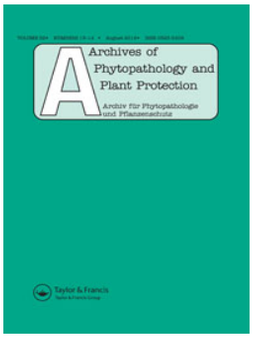

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Integrated management of the striped rice stem borer, *Chilo suppressalis* Walker on the Hashemi Tarom rice under the farm conditions

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ABSTRACT

An experiment was carried out in order to study the methods of managing striped rice stem borer, *Chilo suppressalis* Walker on rice, with 11 treatments including the early planted, late planted, *Trichogramma brassicae* Bezdenko release, 10% Diazinon GR, Bt microbial insecticide, sex pheromone, *T. brassicae* + Bt, *T. brassicae* + sex pheromone, sex pheromone + Bt, *T. brassicae* + sex pheromone + Bt and control. In this study, the studied traits included the percentage of brownish leaf sheath (BS), dead heart (DH), white head (WH), yield per hectare and the percentage of converting paddy rice to white rice. The results showed that the best yield in all traits was related to the integrated treatment of *T. brassicae*+sex pheromone + Bt, which was in the highest group and its amount in BS was 1.99%, in DH was 1.37%, in WH was 0.34%, the yield/ha was 5910 kg and the percentage of converting paddy rice to white rice was 63%.

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KEYWORDS
Chilo suppressalis; IPM; *Trichogramma brassicae*; sex pheromone; Hashemi Tarom cultivar

Introduction

Rice is one of the most important crops in continental Asia and also is the second largest staple food crop in Iran (Khanjani 2009; Feizabadi 2011) One of the most important damaging factors in rice production in world is the striped rice stem borer, *Chilo suppresalis* Walker (Lep.: Pyralidae), which causes a lot of damage to the rice product every year (Ulumi Sadeghi 1978; Jafari 1980; Ulumi Sadeghi et al. 1980; Saeb 1999).

According to various reports, striped rice stem borer, *C. suppresalis* is currently spread across all continental rice-producing regions of Asia, eastern Africa, and in some parts of Europe, including Spain and the

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United States, in the Hawaiian Islands (Pathak and Khan 1994; Zibaee et al. 2009).

Chilo suppressalis is adapted to temperate climatic conditions; larvae survive low winter temperatures. In tropical conditions, up to six generations develop in a year, often overlapping where rice cropping is continuous. In colder climates, final instars remain dormant during the winter (Cho et al. 2005). Rice stem borer has two-three generations per year in Northeastern Iran (Aboutalebian et al. 2016). Rice stem borer females normally fly from 2100 to 2300 h, and lay two to three egg masses (each containing approximately 70 eggs) on the leaf tips. During the tillering stage of rice, larvae sever the vascular system, causing the interior leaf of the tiller to wilt and thus create a dead heart. In the flowering stage, panicles are severed at their base, creating white heads with unfilled grains (Chen and Klein 2012).

The larvae of insect feed on rice stems, prevent the transfer of food from roots to leaves and cause the dead hearts at the vegetative stage and white heads at the reproductive stage (He et al. 2007; Lu et al. 2014). This destructive pest in the world, if not managed correctly in different cultivars, causes 5 to 100% damage and reduces the yield (Alam et al. 1972). In Iranian rice farms, this pest equivalent to 727 kg/ha reduces crop yields (Khosroshahi et al. 1979).

Since 1990s, a variety of insecticides, including diazinon, fipronil, abamectin, methamidophos, chlorpyrifos, and triazophos have been extensively used for *C. suppressalis* control (Li et al. 2007; Yao et al. 2017), their efficiency is questionable due to the cryptic activity of larvae as well as rapid development of pesticide resistance by the pest (Li et al. 2007; Zibaee et al. 2009; Cheng et al. 2010; Yao et al. 2017). Apart from the environmental pollution and human health risks, indiscriminate use of broad-spectrum pesticides may also negatively affect natural enemies (such as egg and larval parasitoids, and predators) and underlie pest resurgence (Zhang et al. 2011). Transplanting date (Huang et al. 2009; Zhang et al. 2009a,b; Zhu et al. 2011), sex pheromones (Chen et al. 2006, 2007; Zheng 2007; Chen and Li 2011; Vacas et al. 2016) and *Trichogramma* wasps (Kaur and Brar 2008; Sherif et al. 2008; Ko et al. 2014) are most important factors for the integrated pest management (IPM) programs.

