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Full Length Research Paper

Significance of Zinc fertilizer utilization on the occurrence of rice stem borers (*Scirpophaga* species) (Lepidoptera: Pyralidae) in rice (*Oryza sativa* L.) crop

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Use of fertilizer within plant protection system can prove a key factor for pest management strategy. The effects of Zinc sulfate (33% - Zn) fertilizer on the incidence of rice stem borers (*Scirpophaga* species) (Lepidoptera: Pyralidae) in rice crop were investigated. The Zn was applied using broadcast method at three levels (20, 25 and 30 kg/ha) in the vicinity of the roots, 30 days after crop transplantation. The results of field experiment on rice cultivars Shadab and Mehak showed that Zn had significant influences on the stem borers population and paddy yield over the unfertilized control. Average yield per hectare was increased at all doses of Zn and by applying it at the rates of 20, 25 and 30 kg/ha, the differences in grain yield were not significant, but production increased significantly over the untreated crop due to varying pest prevalence. With respect to borers incidence, higher dose 30 kg Zn/ha markedly decreased infestation, while, applications at 20 and 25 kg permitted slightly more deadhearts and whiteheads incidence, but differed significantly from unfertilized control. The present study implies that due to suppressive effects of Zn fertilizer on the incidence of the rice stem borers at crop maturity stage increased grain yield, and the use of soil amendments strategy can create an unfavorable environment for pest inducing resistance through antibiosis or feeding inhibition.

Key words: Rice, *Oryza sativa, Scirpophaga,* insect control, rice stem borer, Zinc.

INTRODUCTION

Rice (*Oryza sativa* L.) is the main staple food of around half of the world's population. On a global basis, rice provides 21 and 15% per capita of dietary energy and protein, respectively (Maclean et al., 2002) . One of the main problems and yields limiting factors is the attack of different kinds of insect pests in the rice fields. Rice stem borers, *Scirpophaga incertulas* (Walker) and *Scirpophaga innotata* (Walker) infest the rice crop right from nursery till harvest and cause complete loss of affected tillers (Salim and Masih, 1987). The borers *S. incertulas* or *S. innotata* could attack most of the growing stages of rice plant, beginning with seedling through tillering and up to ear setting (Ranasinghe, 1992). Their caterpillars bore into the rice stem and hollow out the stem completely. The damage symptoms vary according to the growth stage of the plant.

Yield loss is caused by a loss of bearing stems due to the production of deadhearts (the outright death of stems), stems attacked in the vegetative stage, the smaller panicles borne by compensatory nodal tillers, whiteheads (empty panicles) caused by attack in the reproductive phase, a decrease in filled grains and lowering of panicle weight from late damage (Catling, 1992). Sarwar et al. (2010) reported the infestation of 10.4% deadhearts and 19.3% whiteheads observed in aromatic rice, due to stem borers under natural field conditions. The increasing pressure on the land of the fast growing world's population has made it necessary to intensify rice production and efficient use of mineral fertilizers that can prove a quick way of boosting crop yield per unit area of land.

Progressively, the modern research is showing that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils (Altieri, 2002). Soils with high organic matter and active soil biology generally exhibit good soil fertility as well as complex food webs and beneficial organisms that prevent infection. On the other hand, farming practices that cause nutrition imbalances can lower pest resistance (Magdoff and Van, 2000). Much of what we know today about the relationship between crop nutrition and pest incidence comes from studies comparing the effects of organic agricultural practices and modern conventional methods on specific pest populations. Soil fertility practices can impact the physiological susceptibility of crop plants to insect pests by either affecting the resistance of individual plant to attack or by altering plant acceptability to certain herbivores (Chau and Heong, 2005) . Several studies have also been documented that show how the shift from organic soil management to chemical fertilizers has increased the potential of certain insects and diseases. Studies of plant resistance to insect pests have shown that resistance varies with the age or growth stage of the plant (Slansky, 1990). This advocates that resistance is related directly to the physiology of the plant and thus any factor that affects the physiology of the plant may lead to changes in resistance to insect pests.

