and pathogens is dynamic and its understanding provides a basis for reducing the severity of most diseases in intense as well as integrated crop production systems. Hence, it was concluded that application of S and Zn alone as well as in combination improved lentil productivity and also minimized the powdery mildew incidence in lentil. Soil fertility status was also improved due to balanced nutrition.

It appears that the greater reward than before can be achieved through foliar feeding due to more efficient and direct contact to the sheet of reaction (Pande, Sharma, and

Rao 2008; Graham and Webb 1991; Singh, Meena, and Bharati 2011). These events can normally be coexisting for a specific mineral nutrient and disease interface. However, the outcome of these interactions may differ based on agroclimatic situation, growth, stage of plant, and biological activity (Graham and Webb 1991; Huber and Haneklaus 2007). Sulfur and Zn are unswervingly lethal to many disease-causing agents and organisms; it is only because of this fact that S and Zn are active constituents in a particular fungicide. Foregoing arguments confirm the direct and deadly effects of S and Zn on several pathogens including powdery mildew (*Erysiphe trifolii*) (Datnoff, Elmer, and Huber 2006; Graham and Webb 1991).

In conclusion, application of 40 kg S in combination with 5 kg Zn to the previous rice crop is most ideal, not only for rice–lentil system productivity but also to provide better agronomical options to manage powdery mildew disease in lentil and some important diseases of rice as well.

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