Given that Hashemi Tarom rice is one of the best with high quality, great flavor, and excellent cooking, among the low-yielding cultivars, it has the highest cultivation area in Mazandaran province, Iran. This cultivar is one of the most susceptible cultivars to *C. suppressalis*, and many chemical insecticides are used annually to control it by farmers in farms. In this research, it has been attempted to study different methods other

than chemical control against striped rice stem borer, *C. suppressalis* and compare its results with the chemical control method generally performed by with 10% diazinon GR in order to maintain the health of the environment and reduce the pollution of the groundwater, as well as reduce the loss of natural enemies by chemicals.

Materials and methods

Study site

This research was conducted on Hashemi Tarom rice in the crop year of 2017 in the farms of Jamalkola village with the longitude of 52.82075229; latitude of 36.6076907 and −12.79 m above sea level. Studied treatments included: 1) early planted, 2) late planted, 3) releasing *Trichogramma brassicae* Bezdenko, 4) 10% diazinon GR, 5) Bt microbial insecticide, 6) sex pheromone, 7) *T. brassicae*+Bt, 8) *T. brassicae*+sex pheromone, 9) sex pheromone + Bt, 10) *T. brassicae*+Bt + sex pheromone and 11) control. For each treatment, three replicates were considered. The size of the experimental plots was one hectare (100 × 100 m) for each treatment. In order to prevent the effects of treatments on each other, the distance between plots was 100 m. The type of water and soil, climatic conditions, and agronomic operations were the same for all treatments. The planting distance of the rice rows was 25 cm apart. The number of hills per rows was 400 and number of rows per treatment/plot was 400. The number of seedlings per hill was 30, approximately.

The first seedling associated with early planted treatment was planted in the first week of May. Other treatments and the control were cultivated two weeks later (third week of May) and late planted treatment was also cultivated 2 weeks after other treatments (first week of June). The transplanting day was almost 25 day after nursery bed in all treatments.

Application of different treatments

In this study, after the preparation of the nursery, seedling planting and placement of Hashemi Tarom rice in the studied plots, weed control as well as nitrogen fertilizer were applied in 100 kg twice, once in the first week of transplanting (seedling stage) and the next 30 days later (tillering stage). Potassium hydroxide (KOH), phosphate and zinc fertilizers were used at the same time as seedling planting by 200, 150 and 25 kg/ha, respectively. Two experimental light traps were installed to catch the striped rice stem borer, *C. suppressalis* moths, and determine the peak of the flight period and the exact time of the release of *T. brassicae* and

spray with granular insecticide in the experimental farms. Meanwhile, based on the pest biology, the time of each generation control was determined and carried out. In the early planted treatment, only time management was considered, but sampling in this treatment was carried out based on the measurement of dried infested central seedlings and white heads (WH). The late planted treatment was done in the same way. In the treatments using sex pheromones, 10 white delta traps with yellow adhesives per hectare containing pheromone capsule (Spanish Co. Econex) were installed. Because pheromones were able to work up to 6 months from the time they were installed, they did not change, and throughout the course of each trap, a pheromone capsule was fixed, but the yellow adhesives were replaced every 15 days.

In the treatment of the release of *T. brassicae*, in the first generation of *C. suppressalis*, the parasitoid wasps were released twice. So that it was once before the peak and the other at the same time as the flight peak (a total of 200 Tricho cards). In this treatment, the parasitoid release for the second generation was carried out once simultaneously with the advent of the adult moths and the other at the peak of the insect flight (a total of 200 Tricho cards). In order to release parasitoids in the first and second generations, the Tricho cards were installed on sticks up to half a meter above the ground. The Tricho cards' distance from the farm boundary was about half a meter, and the distance between the Tricho cards was 10 m. In the treatment of 10% Diazinon GR insecticide, 15 kg/ha spray was applied 7 days after the flight peak. In Bt spraying treatments, also 7 days after the flight peak of the moths, spraying was done by a tractor sprayer. In the late planted treatment, which was considered only in terms of time management, like the early planted treatment, no control operation was carried out. Finally, the control treatment was carried out without any spraying operations. In the treatments with the release of *T. brassicae*, in the third generation, the parasitoid wasp was released three times: at the start of the flight period, before the flight peak, and once at the time of the flight peak (a total of 300 Tricho cards).

