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Full Length Research Paper

Effects of potassium fertilization on population build up of rice stem borers (lepidopteron pests) and rice (*Oryza sativa* L.) yield

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The effects of potassium (K) application rates on population build up of rice stem borers and rice yield were evaluated using cultivar "Shua-92". The treatments were consisted of K applications at 40, 50 and 60 kg/ha at the top dressing, and no K fertilizer application along with normal doses of nitrogen and phosphorous. The results showed that compared with the untreated control, K fertilizer significantly reduced the rate of rice borers' infestation and increased paddy yield. The treatments 50 and 60 kg K significantly reduced the incidence of pest and increased the grain yield of rice, but none significantly followed by application at 40 kg compared to control treatment. This assures that at low level of K application, biomass of rice plants were significantly less than the plants grown in the higher levels, but, further increase in the amount of K from 50 to 60 kg/ha did not significantly increase the pest growth and biomass of rice plants. Based on observations, it is possible to make sure that by considering cost benefit ratio application of K by adopting the rate of 50 kg/ha might be the most effective strategy in inhibiting rice pest's incidence. The results suggest that application of K fertilizer could be useful in the recovery of plants damage when attacked by larvae of borers which can be safely and successfully managed to contribute larger volume of yield and reduce the environmental pollution.

Key words: Plant nutrition, K fertilizer, herbivore, insect pests, rice, *Oryza sativa.*

INTRODUCTION

The stem borers of the families Pyralidae and Crambidae (Lepidoptera) such as the yellow stem borer *Scirpophaga incertulas*, white stem borer *Scirpophaga innotata*, striped stem bore *Chilo suppressalis*, gold-fringed stem borer *Chilo auricilius*, dark-headed stem borer *Chilo polychrysus*, and pink stem borer *Sesamia inferens* are among the major insects of rice. Among them, *S. incertulas* is the most dominant species in the tropical regions of Asia, while, *C. suppressalis* is the major species in temperate countries. The young stem borer larvae feed within the leaf sheath, and older larvae feed inside the stem and vascular tissues (Alinia et al., 2000). In Pakistan, Sarwar et al. (2010) reported an infestation of 10.4% dead hearts and 19.3% white heads in aromatic rice, due to stem borers under natural field conditions.
Therefore, there is the need to develop optimized stem borers management practices for increasing rice production.

Three mechanisms of host plant resistance are generally recognized (Smith, 1989): antixenosis, or non-preference and antibiosis, which reduce insect survival, reproduction and invasion, where the plant compensates for insect feeding. If plant tolerance was a mechanism of resistance to pest then it is expected that adding K could increase plant vigor and further increase resistance to pest invasion. The plant nutrient status is an indicator of host plant quality, which plays an important role in the population dynamics of many herbivores (Sarwar, 2011). Sustainable agriculture requires both economic and environmental sustainability. One way to reduce agricultural production cost is balanced applications of fertilizer. For increasing food and fiber demands of large and growing populations, development of high yield and high quality crops will result in larger areas of K deficiency unless immediate increases in potash supplies are made available. Until this occurs, the efficiency of N and P fertilizer use will remain low because of imbalances in NPK. As a result, soil K will be further depleted, economic returns to farmers reduced and the cost of restoring soil K to productive levels will become extremely expensive for future generations (Jin, 1997). Potassium in rice producing soils is one of the limiting factors for increasing rice yield (Yang et al., 2003). There is a considerable decrease in available K due to increased cropping intensity and lower K application rates (Zhang et al., 2004).

As agricultural fertilizations entail significant economic and environmental costs, among the fertilizers, potassium plays a vital role in crop growth and metabolism. Potassium is noted for increasing fiber strength and quality in plant (Read et al., 2006). As an enzyme activator, potassium has been implicated in over 60 enzymatic reactions, which are involved in many processes in the plant such as photosynthesis, respiration, carbohydrate metabolism, translocation and protein synthesis (Pettigrew, 2008). Potassium also plays an important role in the maintenance of osmotic potential and water uptake during plant development, and its shortage will result in poorer quality and lowered yields (Oosterhuis, 2001).

Recently, most attention has been paid on the relationship between K content in host plants and changes in performances of herbivores. In an earlier study, K has been proved to improve the rice plant's tolerance to adverse climatic conditions, lodging, insect pests and diseases (Tiwari, 2002). Although potassium is one of the major plant nutrients underpinning crop yield and quality, use of K fertilizer for pest suppression has not been so popular among farmers. The objectives of present research were to investigate the effects of different K doses in combination with N and K fertilization on rice yield and to determine the effects of fertilization on injury of rice stem borers. It is hypothesized that (i) addition of K may increase biological yield in the field; and (ii) applied K can decrease pest density. Consequently, new strategy considering the possible synergy between specific mineral nutrients could permit us to control plant insect pests.

