Field Crops Research 224 (2018) 60–66

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Rice husk ash and imidazole application enhances silicon availability to rice plants and reduces yellow stem borer damage

M. Jeer[a,b,1], K. Suman[a], T. Uma Maheswari[b], S.R. Voleti[a], A.P. Padmakumari[a,*]

[a] ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad, 500030, Telangana, India

[b] Department of Entomology, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, 500030, Telangana, India

ARTICLE INFO

Keywords:
Yellow stem borer
Rice
Silicon
Larval mandibles
Rice husk ash
Imidazole

ABSTRACT

Silicon (Si) has been implicated to reduce damage by rice pests. In this study we validate the field efficacy of rice husk ash (RHA) and imidazole, alone and in combination, against damage by yellow stem borer (YSB) under field conditions for two seasons in five rice cultivars. Field application of RHA and imidazole, either alone or in combination, enhanced Si deposition (43–59.8 $mg\ g^{-1}$) in stem tissues of rice plants as compared to untreated control (30.2 $mg\ g^{-1}$). Deposited Si caused significant wearing of mandible incisors, and lowered larval density, thereby decreasing YSB damage and increasing the grain yield significantly. RHA and imidazole did not alter the total sugars and total phenol content in rice cultivars. Field application of imidazole along with RHA at vegetative phase and again at booting stage was on par with insecticidal treatment (carbofuran 3G) with respect to per cent damage, larval density and grain yield. The B: C ratio in the Si treatments varied from 1.16 to 1.31 and T4-RHA + imidazole (applied twice) was at par with one granular insecticide application (1.32) but higher than the untreated control (1.0). RHA and imidazole can be integrated as one of the eco-friendly components in the present scenario of climate change for the management of YSB in rice.

1. Introduction

Yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) (Lepidoptera: Crambidae), is a monophagous insect and one of the most important pest of Asia and South East Asia (Khan et al., 1991). Larvae of this insect infest the rice crop throughout the crop growth stage (Bandong and Litsinger, 2005). When the larvae infest the crop from nursery to tillering stage (vegetative phase), the growing shoots dry up and they can be easily pulled out. This symptom is commonly called as 'dead hearts'. During heading stage (in reproductive phase), attack by the larvae leads to unfilled panicles commonly known as 'white heads'. Depending on the crop stage that is attacked, the grain yield losses may vary from 10 to 90% (Muralidharan and Pasalu, 2006). The yellow stem borer larvae are exposed to the outside environment from the time they hatch from the egg mass to their entry into the stems of rice plant which is usually a few hours. Therefore, control of this insect is difficult because of its cryptic behavior. Hence, there is a need to search for alternative sustainable strategies to manage this pest.

Si is known to induce defense mechanisms like in leaf scald by reducing malonaldehyde concentration, lignin concentration and total soluble phenolics with greater activities of phenyl ammonia lyase (PAL), peroxidase (POD), polyphenol oxidize (PPO) and lipoxygenase (LOX) (Tatagiba et al., 2014). Induced responses in rice appear to vary in response to damage by different pest species. Chewing damage caused by armyworm or cluster caterpillars, *Spodoptera litura* (Fabricus) (Lepidoptera: Noctuidae), caused signal cascades and expression of genes normally associated with induced resistance against herbivores, such as the jasmonic acid (JA) pathway, phenyl propanoid pathway and terpene biosynthesis (Xu et al., 2003) suggesting that the JA signaling pathway in rice is involved in induced resistance against caterpillars. But on the contrary, Duan et al. (2014) reported that salicylic acid (SA) signaling pathway was activated in the resistant rice variety, Kasalath in response to small brown planthopper (SBPH) infestation and the activities of the defense enzymes PAL, POD, and PPO increased remarkably and PAL gene played a considerable role in imparting resistance to SBPH.