In order to assess the stem damage on the cultivars, at the vegetative stage, the calculation was performed by counting the dead hearts (DH), taking into account the growth period and at reproductive stage, by counting the white heads (WH) one week before the harvest. So that sampling was done randomly in each farm by selecting 10 samples, in each sample 10 hills (almost 20 tillers was in each hills) and totally 100 hills. The infestation percentage of rice stem and heads were calculated and assessed using the Gomez and Gomez (1984) formula.

The boring activity of *C. suppressalis* larvae during the vegetative stage of rice caused the leaf sheathes of rice seedlings to wither, known as brownish leaf sheath (BS), and the central leaves of tillers to dry up, a

disorder known as the dead heart (DH). The larvae at the 2nd generation coincided with the reproductive and maturing stages of the crop and caused white head (WH), resulting in yield loss (Listinger et al. 2011).

BS or DH or WH=(the total number of infested hills/the total number of tested hills)×(the total number of infested tillers/the total number tillers in infested hills)×100

In order to determine the yield of the given cultivar, after removing two rows of side plants and cutting the plants in the centre of each plot with dimensions of 60 square meters, harvesting (Listinger et al. 2011) and threshing were measured by keeping the moisture content of 14% for each cultivar separately between 1 and 2 weeks.

Statistical analysis

Statistical analysis was performed using SPSS version 24 software and the means were compared and grouped using Tukey's multivariate test.

The money profits of the paddy rice and the white rice of the Hashemi Tarom was calculated using the following formula:

Money profits in paddy rice $= (A - B) \times C$

Money profits in white rice $= ((A \times D) - (B \times E)) \times F$

$A =$ Yield of paddy rice in each treatment (kg/ha); $B =$ Yield of paddy rice in control treatment (kg/ha); $C =$ Price of Paddy rice in 2017 (equivalent to \$1.02); $D =$ Percentage of white rice in each treatment; $E =$ Percentage of white rice in control treatment; $F =$ Price of white rice in 2017 (equivalent to \$2.44).

Results and discussion

The results of analysis of variance of BS data showed that a significant difference was found between treatments ($df = 10$, $F = 432.52$, $P < 0.001$). According to the obtained results, the mean comparison of the data, as well as their grouping (Figure 1) showed that the highest amount of BS (20.46%) was observed in the early planted treatment and it was placed in the first group (group A). Subsequently, the control treatment with 13.68% was in the next group (group B). This value for other treatments was different from the early planted and control treatments and their value was between 1.99 and 8.41% that were grouped in different groups. *T. brassicae*+Bt + sex pheromone had the lowest value, which was placed alone in the last group. Given that the first generation of rice stem borer appears in late April and early May it could be damaging. So the early planted rice is attacked by the first generation and the value of BS is increased. In the present study, in the early planted treatment rice is

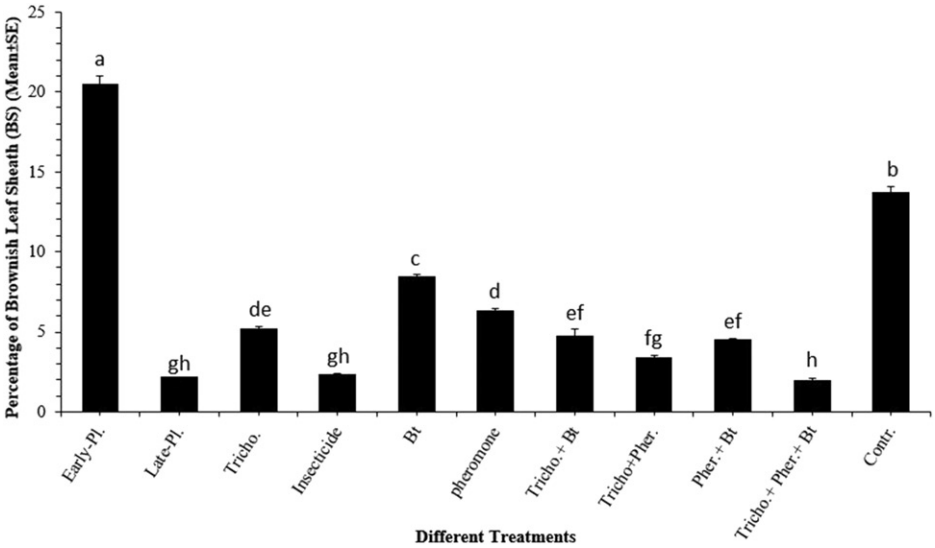

Figure 1. Relationship between the percentage of brownish leaf sheath (BS) of Hashemi Tarom rice to the striped rice stem borer, *Chilo suppressalis* in different treatments. The similar letters indicate no significant difference.

