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Article *in* Plant Pathology Journal · June 2013

DOI: 10.3923/ppj.2013.71.77

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Plant Pathology Journal, 2013
ISSN 1812-5387 / DOI: 10.3923/ppj.2013.

Dynamics of Powdery Mildew (*Erysiphe trifolii*) Disease of Lentil Influenced by Sulphur and Zinc Nutrition

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Abstract: Lentil is one of the major sources of protein for vegetarian population and the second most important legume crops of Indo-Gangetic Plain (IGP) in India. Powdery mildew (*Erysiphe trifolii*) is one of the important fungal disease of lentil grossly affect foliage as well as in severe cases stems and pods also and causes reduction in crop yield and quality of seed. Mineral nutrition especially sulphurs to the great extent and moderately to zinc, plays a very important role in powdery mildew management. A field experiment was conducted at ICAR Research Complex of Eastern Region Patna during 2008-09 to 2010-11 to ascertain the role of sulphur and zinc in rice-lentil cropping system. Four levels of sulphur and zinc (Sixteen treatments combination) were tested in randomized block design replicated thrice. Both the nutrients were applied to rice and residual response was ascertained to rice and lentil in sequence. Least (5.5%) disease index was recorded in the plots received residual sulphur 40 kg and Zn 5 kg per ha. Whereas highest disease index (15.5%) was recorded in the plots having no residual sulphur and zinc. Maximum lentil seed yield (1147 kg ha^{-1}) was recorded with 30 kg residual sulphur whereas minimum seed yield (1015 kg ha^{-1}) was noticed with no application of sulphur in the previous crop in cropping system. Application of 40 kg sulphur in combination with 6 kg zinc to the previous rice crop is most ideal; not only for rice-lentil system productivity, but it also provide better agronomical option to manage powdery mildew disease in lentil. Efficient management of these nutrients to manage disease and to boost crop resistance is crucial as higher sulphur and Zn rates not only improve powdery mildew management of lentil but its production and productivity, which proves the roles of sulphur and Zn in nutrient and disease interactions as well.

Key words: Cropping system, lentil, per cent disease index, powdery mildew disease, seed yield, sulphur, zinc

INTRODUCTION

Pulses/grain legumes are major crops are sources of vegetable protein for human and proves an excellent source of feed and forage for livestock hence, it is vital for life of human kind. Lentil is not an exception and is richest source of protein and carbohydrate among edible pulses and the second most important legume crops of Indo-Gangetic Plain (IGP) in India (Singh *et al*., 2011). Rice-lentil is very important cropping system and second after rice-wheat system in the Indo-Gangetic Plain. It has major contribution to human and animal nutrition as components of indigenous cropping systems and as restorers of soil fertility (Ali *et al*., 2012; Reddy, 2009; Ramakrishna *et al*., 2000). Use of minerals especially sulphur in plant disease management is doubtlessly the older one. The use of elemental sulphur as dust and wettable power are common. There is a need to ascertain and promote the uses of types of fertilizers required to correct the deficiency of all these nutrients especially zinc and sulphur. Zn deficiency is the most widespread micronutrient disorder in lowland rice and application of Zn along with NPK fertilizer increases the grain yield significantly in most cases (Singh and Singh, 2008). Lentil productivity is limited by several biophysical constraints. It experiences several biotic stresses which limit yield considerably, including *Ascochyta* blight (caused by *Ascochyta lentis*, Vassiljevki), anthracnose (*Colletotrichum truncatum*), *Botrytis* gray mold (caused by *Botrytis cinerea* Pers. ex. Fr.), *Fusarium* root rot (caused by several *Fusarium* spp.) and Rhizoctonia root rot (caused by *Rhizoctonia solani* Kühn) (Banniza *et al*., 2004; Bayaa and Erskine, 1998;Morrall *et al*., 1972; Khare, 1981).

Powdery mildew of lentil has been reported from various parts of the world including South Asia, the Middle East, the Mediterranean, East Africa, Eastern Europe, the former USSR, South America and more sporadically, from North America (Agrawal and Prasad, 1997). Although usually a minor disease, it can be

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severe on certain lentil cultivars and in some parts of the world, particularly in India during January and February (Anonymous, 2002; Agrawal and Prasad, 1997).

