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Role of the egg parasitoid, *Trichogramma evanescens* West., release and silica applications in controlling of the stem borer, *Chilo agamemnon* Bles. (Lepidoptera: Crambidae), in rice fields in Egypt

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Abstract

Rice, (*Oryza sativa* L.), is liable to infestation with several insect pests, from which is the rice stem borer, *Chilo agamemnon* Bles. (Lepidoptera: Crambidae). Field trials were conducted in Egypt during 2015 and 2016 rice seasons to evaluate the efficacy of releasing the egg parasitoid, *Trichogramma evanescens* Westwood and applying different silica materials to reduce the pest infestation. The most efficient borer control was achieved when the parasitoid was released twice (each at 30,000 wasps/feddan) at Sakha, Gemmiza, and Sirw Agricultural Research Stations in 2015 season, at the maximum tillering stage plus at panicle initiation, as the borer infestation was reduced by (84.77%). Similar results (79.32% borer control) were obtained when the parasitoid was released at panicle initiation and heading rice plant growth stages. The parasitoid release was as efficient as the application of the widely applied insecticide (carbofuran). A large-scale release (17–20 feddans) was performed at the same research stations in the 2016 season. The parasitoid was released twice (each at 30,000 parasitoids/feddan) at the maximum tillering stage, 30 days after transplanting (DAT) and at panicle initiation (45 DAT). Dead hearts (DH) averaged (1.80 and 3.67%) in release and non-release treatments, respectively, with a reduction in DH of (50.95%). The corresponding reduction in white heads averaged (70.64%). Potassium silicate (68% Si, 500 kg/feddan), as basal after last tillage or magnesium silicate (62% Si, 2 kg /feddan), as a spray 20 and 40 days after transplanting achieved (58.25 and 45.31%) white head reduction, respectively, due to borer infestation.

Keywords: Rice, *Chilo agamemnon* Bles., *Trichogramma evanescens*, Release, Silica applications, Pest control

Background

Rice (*Oryza sativa* L.) is an essential food crop for about one half of the world's population, particularly to Southeast Asian countries. In Egypt, rice shares wheat to satisfy the population requirements of cereals. This crop is liable to infestations with several insect pests, from which is the rice stem borer, *Chilo agamemnon* Bles. (Lepidoptera: Crambidae) that causes yield losses in case of its high population density. Thus, the growers are worried about the borer's infestation, whatever the economic injury level is (Sherif and El-Hefny 2014). The misuse applications of insecticides pollute the environment and destroy the natural enemy balance.

The egg parasitoids, *Trichogramma* spp., are common to parasitize eggs of too many lepidopteran insect species. The eggs of yellow rice stem borer, *Scirpophaga incertulas* (Walker), was parasitized by *Trichogramma japonica* with 7–14% (Marub 1993). Asaady and Navai (1995) released *T. japonica* in rice fields and recorded 12–32% egg parasitism of the white rice stem borer. In Egypt, Sherif et al. (2008) recorded about 70% control of the rice stem borer *C. agamemnon* due to inundative release of *T. evanescens* West.

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For the crop yield, about 11–12% increase was achieved due to the release of *T. japonicum*, which parasitized the eggs of the rice stem borers (Asaady and Navai 1995 and Riba and Sarma 2006).

Monocotyledons accumulate large amounts of silica in their tissues, from which rice accumulates about 12% silica in straw. Thus, large supplies of silica are required for better crop performance against biotic and abiotic stresses (Nayar et al. 1982). Silica deposition in rice plant tissues increases the rigidity and strength of the culms, which enhances plant resistance to lodging (Vasanthi et al. 2014). On the other hand, Tisdale et al. (1985) pointed out that silica accumulation in tissues increases photosynthesis, due to the erect leaves that are more exposed to sunlight. Vasanthi et al. (2014) reported that the resistance of rice plants to stem borer increases by applying silica to the soil. The mechanism by which silica deposits control invading insects was explained by Chandramani et al. (2010) as wearing of insect mandibles, which results in weak feeding ability and may cause high insect mortality.

The present study was conducted to estimate the appropriate timing of *T. evanescens* releases for controlling the stem borer, *C. agamemnon*, and for testing different silica materials in rice fields to reduce the pest infestation.

Materials and methods

Experiments were conducted in rice fields at Sakha, Gemmiza, and Sirw Agricultural Research Stations, Delta, Egypt, in 2015 and 2016 rice seasons.

Cultural practices

All recommended cultural practices were applied until harvest, without applying chemical control in the experimental areas.

The egg-parasitoid, *Trichogramma evanescens*

The egg-parasitoid was obtained from Biological Control Laboratory, established at Rice Research and Training Center, Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt. The parasitoid was reared on eggs of the cereal moth, *Sitotroga cerealella* Oliver and released at late pupal stage. The parasitized eggs of the host were glued onto paper cards, each containing about 1000 eggs. The releases were practiced just before sunset, and the paper cards, containing *S. cerealella* parasitized eggs, were hanged on the rice plants using strings. The rate of release was 30,000 wasps/feddan.