planted in the first week of May, and it was normal that it was attacked by a large number of moths and the damage to BS is increased. While, in the late planting, which was planted late May, because the first generation was almost adult insects and there were few insects in the environment that can oviposit egg and damage, the value of BS was low. In addition, at this time, rice plants were short and did not have good vegetative growth, resulting in less pest attack.

Other treatments were planted at the usual time, all of which was 2 weeks after the early planting. It was observed that in the control treatment, which had no control measurement, BS value was high, but it was the lowest in the integrated treatment of *T. brassicae* + Bt + sex pheromone and the treatment of spray with 10% diazinon granule (Figure 1). One of the reasons for the high efficiency of 10% diazinon granule insecticide at this stage is that the rice height is short, and almost the whole stem is in water, and when the toxin dissolves in water, most of the stem length is impregnated with the solution and the time the larvae will penetrate into the stem it will be killed by exposure to toxic water. It should be noted that the damage of the stem borer at this stage is not serious, as the plant is at the tillering stage and can compensate for the damage caused by the production of more tillers.

Studies conducted by Su et al. (2003) showed that the percentage of BS in the sex pheromone treatment was 32.5%, but in the control treatment 104.7%, a significant difference was found. In the present study, as

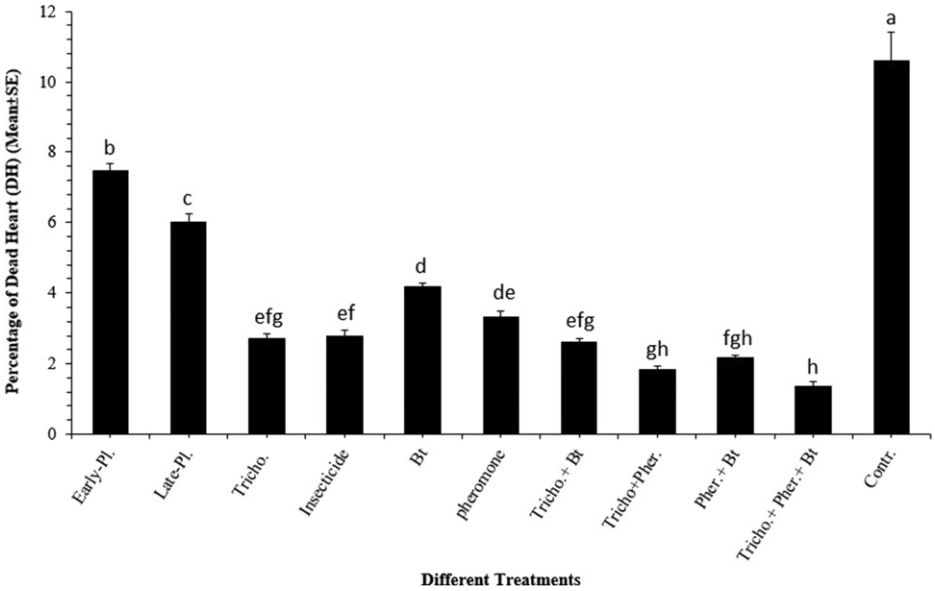

Figure 2. Relationship between the percentage of dead heart (DH) of Hashemi Tarom rice to the striped rice stem borer, *Chilo suppressalis* in different treatments. The similar letters indicate no significant difference.

with the mentioned research, sex pheromone treatment had much less BS compared to the control.

According to the results of analysis of variance obtained from the data of dead heart (DH), a significant difference was found between the treatments ($df = 10$, $F = 221.48$, $P < 0.001$). The results of mean comparison and grouping in Figure 2 show that the highest value of DH was observed in the control treatment, which was placed alone in the first group (group A). Following this, early and late planted treatments were grouped as B and C, the values of which, were 7.48 and 6.02%, respectively. No significant difference was observed between the treatments of *T. brassicae* release and *T. brassicae*+Bt spray and they all belonged to the same group. The values of these treatments were 2.73 and 2.6%, respectively. The lowest value of dead heart (DH), like BS, belonged to the integrated treatment of *T. brassicae* + Bt + sex pheromone, which was placed in the last group.