It is being continuously noticed that powdery mildew disease is an obnoxious disease problem and posing a great threat for lentil production. It is now increasingly realised that powdery mildew disease is going to major limiting factor for diminishing area and production of lentil largely due to sever attack of powdery mildew (Chitale *et al*., 1981; Beniwal *et al*., 1993). Powdery mildew (*Erysiphe trifolii*) is an important foliar fungal disease of lentil crop affect all the above ground part of the plant including leaves, stems and pods. The infected leaves are dropped 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 distributed 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 are appears. 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; Pande *et al*., 2008; Taylor *et al*., 2007). Later on, the leaflets become dry and curled and under sever attack leaves are bound to shed prematurely. This condition not only causes significant decrease in seed harvest but its seed quality also. Further, seeds harvested from infected plants/field remain unable to attend its normal size and remain small and shrivelled (Beniwal *et al*., 1993; Kaiser *et al*., 2000; Pande *et al*., 2008). Recent indication demonstrated that *E. trifolii* also infects lentil. The anamorph stage is by and large responsible for spread of the disease; however, Chitale *et al*. (1981) reported that the teleomorph stage occurs especially in India and Sudan.

Prevailing atmospheric/weather condition is very much important and plays a great role in its initiation and rapid spreads. Powdery mildew fungi produce airborne spores and infect plants when temperatures are moderate It prefers high humidity; above 50% to thrive. Slightly high temperatures and modest relative humidity do favour the disease development (Pande *et al*., 2008; Saxena and Khare, 1998; Wicks *et al*., 2007).

Powdery mildew causing fungal (*Erysiphe trifolii*) infection occurs as its spores germinate on plant surfaces. Fungus should pierce the surface (epidermal) cell wall. The power and firmness of the cell walls and intercellular spaces is the first line of defence of plant to deny the entry of pathogen into plant system (Bayaa and Erskine, 1998; Kaiser *et al*., 2000; Pande *et al*., 2008). Mineral nutrients take foremost responsibility to develop strong cell walls and other tissue to upscale plants capability to these foreigner objects (Datnoff *et al*., 2006; Bayaa and Erskine, 1998). Spores germination is encouraged by compounds ooze out from the plants. The amount and composition of these plant exudates is regulated by the nourishment of the plant. Deficiency of main nutrients diminishes the quantity and superiority of the plants natural antifungal compounds at the site of infection (Graham and Webb, 1991). When plants have low levels of S and Zn nutrients, these exudates will contain higher amounts of compounds such as sugars and amino acids that promote the establishment of the fungus.

Tikoo *et al*. (2005), reported that now powdery mildew resistant lentil genotypes are available and one can chose from them. Since seed replacement rate is very limited in this part of globe, sustainable agronomic management practice could be one of the best alternatives for successful lentil production (Singh *et al*., 2011).

Sulphur containing fungicides are recommended as a foliar spray. Beniwal *et al*. (1993) reported that chemicals viz., benomyl, tridemorph, aqueous sulfur, karathane (dinocap), calixin or sulfex (ferrous bisulfide) can be used as safe fungicides, however some insecticides (Quinalphos, Tnazophos, Phoxim) can also be used as alternative to above and should be applied on foliage at 10-15 days interval, will proves effective in suppressing powdery mildew growth in lentil crop.

As it is well advocated that sulphur reduced pathogen virulence or survival by changing the abiotic environment well as by modification in the biological environment, whereas sulphur compound present in root exudates and metabolites from residue decomposition affect pathogen virulence, plant resistance and biological control. Sulphur can also be utilizes to balance other nutrients and make the circumstances less encouraging for the disease causing pathogen (Huber, 2001).