MATERIALS AND METHODS

An experiment was conducted at Nuclear Institute of Agriculture, Tandojam, Sindh, Pakistan, to determine the effects of potassium application rates on population build up of rice stem borers and rice yield. The soil of experimental site is loamy textured with organic matter 0.9%, an ECe of 1.3 dS m^{-1}, pH of 7.9, Olsen's P 6.7 mg kg^{-1}, and $CaCO_3$ 10.6%. Soil was plowed and harrowed when its mellowness was considered physically acceptable. A high-yielding commercial rice cultivar "Shua-92"was used for carrying out the current experimentation. One month old rice seedlings were transplanted in standing water having one seedling per hill keeping 25 × 25 cm plant to plant and row to row distance. Seedlings were thinned by hand by leaving one vigorous plant per hill at the two-leaf stage. Throughout the growing season, crop was irrigated regularly. Other management practices, including insect and weed control were conducted according to local agronomic practices unless otherwise indicated.

Experiment design and procedure

A randomized complete block experimental design was used with three replications and each experimental unit measuring an area of 3 m^2. Four treatments were used: (1) Potassium applications of 40, 50 and 60 kg ha^{-1} separately at the top dressing and (2) no K fertilizer application during the growing season. The customary sources of nitrogen (N), phosphorous (P) and potassium (K) were urea, single super phosphate and potassium sulfate, respectively, applied by broad cast method. The standard amount of N fertilizer recommended on rice in the region was 60 kg ha^{-1}. The N fertilizer was applied in 2 splits; 30 kg ha^{-1} during transplantation and 30 kg ha^{-1} at 30 days after transplantation. All treatments received a basal rate of 50 kg ha^{-1} P according to local practice.

During growing season, data on stem borers were started after one month of transplanting at fortnightly intervals basis. An area of 1 m^2 from each of treatments was randomly selected to quantify the incidence of stem borers as dead hearts $hill^{-1}$. At the later stage of borers infestation data were recoded on white heads basis. Then percent dead hearts and white heads were thus calculated. Pest samples were taken toward the middle of every treatment to reduce edge effects. Specimens of common rice borer pests were identified in the field and counted. If identification of specimens could not be determined in the field, they were brought to the laboratory for further identification. At the end of the crop production season, plants from each treatment were manually harvested, threshed and weighed for yield of the respective treatments.

Statistical analysis

Data collected for grain yield and pest density were tabulated, and difference between treatment means were separated using the least significant difference (LSD) test at the 5% probability level (P= 0.05). An analysis of variance was performed using Statistix 8.1 data processing system.

RESULTS AND DISCUSSION

Application of K fertilization significantly affected rice plant growth and yield, and their effects were documented on pest density and grain among treatments. The arthropod pest damage and yield observed during the growing season are shown in (Table 1).

Pest invasion due to different fertility levels in rice field

Among rice stem borers, *S. incertulas* was the most dominant species at the experimental site. Potassium fertilizer for rice reduced the rate of borer's infestation and increased rice yield. Potassium fertilization treatments of 40, 50 and 60 kg ha^{-1} significantly reduced the incidence of pest with 3.05, 2.40 and 2.64% dead hearts, respectively, compared with no K fertilizer application (4.33% dead hearts) during the growing season. Potassium fertilization significantly affected white heads formation, pest prevalence was very low and irregular in 50 and 60 kg $ha-^{1}$ treatments (3.58 and 3.37% white heads, respectively, but not significantly different

Table 1. Impacts of soil potassium on population build up of rice stem borers and grain yield within rice field.

S. No.	Potassium treatments (kg ha^{-1})	Stem borers infestation (%)		Yield/ plot (gm/ 3 m^2)	Yield (kg ha^{-1})
		Dead hearts	White heads		
1	40 kg	3.05^{b}	5.37^{b}	1913.00^{b}	6376.66
2	50 kg	2.64^{bc}	3.58^{c}	2287.00^{a}	7623.33
3	60 kg	2.40^{c}	3.37^{c}	2317.00^{a}	7723.33
4	Control	4.33^{a}	7.12^{a}	1690.00^{c}	5633.33
LSD value		0.619	0.561	219.4	

Means, in each column followed by at least one letter in common are not significantly different at the 5% level of probability ($p \geq 0.05$).

from one another) compared with 40 kg treatment (5.37% white heads). White heads were abundant (7.12%) in no K fertilizer application than in the other treatments throughout the season. Pest incidence was low throughout the period in the higher K treatment, while, significantly lower in the minimum K during growing season. Not surprisingly, K fertilization had a significant effect on the insect pest populations in all cases.