Despite the fact that the late-planted treatment had the lowest BS, it was observed that for DH level, it is in the second group. After careful examination of the stems in the late planted treatment, it was found that the stems were subjected to second-generation of European corn stem borer, *Ostrinia nubilalis*, and because no control was performed in this treatment, therefore, DH was increased. The study results of Majidishilsar and Ebadi (2013) showed that DH values for the treatments

of early planted, 10% granule spraying, *Trichogramma* parasitoid release, late planted and control on hybrid rice in the farm were 3.22, 1.07, 2.01, 1.6, 2.4 and 5.54%, respectively. In terms of grouping, the results of the research mentioned in the first three groups were similar to those of the present study, so that the control treatment with the highest value was in the first group, the early planted treatment was in the second group, followed by the late planted treatment that was in the third group. The percentage of DH in the present study was much higher than that of Majidishilsar and Ebadi (2013) study and the reason can be the higher susceptibility of Hashemi Tarom rice than hybrid rice, as well as the pest high population in the present research compared to the mentioned research.

The results of analysis of variance for the number of white heads (WH) among the treatments showed that a significant difference was found between them ($df = 10$, $F = 460.71$, $P < 0.001$). The results of the mean comparison of the treatments as well as the grouping showed that the early harvesting had the highest number of white heads and was placed in the first group alone. Bt and 10% diazinon GR spraying treatments were grouped as the groups c and d, respectively. The lowest value of dried white heads was observed in *T. brassicae*+Bt + sex pheromone and early planted treatments, both in g group and their values were 0.34 and 0.36%, respectively (Figure 3). In an attempt to incorporate biological control into rice

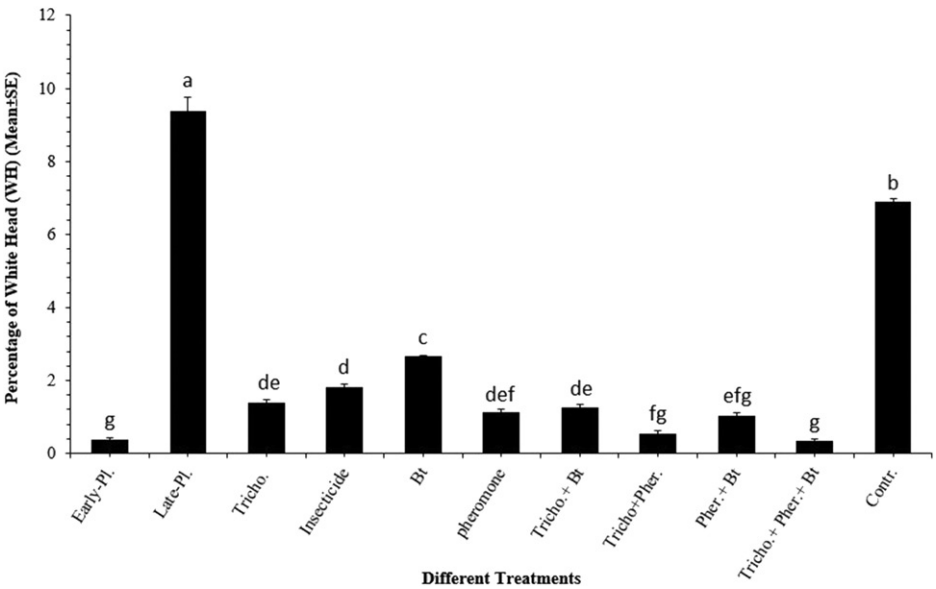

Figure 3. Relationship between the percentage of white head (WH) of Hashemi Tarom rice to the striped rice stem borer, *Chilo suppressalis* in different treatments. The similar letters indicate no significant difference.