Information pertaining to the exact association of zinc nutrition with powdery mildew pathogen is diverse. Zinc is unswervingly lethal to many disease causing agents/organisms. However, at the same time modest sources put forward that there is no understandable evidence to explain how Zn suppresses diseases. However the fact is that zinc is an active constituent in some fungicides. It is confirmation that it is straight deadly to several pathogens (Graham and Webb, 1991). Deficiency of zinc nutrition in the soil laid foundation for the outflow of sugars on the leaves surface leads to amplify the severity of powdery mildew infections (Huber and Graham, 1999). However, Zinc applications can reduce the severity of such pathogens, because it is (Zn) is essential to the integrity and stability of plant membranes and it is thought to help prevent "leakage" of essential elements or compounds from plant cells (Datnoff *et al.*, 2006; Huber and Graham, 1999).

Though the interaction of mineral nutrition with disease are by and large based on events which 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 (iii) Circumstances influence the accessibility of a particular mineral nutrient with particular disease. Above mentioned events can normally be coexisting 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 sulphur and zinc 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 as well keeping in the view of the importance of powdery mildew disease in lentil crop production in the Indo-Gangetic plains, the role of sulphur and zinc minerals was also ascertain to know the magnitude of powdery mildew disease management if any.

MATERIALS AND METHODS

A field experiment was conducted at ICAR Research Complex for Eastern Region Patna during 2008-09 to 2010-11 in Randomized Block Design (RBD) replicated thrice to evolve suitable nutrient management strategy with respect to one secondary nutrient (sulphur) and one micro nutrient (zinc) under rice - lentil cropping system for Indo- Gangetic plains of Bihar (India).

Experimental sits: The texture of soil of experimental field was silty clay loam with mean pH value of 6.8, organic carbon 0.68%, with available nitrogen 244.7 kg ha^{-1}, available phosphorus 28.6 kg ha^{-1}, available potash 185.8 kg ha^{-1}, sulphur 8.3 kg ha^{-1} and zinc 0.8 kg ha^{-1}. The plot size was 10.0×5.0 m. was kept under study. The surface soil up to 30 cm depth were sampled and collected from the experimental field, air dried, mixed and passed through 2 mm sieves and analyzed for various physical and chemical prosperities. The chemical and physical characteristic of soil at experimental sites is listed in Table 1.

Treatments combination of sulphur and zinc: Four level of sulphur S_1(0 kg), S_2(20 kg), S_3(30 kg), S_4(40 kg) and four level zinc Zn_1(0 kg), Zn_2(4 kg), Zn_3(5 kg), Zn_4(6 kg) were applied in combination to rice crop and their residual effect on lentil was investigated.

Crop management: Based on actual situation under rice -lentil cropping system, 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 15th July during rainy seasons and harvested during last week of November for both years. Seedbed with medium tilth was prepared every year lentil sowing. Sowing of lentil was performed on 10th of December during both occasions. Seeds were sown at 3 cm depth at 30 cm row distance. Nutrients particularly, nitrogen, phosphorus, potassium sulphur and zinc were applied as basal dose. 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.

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

Disease assessment: Till 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. In each plot ten plants were randomly selected and disease intensity was rated by following 0-5 scale (Mayee and Datar, 1986; Townsend and Heuberger, 1943) with slight modifications which has been described here (Table 2).

The disease intensity in each plot was calculated by the formula as employed by Wheeler (1969):

Table 1: Soil characteristic of experimental site

Year	Sand (%)	Silt (%)	Clay (%)	Soil pH	Organic carbon (%)	Bulk density (m m^3)	Electrical conductivity (dS m^{-1})	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Exchangeable potassium (kg ha^{-1}) (ppm)	Sulphur (kg ha^{-1})	Zinc (kg ha^{-1})
Initial	26.4	42.6	31.0	6.8	0.68	1.47	0.21	244.7	28.6	185.8	8.3	0.8

Table 2: Disease rating scale

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

$$\text{Percent disease index} = \frac{\text{Sum of all numerical rating}}{\text{Total No. of leaves observed} \times \text{Maximum rating}} \times 100$$

Statistical analysis: Two-way analysis of variance (ANOVA) was performed for each trait for all three seasons and the combined (Pooled) analysis over seasons after testing error variance homogeneity was carried out according to the procedure Gomez and Gomez (1984), using the MSTATC version 2.1 (Michigan State University, USA) statistical package design. Significant differences between the treatments were compared with the critical difference at (±5%) probability by LSD.