Paddy yield due to different fertility levels in rice field

Yield tended to be quite responsive to plant K levels, when nitrogen and phosphorus were combined with K fertilization; it was the best treatment combination for higher yield formation among the treatments. But the yield variability was not significantly observed among 50 and 60 kg ha^{-1} treatments, although the differences were significant from 40 kg treatment and no K used treatment. Numerically higher yields were found in the K treatments with 1913.0, 2287.0 and 2317.0 gm per 3 m^2 (6376.66, 7623.33 and 7723.33 kg ha^{-1}) than in the no K treatment (1690.0 gm per 3 m^2) (5633.33 kg ha^{-1}) (P= 0.23). Thus, at low level of K application, biomass of rice plants were significantly less than the plants grown in the higher levels, but, further increase in the amount of K from 50 to 60 kg/ hectare did not significantly increase yield. Thus, resistance to insect pest in rice plants was enhanced due to K application and rice plants receiving high amounts of potassium accumulated high grain yield.

This study had added new information on the common perception that K fertilizer application is a most important practice to suppress pest population and for improving yield components. Lower pest damage on high dose K applied plants can arise from (1) pest's non preference due to high quality nutrients in plants; (2) higher pest mortality by high K level in plants; and (3) plant's chemical composition such as higher contents of defensive compounds that caused higher pest mortality. This demonstrates the capability of mineral nutrient to induce the activation of specific defense mechanisms developed by plants against the attack of pest. Similar results had also been observed previously where a number of studies have shown the potential of certain mineral nutrients to provoke the creation of definite defense system by plant which is not in favor of the pest due to presence of mono-potassium phosphate (Reuveni and Reuveni, 1998) and K (Sarwar et al., 2011). Role of potassium in imparting resistance is well documented, culm strength of rice plants was noted increased with improved K nutrition, and increased stalk strength and decreased lodging are associated with proper K nutrition (DeDatta and Mikkelson, 1985). On the other hand, K deficiency in rice can make tissues vulnerable to pest attack by reducing grain yield. Vaithilingam and Baskaran (1985) examined the mechanism of induced resistance to insect pests in rice plants with enhanced potassium application. Increase in the application of K in the culture solution increased K, but decreased N, P, Mg, Si, Zn and soluble proteins in the rice plants. Deficiency of K in rice plants increased intake and assimilation of food, honey dew excretion, growth index, adult longevity and population build up of pest. While, application of high dose of K to rice plants decreased adult life and population build up of the insect (Salim, 2002).

Potassium fertilization in this study generally seemed to increase plant K level and promoted rice plant growth, as had been shown in other studies (Dudt and Shure, 1994; Stiling and Moon, 2005). These changes have the potential to affect pest populations (Bi et al., 2001; Chau and Heinz, 2006), suggesting possible compensatory reproduction by the plant, so, the yield was positively affected. Singh et al. (2003) reported that K has been known to impart resistance against diseases and a high concentration of K ions in the cell sap restricts attack by insects.

The study by Dong et al. (2011) found a strong positive relationship between K fertilization and grain abundance and suggested that K fertilization was extremely important for maintaining high yield. The yield advantage was attributed to increases in the tillering capacity of the rice plant and spikelet production. Potassium played a critical role in plant physiology, it provided regulatory control over such processes as transpiration, starch synthesis, sucrose translocation, respiration, and lipid synthesis (Tisdale et al., 1985). Previous studies had indicated that the amount, rate and quality of food consumed by immature herbivores influenced their fitness, growth rates, developmental duration, final body weights, dispersal abilities and probabilities of survival. Similarly, the amount, rate and quality of food consumed by adults influenced their performance in mating success as well as timing and extent of reproduction and disposal ability (Slansky and Scriber, 1985). However, a rise or decrease in a single nutrient sometimes may not be reflected in the yield. As such, K fertilization effects on plant growth and pest populations can be offset by other factors in the field. These factors may include natural enemies, environmental factors and the health and defensive responses of the plant to insect pest herbivore (Hacker and Bertness, 1995). Some more recent studies have also shown significant yield changes due to uses of K as stated by Quampah et al. (2011) that K fertilizer increased the yield of rice. The present .finding suggests that K application should be emphasized for high-yielding rice production. This could reduce the input of fertilizers, and decrease the application of pesticides due to lower occurrence of pests, reduce losses of yield and finally increase farmers' income to sustainable development of rice protection and production.

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