stem borer management in China, the egg parasitoid, *Trichogramma chilonis* lshii was released either alone or dusted with *Bacillus thuringiensis* Berliner. With the addition of *B. thuringiensis*, *T. chilonis* provided ca. 70% control (13.3% higher than with *T. chilonis* alone) (Chen et al. 2007). In this regard, Srivastava et al. (2003) reported that rice planting time setting, especially in early maturing cultivars or early planting of bred cultivars, causes the rice plant passing through the critical stage, which is the reproductive stage, and its damage is reduced. This is, in fact, a confirmation of the present study. They also showed that the growth of the rice plant becomes complete at the stage the occurrence of larvae infestation does not coincide with the plant. They considered this as a part of the host resistance mechanism called the escape mechanism. At this stage, the late planted treatment and the control treatment showed the highest infestation. The late planted treatment at the reproductive stage was fresher and greener at the end of the season than other treatments because the rice plant was planted after 15 days to one month from the rest of the treatments. Also, because the rice plant was at the stage of reproduction and head formation, it attracted more stem borers, and the population of this pest was higher in this treatment. Of course, at this time, coincided with the second generation of pest, more populations were created and more damages were made. The early planted treatment due to early planting, entered reproductive stage early, made heads, the grains were hardened earlier in the panicle early and the least infestation was observed in the treatment. The important point of the treatment of spray with 10% diazinon granule is that after the planting date, the percentage of damage was higher than other treatments. In this way, for the percentage of BS, this treatment was grouped in group 7, while for DH, this treatment was in the fifth group, and then for WH, 10% diazinon treatment was placed in the fourth group. The reason for this is that by increasing vegetative growth of the plant, the stem borer larvae can enter the stem tissue from the higher parts of the stem that is not in contact with the water. Therefore, soluble chemicals in water would have no necessary efficiency, the percentage of larval death is reduced and the damage is also increased.

The obtained data from the results of analysis of variance of the yield of paddy rice from the farms where the treatments were implemented indicate that a significant difference is found between them ($df = 10$, $F = 800863.34$, $P < 0.001$). The highest amount of paddy rice yield per hectare was related to the farm where *T. brassicae* + Bt + sex pheromone integrated treatment was applied. In this treatment, 5910 kg of paddy rice yield was harvested per hectare that was in the first group (a). The lowest amount of yield was related to the late planted treatment (4142 kg/ha) that was in the last group (i) (Figure 4). The normal and

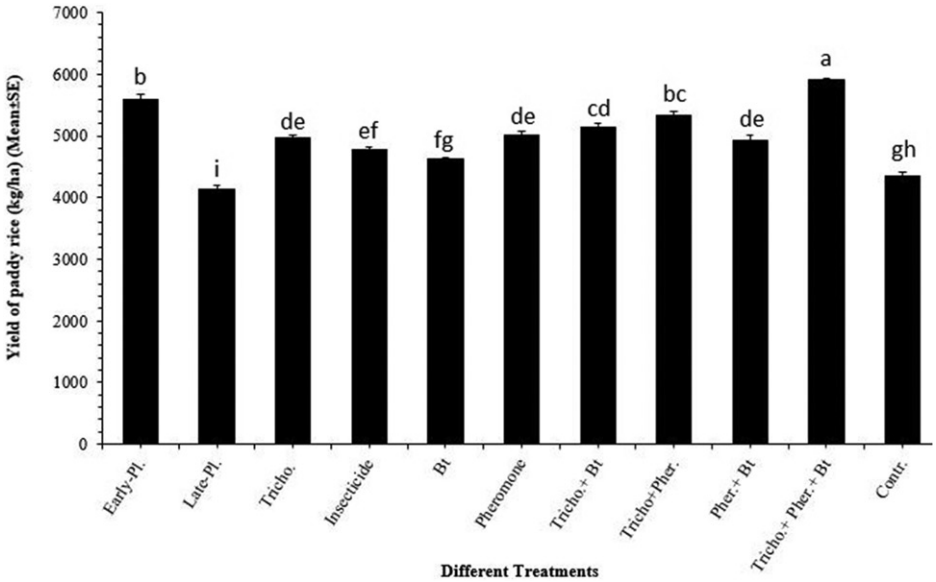

Figure 4. Relationship between the yield of paddy rice (kg/ha) of Hashemi Tarom rice to the striped rice stem borer, *Chilo suppressalis* in different treatments. The similar letters indicate no significant difference.

standard level of Hashmi Tarom paddy rice yield of Mazandaran province farms is between 4500 and 5000 kg, while in this study in the treatments with sex pheromone or *T. brassicae* parasitoid, more than 4900 kilograms of paddy rice were harvested, or even this value in the integrated treatment of *T. brassicae*+Bt + sex pheromone, also reached 5910 kg/ha. While this treatment was cultivated with the control treatment at the same time, it indicates that integrating the use of *T. brassicae* parasitoid with sex pheromone and Bt can be associated with as much as 1556 kg product increase. Studies have shown that egg parasitoids such as *Trichogramma* wasps are very important in reducing the population of rice stem borer (Kaur et al. 2000).