RESULTS AND DISCUSSION

Lentil plays a vital role in vegetarian diet to supplement the protein and second important legume crops in Indo-Gangetic Plains mainly grown under unfavourable conditions. It is being attacked by several disease and pests including powdery mildew. During experimentation, residual impacts of sulphur and zinc which was directly applied to rice were observed on the dynamics of powdery mildew disease (Graham and Webb, 1991; Datnoff *et al*., 2006; Huber and Graham, 1999; Vishwa *et al*., 2004). Disease scoring was carried out during all the three years and for sake of convenient pooled data were performed and presented in table farm, discussed under suitable subheads as under. Integration of all possible mechanism to manage powdery mildew of lentil is also advocated by several workers (Muehlbauer *et al*., 1995; Singh *et al*., 2011; Vishwa *et al*., 2004).

Effects of sulphur and zinc on powdery mildew of lentil: Influence of residual sulphur and zinc on the dynamic (extent and pattern) of powdery mildew of lentil was recorded and presented in Table 3 and Fig. 1. Results indicated that residual sulphur and zinc influence disease severity individually as well as in combination both. Individually in case of sulphur it was observed that lowest (7.5%) and highest (12.3%) incidence of powdery mildew was recorded with application of S_4(40 kg) and S_1(0 kg) respectively (Huber, 2001; Wicks *et al*., 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 *et al*. (2011) and Wicks *et al*. (2007). Similarly in case of residual zinc nutrition it was noticed 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 *et al*., 2011; Datnoff *et al*., 2006;; Vishwa *et al*., 2004). Interaction effect of both the nutrient was found effective in the reduction of powdery mildew disease severity significantly. Corresponding least (5.5%) and most (15.5%) incidence was recorded in the plots having residual sulphur (40 kg) and zinc (6 kg) and (0 kg) and zinc (0 kg) respectively (Datnoff *et al*., 2006; Graham and Webb, 1991; Huber and Haneklaus, 2007).

Table 3: Effect of sulphur and zinc nutrition on Powdery mildew disease index (%) in lentil

	Mean effects 3.2		Interaction (5.3)		
Treatments	Zn_1 (0 kg)	Zn_2 (4 kg)	Zn_3 (5 kg)	Zn_4 (6 kg)	Mean of S
CD (±5%)					
S_1(0 kg)	15.5	12.0	11.5	10.0	12.3
S_2(20 kg)	12.5	11.5	10.5	9.5	11.0
S_3(30 kg)	10.5	10.0	9.0	7.5	9.3
S_4(40 kg)	9.0	8.5	7.0	5.5	7.5
Mean of Zn	11.9	10.5	9.5	8.1	

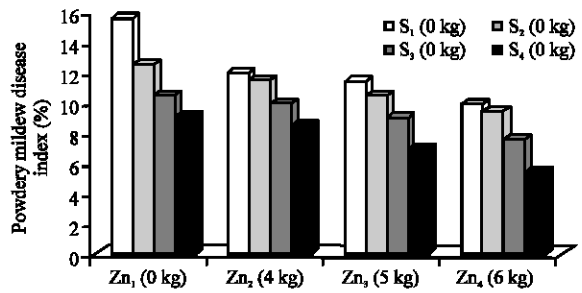

Fig. 1: Effect of sulphur and zinc nutrition on powdery mildew disease index (%) in lentil

Effects of sulphur and zinc on lentil performance: Perusal of data presented in Table 4 revealed 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) was recorded with of 0 kg and 40 kg residual sulphur (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 *et al*., 2011; Tikoo *et al*., 2005). Minimum (13.9 Nos.) productive branches per plant have been recorded in the plots with no application of zinc in

Table 4: Effect of sulphur and zinc nutrition on growth, yield attributes and yield of lentil during (pooled of three years)