In addition to phenols, Si application has proved to impart resistance to rice insect pests *viz.*, African striped borer (Ukwungwu, 1984); yellow rice borer (Panda et al., 1975); striped stem borer (Sasamoto, 1958); brown planthopper (Yoshihara et al., 1979;

* Corresponding author.
E-mail addresses: mjeer.nibsm.cg@nic.in, mallihugar@gmail.com (M. Jeer), sumankarre1@gmail.com (K. Suman), uma_ento@yahoo.co.in, uma_maheswaritelugu@pjtsau.edu (T.U. Maheswari), voletisr58@rediffmail.com, drvoletisr@gmail.com, SR.Voleti@icar.gov.in (S.R. Voleti), Padma.APK@icar.gov.in, padmakumariento@gmail.com (A.P. Padmakumari).

[1] ICAR-National Institute of Biotic Stress Management, Raipur, Chattishgarh, 493225, India (Current address).

https://doi.org/10.1016/j.fcr.2018.05.002
Received 14 August 2017; Received in revised form 25 April 2018; Accepted 1 May 2018
0378-4290/

Wenqiang et al., 2015); leaf folder (Han et al., 2015). Most of the sources of Si are insoluble and not available to plant as its uptake is in the form of soluble monosilicic acid (Lindsay, 1979). Si can be applied as many inorganic forms such as sodium silicate (Na_2SiO_3), potassium silicate (K_2SiO_3) and calcium silicate (Moraes et al., 2004; McCray et al., 2011) and organic source like rice husk ash (RHA) (Sawant et al., 1994) for insect pest control though dissolution rates vary for different Si sources (Savant et al., 1997). For rice production entirely relying on release of H SiO_4 from amorphous silica as its Si source, the supply of plant-available Si is expected to be exhausted after 5 years of continuous cultivation (Desplanques et al., 2006). It was suggested that the decline in yields of rice grown in many areas of the world was associated with soil depletion of plant-available Si (Savant et al., 1997). This may pose further problems in soils with large fractions of quartz sand, high organic matter content, and characterized as highly weathered, leached, acidic, and low in base saturation (Datnoff et al., 1997). The replenishment of plant-available Si in soil solution is critical and may be characterized based on soil Si dissolution kinetics and Si release from organic sources, including crop residues and burned rice husk. Babu et al. (2014) pointed out that the release of H SiO_4 into soil solution is critical for the amount of plant-available Si and is influenced by different processes (e.g., desorption, polymerization) and soil properties other than pH. This phenomenon explains the unexpected response of rice to Si grown on soil despite high initial Si level and clay content. Therefore, Si fertilization could be important and can be decided based on the soil's ability to replenish the Si removed by plants from the soil solution, especially for soils under continuous, intensive farming systems. A soil's clay content, pH, organic matter content, and Al and Fe oxide content are essential factors to consider when making a recommendation for a Si fertilizer. Hence it is appropriate to apply a material that is rich in Si and also soluble. Therefore in the present study, we have chosen two products RHA which is rich in Si and imidazole which is a proven Si solubiliser and carrier to study their effect on yellow stem borer damage.

RHA is one of the byproducts of rice milling and is a huge source of Si and K with high specific surface which plays an important role in soil stabilization and has long term positive effects (Brenda et al., 2016). RHA, a potential available form of Si (Prakash et al., 2007) is easily available and less expensive. Sawant et al. (1994) reported that the application of black to grey RHA at 0.5–1.0 kg m^{-2} to rice nursery resulted in healthy and strong seedlings that were tolerant to stem borer attack. Application of Si solubilisers such as simple amino acids which proved to be cost effective, reduced damage by yellow stem borer and blast (*Pyricularia grisea*) (Ranganathan et al., 2006; Voleti et al., 2008). Among the simple amino acids, imidazole ($C_3H_4N_2$), an organic, aromatic heterocyclic compound was found to be effective and promoted the equilibrium in favour of silicic acid by a dual mechanism involving Si hydrolysis and its subsequent stabilization by hydrogen bonding (Voleti et al., 2009; Ranganathan et al., 2011). In our recent study under greenhouse conditions, we demonstrated that application of RHA + Imidazole resulted in reduced yellow stem borer damage due to 1) increased mandible wear 2) larval mortality and 3) abrasion in larval midgut epithelium (Jeer et al., 2016). In this paper, we report the field efficacy of rice husk ash and imidazole alone, and in combination, for minimizing YSB damage.