According to the results of the present study, comparison of the yield of the integrated treatment of *T. brassicae*+Bt + sex pheromone that had the best yield with the control treatment, and the damage caused by *C. suppressalis* on Hashemi Tarom cultivar in the farm under controlled conditions it can be concluded that by 1% BS, vegetative stage yield has been reduced up to 133.10 kg; by 1% WH, reproductive stage yield has been reduced up to 168.76 kg and by 1% DH, the yield has been reduced up to 237.92 kg under natural conditions.

In this research, the late planted treatment at the reproductive stage was fresher and greener at the end of the season than other treatments, because the rice plant was planted after 15 days to one month after the

early and on time planted treatments. Also, because the rice plant was at the stage of reproduction and panicle formation, it attracted more stem borers, and the population of this pest was higher in this treatment.

By study the management of rice and wheat stem borers in rice and wheat cultivation systems in Pakistan, Nepal, India, and Bangladesh, it was reported that setting rice planting time, especially for early cultivars or early planting of bred cultivars, makes the rice plant passes a susceptible stage, reproductive stage, and its damage is reduced (Srivastava et al. 2005). The results of the research on the effect of three planting dates on the resistance of rice varieties to the yellow stem borer in Pakistan have shown that the early planting had the least infestation compared to other planting dates (Sarwar 2012). The results of these researchers are similar to those of the present study.

In the present study, the treatment of Bt microbial insecticide had low yield on reducing the damage of rice stem borer, and some factors may be the reasons for this weakness, such as 1) high temperature of the environment, given that the effect of Bt is reduced at high temperature, as well as direct sunlight, and the temperature was high at the time of performing the experiment, 2) on the other hand, because rice stem borer larvae enter the stems of rice after hatching and passing time, Bt solution spray does not have much effect as this acts digestive and should be eaten by the larvae.

In the present study, in all treatments that were planted at the normal time (except for the early and late planted treatments), the third generation of stem borer emerged when all rice heads were fully revealed and the milk-coloured material was in the panicle grain, but the third-generation damage causes the grains not hardening thoroughly and forming a semi-fine grain. So, the percentage of the grain formation indicates to what extent the yield of the treatments was effective and according to the results, it can be concluded that 10% diazinon granular as well as Bt treatments have a low yield on the control of the third generation of stem borer.

According to the results of variance analysis of the formation percentage of paddy rice to white rice, a significant difference is found between the treatments ($df = 10$, $F = 45.66$, $P < 0.001$). The grain formation percentage was observed among the treatments between 50 and 63%. The highest formation percentage of paddy rice to white grains belonged to the integrated treatment of *T. brassicae*+Bt + sex pheromone, which with 63% was alone in the first group. Following this, the integrated treatment of *T. brassicae*+sex pheromone with 60% was in group bc. The lowest percentage of conversion of paddy rice to white rice was observed in the late planted treatment (50%), which was in the last group (c), while this