Zinc is essential for the normal healthy growth and reproduction of plants, animals and humans, and when the supply of plant available Zinc is inadequate, crop yields are reduced and the quality of crop products is frequently impaired. In plants, Zinc plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes in many important biochemical pathways and these are mainly concerned with, carbohydrate metabolism (both in photosynthesis and in the conversion of sugars to starch), protein metabolism, auxin (growth regulator) metabolism, pollen formation, the maintenance of the integrity of biological membranes, and the resistance to infection by certain pathogens (Alloway, 2004). Zinc deficiency is usually more prevalent in rice soils with a high pH and high content of organic matter or when organic manures are applied (Dobermann and Fairhurst, 2000). There is a dire need to explore the alternative means of pest management in rice, and fertilizer management seemed as the basic and unexplored point in this regard. Better growth of plants and yield depend upon balanced fertilization, which in turn may have an indirect effect on pests. Pioneer work of Padhee and Mishra (1993) has established Zinc requirement for optimum yield of rice and Zinc application has been shown to impart resistance against insect pests of rice. Shu et al. (2009) investigated the effects of Zn on reproduction of phytophagous insect *Spodoptera litura* Fabricius in artificial diets of larvae at ecological and molecular levels. A significantly shorter period of laying eggs was observed in *S. litura* exposed to 300 to 750 mg Zn/kg. The oviposition rate, fecundity and hatchability of female adults treated with 750 mg Zn/kg were significantly lower than those of the controls.

Therefore, the objective of this work was to assess effects of Zinc fertilizer application against the incidence of rice stem borers in rice crop to determine its potential effectiveness to improve farmers' income and to encourage its adoption by farmers in Pakistan and other similar regions.

MATERIALS AND METHODS

This study was carried out during 2008 crop season at the Nuclear Institute of Agriculture, Tandojam-70060, Sindh, Pakistan. The experiment was done under field conditions by planting rice varieties namely, non aromatic Shadab and aromatic Mehak. Seedlings of 30 days old were uprooted from the nursery beds carefully and transplanted at 25 × 25 cm spacing in the well prepared beds of experimental area (each replicate measuring 4.5 m^2). The experiment was laid out in a Randomized Complete Block Design having three replications with Zinc and varieties as factors, while, pest and yield as parameters.

Research Farm has an ample of good quality canal water available for irrigation, and irrigations were given to crop continuously after every 6 to 7 days interval. The soil is silt loam in texture having an ECe of 1.3 dS m^{-1}, pH of 7.9, Olsen's P -6.7 mg kg^{-1}, organic matter -0.9% and $CaCO_3$ -10.6%. Nitrogen doses and a dose of phosphorus were uniformly applied to all treatments. A basal and starter dose of N at the rate of 30 kg ha^{-1} as urea was applied to all the treatments at the time of sowing and second dose at mid tillering stage 35 days after transplanting. The phosphorus as triple super phosphate was applied at the rate of 50 kg ha^{-1} to the respective treatments and uniformly spread out on the soil surface and incorporated in the soil with spades before sowing of crop. In order to explore the effects of Zinc fertilizer, it was applied alongside the crop rows by using broadcast method, three weeks after crop transplantation. The Zinc sulfate (33%) was applied at three levels (20, 25 and 30 kg/ha) in the vicinity of the crop roots. Normal cultural practices were carried out throughout the growth period, and no pesticide was used as plant protection measure.

Observations on insect pest incidence were recorded at fortnightly intervals. In each treatment, an area of 1 m^2 was randomly selected at three different sampling sites in each treatment, and numbers of healthy and infested tillers were observed. Total number of plants in selected area was counted and then total numbers of tillers in the unit row area were also recorded in order to calculate pest percentages infestation. Stem borers damage was recorded as whitehead percentage at maturity stage by counting number of whiteheads per 1 m^2 area of rice plants. The observations on percent infestation of stem borers (dead heart and whitehead) were calculated using the following formulae:

Deadheart (%) = No. of deadhearts×100/ Total no. of tillers;

Whitehead (%) = No. of white heads×100/ Total no. of tillers with panicles in sample area

The crop was sampled at maturity stage to examine grain yield, plants were separated into straw and grain, dried in sunlight to have a constant weight, and grain yield was recorded separately (per 4.5 m^2) by using an electronic balance. After harvesting, data on paddy yield and other yield components were also recorded. Plot yields of all treatments were converted to kg ha^{-1} subsequent to data analysis. The data were checked for the need for transformation and analyzed statistically using ANOVA and treatment means were compared at 5% level of probability. Mean separation was done by LSD-test by using Statistical Product and Service Solutions (2005), and Statistix 8.1 softwares to assess the significance of the treatment effects. Standard errors of the differences were computed for mean comparisons.

RESULTS AND DISCUSSION

Effects of Zinc fertilizer on population of rice stem borers

Seasonal mean population of rice stem borers was different on both cultivars on most of the samplings; pest density was recorded lower on variety Shadab than that on Mehak. Population was non-significantly different between applications of different Zinc levels but differed significantly from control. The population of rice borers was significantly affected by different treatments though the highest prevalence was found in control treatment (3.09±0.16 and 4.81±0.20; 5.24±0.83 and 7.06±0.20 deadhearts and whiteheads on both varieties Shadab and Mehak, respectively) . The prevalence of the borers tended to decrease with increasing doses of Zinc. The higher prevalence of deadhearts was found in the treatment of 20 kg Zinc, while, the percentage of damage was found lower with 30 kg treatment. The higher percentage of whiteheads was found with 20 kg Zinc treatment, that was statistically non- significant to that of 25 and 30 kg treatments. During the growing season, the relative prevalence of insect in the rice field environment could be ranked in the order of 20>25>30 kg Zn ha^{-1} treatments (Table 1).