Treatments	Plant Height (cm)	Branches/plant	Pod/plant	Biomass (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest Index	1000 grain wt (g)
S_1 (0 kg)	32.8	14.4	45.9	2537.5	1015	0.40	24.7
S_2 (20 kg)	38.7	15.9	54.2	2825.6	1102	0.39	24.7
S_3 (30 kg)	39.8	16.3	58.0	2902.6	1132	0.39	24.8
S_4 (40 kg)	42.2	16.2	63.8	2942.1	1118	0.38	25.0
Zn_1 (0 kg)	34.7	13.9	47.9	2723.7	1035	0.38	24.7
Zn_2 (4 kg)	38.8	14.7	53.2	2833.3	1105	0.39	24.7
Zn_3 (5 kg)	40.7	15.4	59.3	2800.0	1120	0.40	24.9
Zn_4 (6 kg)	39.5	16.1	62.9	2637.5	1108	0.40	24.9
CD (±5%)	2.8	1.9	8.6	87.5	35.2	NS	NS

Table 5: Effect of sulphur and zinc application on seed yield (kg ha^{-1}) yield of lentil

	Mean effects 35.2		Interaction (69.3)		
Treatments	S_1 (0 kg)	S_2 (20 kg)	S_3 (30 kg)	S_4 (40 kg)	Mean of Zn
CD (±5%)					
Zn_1(0 kg)	960	1003	1073	1103	1035
Zn_2(4 kg)	1038	1138	1118	1125	1105
Zn_3(5 kg)	1070	1125	1153	1131	1120
Zn_4(6 kg)	992	1143	1183	1112	1108
Mean of S	1015	1102	1132	1118	

previous rice crop whereas maximum (16.3) was obtained in case of 30 kg residual sulphur. Similarly, maximum (63.8) pod/plant was recorded in plots fertilized with 40 kg residual sulphur and minimum (45.9) with no application of zinc. Total above ground biomass was also gets influenced significantly with the residual effects of both applied nutrient. 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 (2942.1 kg ha^{-1}) and minimum biomass yield (2537.5 kg ha^{-1}) was recorded with the plot previously fertilized with 40 kg and 0 kg sulphur ha^{-1} (Table 4). Highest lentil seed yield (1147 kg ha^{-1}) was recorded with 30 kg residual sulphur whereas lowest yield (1015 kg ha^{-1}) was noticed with no residual/application of sulphur. Perusal of interaction effects of both the nutrient on lentil seed yield (Table 5) results clearly shows that highest seed yield (1243 kg ha^{-1}) was recorded with combined application of 30 kg sulphur and 6 kg zinc whereas corresponding lowest lentil seed yield (960 kg ha^{-1}) was recorded in control plots. 1000-Grain weight (g) was not influenced by of the levels of treatments as it is genetic characters and in general not influenced by management practices. 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 and Singh, 2008; Singh *et al*., 2011; Tikoo *et al*., 2005).

Balanced nutrition management has an important role in determining plant resistance or susceptibility to diseases. A severely nutrient stressed plant is often more susceptible to disease than plant at optimum nutritions (Huber, 1980; Huber and Haneklaus, 2007; Datnoff *et al*., 2006; Tikoo *et al*., 2005). Micronutrients/mineral elements are directly involved in all mechanism of plant defences such as integral component of cells, enzymes, activators or inhibitors and regulators of metabolism. The intricate relationship between nutritional status of plant and pathogens is dynamic and its understanding provides a basis for reducing severity of most diseases in intense as well as integrated crop production systems. Hence, it was concluded that application of sulphur and zinc alone as well as in combination improves lentil productivity and also minimized the powdery mildew incidence in lentil. Soil fertility status was also improved due to balanced nutrition. Under Indo-Gangetic condition of Bihar, combined application of 40 kg sulphur and 6 kg zinc is most ideal, not only for rice-lentil cropping system, but it provide better agronomical option to manage powdery mildew incidence in lentil also (Beniwal *et al*., 1993; Huber, 1980; Huber and Haneklaus, 2007; Singh and Singh, 2008; Singh *et al*., 2011; Tikoo *et al*., 2005).

It is now clear that plant nutrition sulphur and zinc has a crucial effect on powdery mildew disease management of lentil. The twofold remuneration of fertiliser applications with regards to improvement in production as well as improved disease resistance has been being realized. 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.

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