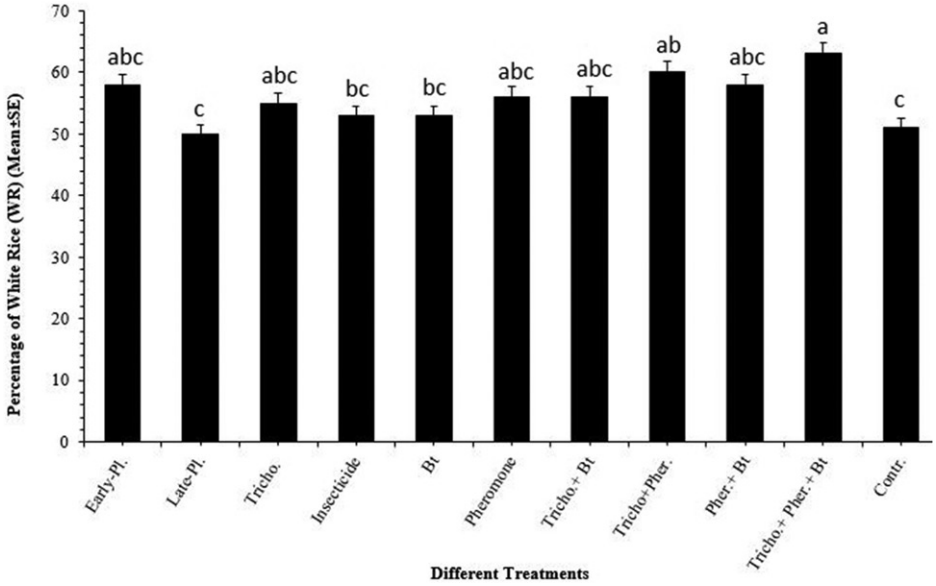

Figure 5. Relationship between percentage of white rice of Hashemi Tarom rice to the striped rice stem borer, *Chilo suppressalis* in different treatments. The similar letters indicate no significant difference.

value was 51% for the control treatment (Figure 5). According to the results, it can be noted that the non-use of chemical pesticides and the use of integrated and biological methods can increase the yield of rice products. Because the average percentage of white rice production in Hashemi Tarom rice cultivar was between 55 and 60% in the factory, but the present study showed a significant increase of 63% in the integrated treatment of *T. brassicae*+Bt + sex pheromone (Figure 5). The value of the information shown in Figure 5 when is determined that in Table 1, the combined treatment of sex pheromone + Bt in the amount of profit from paddy rice was placed at the seventh place, but this treatment in the rate of profit from white rice was ranked in fifth place with two steps of climbing. And the reason is the percentage of white rice shown in Figure 5, so that the treatment listed was 58% in the third place. The reason for that was the percentage of white rice, as shown in Figure 5, so that the mentioned with 58% was listed in the third place.

Table 1 shows the cost information for each treatment and the financial profitability of paddy and white rice. Based on this information, the integrated treatment of *T. brassicae*+sex pheromone + Bt and following a very small interval of spray treatment (10% Diazinon GR) had the highest amount of costs compared to other treatments with 39.39 and 38.27 dollars, respectively. In the same table, the results of paddy and white rice profits in each treatment indicated that the highest amount of profit

Table 1. Amount of cost, financial gain in paddy rice and white rice in Hashemi Tarom rice per hectare in 2017.

Treatment	Cost ($)	Money profits in paddy rice ($)	Money profits in white rice ($)
Early planted	0	1270.92	2507
Lately planted	0	−216.24	−364.88
T. brassicae	4.25	631.38	1255.65
10% Diazinon GR	38.27	435.54	764.67
Bt	17.01	273.36	559.05
sex pheromone	18.01	677.28	1438.48
T. brassicae + Bt	21.26	800.70	1603.81
T. brassicae + sex pheromone	22.26	1002.66	2395.25
sex pheromone + Bt	35.02	577.32	1544.67
T. brassicae + sex pheromone + Bt	39.39	1587.12	3666.73
Control	0	0	0

is achieved in the integrated treatment of *T. brassicae*+sex pheromone + Bt compared to the control, which is in the first place compared with other treatments.

In general, the results of Figures 1–5 and Table 1 confirm this that the combination of different treatments is useful. For example, in Figure 1, when *T. brassicae*+sex pheromone or *T. brassicae*+Bt treatments were applied, not only BS was decreased, but also there was significant difference between binary treatments and single treatments. The usefulness of the combination of treatments can be realized in Figures 1–5, in which the combination of *T. brassicae*+Bt + sex pheromone had not only the lowest BS, DH, WH, and the highest amount of paddy and white rice percentage, but also has a significant difference with other treatments and was better than them. Also, the results presented in Table 1 showed the profit level of *T. brassicae*+Bt + sex pheromone treatment, which showed the highest financial benefit of paddy and white rice compared to control in this combination.

Since each of the factors used in this experiment affects different life stages of the pest and reduces its population, their simultaneous use can further reduce the damage by the pest. For example, *Trichogramma* wasp parasitized the pest eggs and also Bt toxin caused the deaths of the larvae. In addition, the pheromone caused the adult moths capture and reduced its population. The total of these factors led to a decrease in damage and a rise in performance.

Also, the results presented in Table 1 showed the profit amount of combined treatment of *T. brassicae*+Bt + sex pheromone, had the highest financial benefit of paddy rice and white rice compared to control treatment. The results of this research showed that the best yield in all traits was related to the integrated treatment of *T. brassicae*+sex pheromone + Bt.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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