Treatments

In 2015 rice season, the parasitoid was released in two plots, occupied a total area of about 8 feddans (as 4000 m^2 per treatment). An area of about 20 m width along the length of the experimental plot was left without releases to separate between the two treated plots. Treatments and dates of the parasitoid releases are listed in (Table 1). Three weeks before rice harvest, four random samples of rice hills were collected from each treatment, each contains 100 rice hills. The total number of rice tillers and tillers having white head symptom was counted and used to calculate the percentage of white head infestation.

Large-scale release

In 2016 rice season, the parasitoid was released on a relatively large scale at Sakha, Gemmiza, and Sirw Agricultural Research Stations; treated areas were 20, 15, and 17 feddans, respectively, at the rate of 30,000 parasitoids/feddan. The experimental areas, at the three locations, were sown by Giza 178 rice cultivar. Percentages of dead heart infestations were assessed 45 days after transplanting, and white heads were assessed 3 weeks before harvest. At each assessment, four samples (100 hills each) were collected randomly to represent the infestation rate per feddan.

Silica treatments

Different silica materials tested in the present study were kindly provided by Al-Ahram Mining Company, Cairo, Egypt. The silica materials applied were:

- Check (without silica)
- Compost straw, 7% Si, at 2.1 t / feddan as basal after last tillage
- Mixed minerals, 38% Si, 500 kg / feddan as basal after last tillage.
- Potassium silicate, 68% Si, 500 kg / feddan as basal after last tillage
- Biocide ore, 46% Si, 2 kg/feddan as a spray 20 and 40 days after transplanting.
- Magnesium silicate, 62% Si, 2 kg /feddan as a spray 20 and 40 days after transplanting.

This experiment was conducted in two seasons; 2015 and 2016. The permanent rice field was prepared as recommended and transplanted by Giza 178 rice cultivar on 1 June. The completely randomized block design, with four replicates, was followed. Normal dose of nitrogen (69 kg N/feddan) was applied. Percentage of white heads was assessed 3 weeks before harvest.

Statistical analysis

Data were subjected to analysis of variance and different means were compared by Duncan (1955).

Table 1 Schedule of *Trichogramma evanescens* release (30,000 wasps/feddan) for control of the rice stem borer, *Chilo agamemnon*, in rice fields, 2015 season

Release treatment			White head	
Date	Days after transplanting (DAT)	Plant growth stages	%	Reduction %
Check	–	–	14.31[a]	–
15 June	15	Tillering	14.28[a]	0.21
30 June	30	Maximum tillering	10.99[b]	23.20
15 July	45	Panicle initiation	8.64[bc]	39.62
30 July	60	Heading	6.55[c]	54.23
30 June + 15 July	30 + 45	Max. tillerin + panicle init.	2.18[d]	84.77
15 July + 30 July	45 + 60	Panicle init. + heading	2.96[d]	79.32
Carbofuran (6 kg/feddan)	15 + 45	Tillering + panicle init.	1.73[d]	87.91

[a,b,c,d]Means followed by the same letter are not significantly at the 5% level of probability

Results and discussion

Treatments with *Trichogramma evanescens*

The egg-parasitoid, *T. evanescens*, was released in the rice treatment plots at the rate of (30,000 wasps/feddan). The carbamate insecticide, carbofuran (Furadan 10 G), widely applied by rice growers, was used as for comparison check. In 2015 rice season, data in (Table 1) revealed that the parasitoid released at tillering stage, 15 days after transplanting (DAT), almost did not reduce the borer's infestation, which was evaluated as white heads (WH), 3 weeks prior to harvest. The release practiced at maximum tillering stage (30 DAT) or at panicle initiation (45 DAT) induced a moderate borer control (23.20 and 39.62%) insect infestations, respectively. However, the most efficient borer control was achieved, when the parasitoid was released twice, at maximum tillering growth stage and at panicle initiation, as the WH was reduced by (84.77%). A similar result was obtained when the parasitoid was released at panicle initiation and at heading (79.32% WH reduction). The application of the insecticide (carbofuran) was as efficient as the results of release at maximum tillering and at panicle initiation stages.

Depending on the results of the 2015 rice season, large-scale releases (17–20 feddans) were treated (Table 2). The parasitoid was released twice (each 30,000 parasitoids/feddan), at maximum tillering (30 DAT) and at panicle initiation (45 DAT). Dead hearts (DH) averaged 1.80 and 3.67% in release and non-release treatments, respectively, with a reduction of (50.95%) in DH. Correspondent reduction in white heads averaged (70.64%).