2. Materials and methods

2.1. Experimental site

Field experiments were carried out for two seasons at ICAR-Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad, India (17°19′N and of 78° 24′ E, 542 MSL) during 2011–2012. The soils were clayey, slightly alkaline (pH 8.1), non saline, medium in organic carbon content with, 225 kg/ha available N, 75–80 kg/ha available P_2O_5 and > 500 kg/ha K_2O.

2.2. Experimental procedure

Field trials were laid out to study the efficacy of Si sources *i.e.* Rice husk ash (RHA) and silicon solubiliser cum carrier *i.e.* imidazole (Chemical formula: $C_3H_4N_2$, Mol. Wt – 68.08; Hi-Pure fine Chem. Industries, Chennai, India) on silicon deposition, incidence and damage by YSB, *S. incertulas* in selected rice cultivars during dry season, 2011–12 and wet season, 2012. The experiment was planned in split-plot design with five rice cultivars as main treatments and different doses of RHA and imidazole as subplot treatments with four replications. Cultivars were BPT 5204, MTU 1010, KRH 2, Vandana and Pusa Basmati (PB) 1, which are the most popular and commonly grown rice varieties/hybrids in India. Si sources as treatments included only RHA (T1), only imidazole (T2), RHA + imidazole applied once at maximum tillering (MT) stage (T3), RHA + imidazole applied at MT and another dose of imidazole alone at booting stage (T4), carbofuran 3G applied at 33 kg/ha during MT stage (T5) and an untreated control (T6.) The crop was raised as per the recommended package of practices except for crop protection measures with an individual plot size of 7.2 m^2. Based on the solubility of Si by imidazole, 40.8 g/ha/application of imidazole and RHA equivalent to 85 mg of Si m^{-2} $application^{-1}$ was applied to the soil (Jeer et al., 2016).

2.3. Preparation of Rice husk ash

Rice husk was collected from a single source, burnt to grey black color in earthen pots, powdered and sieved through a fine mesh (60 mesh). Grayish black colored ash was collected and used for all the studies. The quantification of Si present in RHA was carried out by molybdenum yellow method (Saito et al., 2005).

2.4. Soil application of Si

Before imposing the treatments, the plant samples were collected from all the plots for analysis of initial Si content, total sugars and total phenols in stem tissues. All the treatments were imposed in individual plots at 30 days after transplanting (DAT) by dissolving in a small quantity of water for proper distribution (Jeer et al., 2016). In T4 treatment, a second dose of imidazole was applied at booting stage. Booting stage varied with the duration of the variety.

2.5. Field efficacy studies

Field incidence of YSB was recorded as total number of dead hearts and total number of healthy tillers in 10 randomly selected hills per replication at 45 and 60 days after transplanting (DAT). Similarly, total number of white ears and total number of panicle bearing tillers were recorded at harvest. Per cent dead hearts and per cent white heads were calculated as follows:

$$\text{Percent dead hearts} = \frac{\text{Total number of dead hearts}}{\text{Total number of tillers}} \times 100$$

$$\text{Percent white heads} = \frac{\text{Total number of white heads}}{\text{Total number of panicle bearing tillers}} \times 100$$

Grain yield was recorded on net plot basis by leaving one border row on all sides of each plot.

2.6. Larval density

From each replication of a treatment in the field, a sub sample of four infested rice plants were uprooted separately, dissected and observed for total number of YSB larvae. From each treatment eight larvae were preserved in 70% ethyl alcohol for mandible studies.