Zn proved to be a better mode of fertilization for the crop at all levels of application, as it allowed a balanced nutrient blend in soil and reduced the crop damage. Hence, reduced susceptibility of plant to pests may be a reflection of differences in plant health, as mediated by soil fertility management through Zinc. The soils with well Zinc fertilizer normally exhibited good soil fertility, as well as complex food webs and supported beneficial organisms that prevented pest contamination. In contrast, in control treatment, crop nutrition inequity resulted to lower pest tolerance in host. These findings are in close conformity with those reported by Magdoff and Van (2000), who observed that nutrition imbalance could lower pest resistance.

Effects of Zinc fertilizer on grain yield and yield components

The yield of rice was increased significantly by Zinc treatments compared to control without fertilizer application. With the increase in dose level from 20 kg to 30 kg Zn ha^{-1}, there was corresponding increase in grain yield regardless of the two varieties. The highest grain yield of 2926.66±78.81 and 1700.00±87.36 g/ plot (4.5 m^2) on both varieties Shadab and Mehak, respectively was recorded at 30 kg Zn ha^{-1} applied. The control treatment produced the lowest grain yield (1886.66±63.33 and 1320.00±60.62 g/ 4.5 m^2 plot) on both varieties (Table 1). The mean values of grain yield varied significantly in both cultivars but parameters like number of productive tillers per hill and number of grains per panicle did not vary among themselves. However, plant height, panicle length and 1000- grain weight differed significantly from one another in Zn treated and untreated plants, maximum grain yield was obtained from minimum percent infestation level, conversely, at privileged percent infestation levels, average grain yield was inferior per treatment.

The plant height response to Zn application was more pronounced, significantly higher growing efficiency were recorded (96.10 to 97.00 cm and 132.83 and 133.33 cm) with Zn and the lowest (94.00 and 130.00 cm) without Zn application in Shadab and Mehak, respectively. The low size of panicle length (25.66 and 27.16 cm) without Zn application resulted in a relatively minimum 1000 grain weight (24.00 and 22.00 g) compared to higher length (26.50 to 26.83 and 28.00 to 28.50 cm) and its effects on rice grain weight (27.33 to 28.00 and 25.33 to 26.00 g, respectively) due to Zn application on both cultivars (Table 2) . The application of Zn fertilizer got an edge at all levels of application over control without fertilizer by producing significantly higher grain yield. The superiority of Zn application for grain yield may be due to improvement in soil properties to support the roots of treated plants due to Zn supply. Similar explanations have been given by Miguel and Nicholls (2003) that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils. The better performance of Zn over control may also be attributed to high Zn fixing capacity of the calcareous soils and undergoing a series of reactions that gradually increased its solubility and availability to plants in many important biochemical pathways.

These findings are in close conformity with Alloway (2004), who observed that Zn is required for the synthesis of auxin (a growth regulating compound-indole acetic acid). Stunted growth and ‘little leaf’ are the most distinct visible symptoms of Zinc deficiency and are the result of disturbances in the metabolism of auxins. Flowering and seed production were severely depressed in Zinc deficient plants. On the other hand, application of Zinc to plants produced more grain yield than the control as it plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes in many important biochemical pathways concerned with; carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, protein metabolism, auxin metabolism, pollen formation, maintenance of the integrity of biological membranes, and the resistance to infection by certain pathogens.

In case of Zinc deficiency, one or more important physiological functions are unable to operate normally and the growth of the plant is adversely affected

Table 1. Mean numbers of rice stem borers on rice plants receiving different Zinc doses.

S.N	Variety	Zinc treatment (kg ha^{-1})	Borers infestation (%)		Yield/plot (4.5 m^2) (g)	Yield (kg ha^{-1})
			Deadhearts	Whiteheads		
1.	Shadab	20	1.13a ± 0.06	3.26a ± 0.30	2746.66b ± 37.11	6103.68
2.		25	1.03a ± 0.09	2.57a ± 0.25	2873.33b ± 61.73	6385.17
3.		30	0.78a ± 0.08	2.09a ± 0.11	2926.66b ± 78.81	6503.68
4.		Control	3.09b ± 0.16	5.24b ± 0.83	1886.66a ± 63.33	4192.57
1.	Mehak	20	2.52a ± 0.27	3.22a ± 0.06	1583.33b ± 44.09	3518.51
2.		25	2.34a ± 0.18	2.88a ± 0.36	1656.66b ± 32.82	3681.46
3.		30	1.90a ± 0.18	2.56a ± 0.05	1700.00b ± 87.36	3777.77
4.		Control	4.81b ± 0.20	7.06b ± 0.20	1320.00a ± 60.62	2933.33

Means sharing similar letters in columns are non- significantly different (P= 0.05).