Table 2 Large-scale release of *Trichogramma evanescens* to control the rice stem borer, *Chilo agamemnon*, season 2016

Agricultural Research Station	Treated area	Dead heart %		White head %	
		Treated	Check	Treated	Check
Sakha	20	1.80	3.00	2.30	8.15
Gemmiza	15	2.01	5.15	2.16	6.40
Sirw	17	1.60	2.86	1.90	7.11
Average	–	1.80	3.67	2.12	7.22
Reduction %		50.95		70.64	

The release of *T. japonica* in rice fields against rice stem borer (*Chilo suppressalis* Walker) and green rice semi-looper (*Naragna aenescens*) achieved a reduction of (77%) in dead hearts and (29%) in white heads, respectively, meanwhile increased the rice yield by about 11% (Asaady and Navai 1995). Similar findings were obtained by Riba and Sarma 2006) who achieved 12% rice yield increase due to the release of *T. japonicum*, at the rate of 200,000 wasps per hectare, in two or four split applications. The findings of Kaur and Brar (2008) and Ko et al. (2014) indicated that *Trichogramma* releases might be considered practical for the control of the striped stem borer, *C. suppressalis*. In paddy field trials, the release of *T. japonicum* reduced the stem borer infestation by 9%, while *T. chilonis* reduced it by 15%, without significant differences among 50,000, 100,000, or 200,000 wasps/hectare (Tang et al. 2017).

The present study revealed the efficacy of *T. evanescens* as a bio-agent against the rice stem borer, *C. agamemnon*. Similar results were obtained by Sherif et al. (2008) who achieved borer infestation reduction of 25–71% due to the release of the same parasitoid, at rates ranged between 10,000 and 50,000 wasps/feddan.

Treatments with silica

Throughout the two seasons of 2015 and 2016, rice stem borer infestation was evaluated as white heads' percent that averaged 9.39% in the check (untreated) plots (Table 3). All forms of silica tested against the pest achieved moderate control, as they reduced the white heads by (52.50–58.25%). Accordingly, the silica applications could be used to reduce the infestation of the rice

Table 3 Influence of silica materials application on the rice stem borer, *Chilo agamemnon*, infestation, assessed as percentages of rice plant white heads

Treatment	Rate/feddan	2015	2016	Average	Reduction %
Check (without)	–	11.63[a]	7.15[a]	9.39	–
Compost straw (basal)	2.1 t	9.58[b]	6.58[b]	8.08	13.95
Mixed mineral (basal)	500 kg	4.85[c]	3.92[c]	4.39	53.25
Potassium silicate (basal)	500 kg	4.14[c]	3.69[c]	3.92	58.25
Biocide ore (two sprays)	2 kg spray	4.88[c]	4.04[c]	4.46	52.50
Magnesium silicate (two sprays)	2 kg spray	4.30[c]	4.28[c]	4.29	54.31

[a,b,c]Means followed by the same letter are not significantly at the 5% level of probability

stem borer, *C. agamemnon*. Monocotyledons, including rice, are categorized as high accumulators of silica (Liang et al. 2007), and the straw of rice plants may contain about 4.8–13.5% silica (Nayar et al. 1982). Several investigators applied silica to rice soils to enhance rice tolerance to biotic and abiotic stresses. Adding different forms of silica to the soil increased the resistance of rice plants to stem borers (Vasanthi et al. 2014). Chandramani et al. (2010) found that the occurrence of stem borer had a highly significant negative correlation with silica (− 0.930). Many authors studied and explained the mechanism of silica against the insects feeding upon plants with high levels of such element. Epstein (1994) concluded that the silica accumulated and deposited in epidermal cells of rice tissues that act as a barrier against pest invasion to the plants. In an experiment, where fly ash (high silica content) was applied to the soils of rice, Chandramani et al. (2010) attributed the main cause of insect mortality to the wearing of mandibles and other feeding organs of the insects, which results in failure of the normal feeding upon rice plants. This phenomenon is in parallel with the result of Vasanthi et al. (2014) who found that silica is deposited as 2.5 mm layer under the cuticle, forming additional defense mechanism against the invading insects.

The effect of silica deposited in plant tissues could be complementary with the role of natural enemies in suppressing the damage caused by insect pests. Because the silica barriers delay the invasion of insects to plant tissues, the retarded insects become more exposed to their parasitoids and predators. On the other hand, the delayed invasion renders the insect pests exposed to unfavorable environmental conditions or oblige these pests to feed upon less preferred plant hosts (Reynolds et al. 2009).

Conclusion

It could be concluded that release of egg parasitoid, *T. evanescens*, in rice fields at a maximum tillering growth stage (30 days after transplanting) and at panicle initiation, at the rate of 30,000 wasps/feddan, could achieve an efficient control against the rice stem borer, *C. agamemnon*. In addition, applying materials, with high silica contents in rice fields either as soil incorporated or spray on rice foliage, can also reduce the infestation levels. Further studies are required to test the combined applications of silica materials and biological control agents.

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