Table 2. Comparison of different yield components of rice by application of different Zinc levels.

S.N	Variety	Zinc treatments (kg ha^{-1})	Plant height (cm)	No. of productive tillers/ hill	Panicle length (cm)	No. of grains/panicle	1000 Grain weight (g)
1.	Shadab	20	96.10a	17.00a	26.50a	156.00a	27.33a
2.		25	96.50a	17.66a	26.63a	156.33a	27.66a
3.		30	97.00a	18.00a	26.83a	156.50a	28.00a
4.		Control	94.00b	16.66a	25.66b	155.50a	24.00b
Standard error			0.804	0.593	0.162	0.471	0.304
LSD value			1.967	1.451	0.398	1.153	0.744
1.	Mehak	20	132.83a	15.00a	28.00a	125.83a	25.33a
2.		25	133.00a	15.66a	28.33a	126.00a	25.66a
3.		30	133.33a	16.00a	28.50a	126.33a	26.00a
4.		Control	130.00b	14.66a	27.16b	125.50a	22.00b
Standard error			0.245	0.593	0.225	0.504	0.304
LSD value			0.600	1.451	0.552	1.234	0.744

Means sharing similar letters in columns are non-significantly different (P= 0.05).

(Alloway, 2004). The prevalence of the borer pests tended to decrease in Zn added treatments. It is likely to state that Zn addition can lead the plant to become less succulent and consequently with a reduction of attractiveness to insects. High levels of Zn can stimulate early vegetative growth resulting to increase the photosynthetic activity leading to a decreased insect pest infestation and elevated crop yield. Further, the indirect effects of Zn fertilization acting through changes in the nutrients composition of the rice crop have influenced plant resistance to borer insect pests. In conformity to present findings, many researchers have suggested that increasing insect pest pressure in agro-ecosystems is due to changes that have occurred in agricultural practices. For example, Meyer (2000) argues that soil nutrient availability not only affects the amount of damage that plants receive from herbivores but also the ability of plants to recover from herbivory. Miguel and Nicholls

(2003) showed that cultural methods such as crop fertilization can affect susceptibility of plants to insect pests, by altering plant tissue nutrient levels. As a consequence, current data suggest that the addition of Zinc along with other fertilizers would be the best combination for maximizing rice yield and reducing insect prevalence in rice. Hence, due to the combine action of above mentioned different factors, the resistance has developed in the rice plant against borers with the application of Zn that led to reduce pest damage and ultimately grain yield enhanced.

The present studies documented that numbers of deadhearts and whiteheads per plant were affected by different doses of Zinc application. The differences in population between these treatments were non-significant receiving different levels of Zn, but maximum population was recorded on plants receiving no Zn. Mean seasonal population of borer pests was also different on different varieties, where maximum population was observed on Mehak and minimum on Shadab. Based on the number of pest prevalence and grain yield variety, Shadab could be classified as resistant and Mehak as susceptible, under the ecological conditions of this region. Further, the lower abundance of stem herbivores in lofty Zinc grown crop, attributed an increase in the yield level, thus the use of soil amendments can create an unfavorable environment for pest, inducing resistance through anti-biosis or feeding inhibition. Zinc applications decreased the borers' populations to reduce pest damage, which is parallel to the findings of Babczynska et al. (2008) who stated that insect reproduction is influenced by various factors, including food quality and quantity, temperature, population density and female age. The metals like Zinc may disturb reproductive processes in insects. When a comparison was done, the basic developmental parameters (number of hatchlings, body mass, embryonic developmental rate) in grasshopper nymphs were additionally exposed to Zinc during diapause. Zinc application caused the decrease in hatching success and duration of embryogenesis in insects from each site. Shu et al. (2009) indicated that excess Zn made expression of vitellogenin gene down-regulated and caused poor accumulation of egg yolk, which led to a reduction in egg numbers and failure of eggs to hatch. Results of the current experiments showed that addition of Zinc along with other practices, can play an important role in the management of rice stem borers and there is a need to integrate this component into integrated pest management systems to maximize crop yield for encouraging farmers to adopt this improved technology for further improving their livelihoods. Optimizing the dose of Zn in relation with other macronutrients and its split applications are extremely essential to investigate in future because the nutrients can make plant tissue either tolerant or vulnerable to pest attack.

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