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Effects of Host Plant Cultivar and Insecticide Type on Rice Damage and Growth of *Chilo suppressalis* (Lepidoptera: Crambidae) Larvae in Semi-field Conditions

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ABSTRACT

Rice striped stem borer, *Chilo suppressalis* (Walker, 1863), is considered as a major destructive pest in paddy fields in the most regions of Iran. In this study, the impact of the rice cultivars, Tarom and Shiroudi, and the insecticides, cypermethrin, tebufenozide and the emulsion and granule formulations of diazinon were examined on the damage indices, percentages of dead heart and whitehead. The study was performed as factorial randomized complete block design using artificial infestation in semi-field conditions in Amol County. No significant interaction was found between rice cultivar and insecticide for all indices in both vegetative and reproductive stages (P>0.05). The results of main effects in both phenological stages indicated that the weight of live larvae and damage indices were significantly higher on Tarom than those of Shiroudi (P≤0.05), while no significant difference was detected in larval mortality on the cultivars (P>0.05). The main effects of insecticide were significant for all biological and damage indices (P≤0.05). The efficacies of tebufenozide and cypermethrin in terms of larval mortality were 47.57 and 74.90 % at vegetative stage reaching to 79.15 and 92.08% at reproductive stage, respectively. The

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lowest efficacy in terms of larval mortality (73.33%) was obtained on plants treated by diazinon emulsion. At reproductive, the survived larvae weighed 170.80 mg.seedling^{-1} and the corrected whitehead index compared to the control reached 50.04% on plants treated by diazinon emulsion. According to the results, tebufenozide, regarding its relatively high efficacy and environmental compatibility, is suggested to be assessed further for integrated *C. suppressalis* management in the field conditions.

Keywords: Striped stem borer, Dead heart, Whitehead, Rice cultivar, Larval weight, Insecticide efficacy

INTRODUCTION

Rice (*Oryza sativa* L.) is considered as a primary food source in Iran and worldwide. (Tabari, Fathi, Nouri-Ganbalani, Moumeni, & Razmjou, 2017). Mazandaran province located in the north of Iran is the largest rice-producing area of Iran, with 235,000 hectares of rice cultivation (Youseftabar, Heidari Sharifabad, & Majidi Heravan, 2020). The striped stem borer*, Chilo suppressalis* (Walker, 1863), is one of the main destructive pests of the rice crop in Iran (Tabari et al., 2017) and the world (Lei, Zhang, Yun, Zhou, & Peng, 2020). This insect was introduced as a key pest in rice field of the Northern Iran in 1973 (Amooghli-Tabari et al., 2015). The adult insects lay their eggs on blade and sheath of the rice leaves in the nursery and field. The larvae enter into leaf sheath and feed on tissues causing yellowing and withering of tillers or dead heart at vegetative stage, usually 30 to 45 days following rice transplanting. The larvae also conduce to whitehead later in the reproductive stage of rice crop (Amooghli-Tabari et al., 2015). If *C. suppressalis* is not controlled in accurate time, the yield will be considerably reduced. Annual pest damage has been reported variably from 5 to 60% (Tabari et al., 2017).

The simultaneous using pest-resistant cultivars and insecticides has been suggested as IPM strategy in many injurious pests (EL-Gammal, EL-khyat, Abd El-Zaher, & Morsy, 2022). The use of resistant cultivars in pest control is perceived as a friendly environmental method (Tabari et al., 2017). In the present study, the commercial Iranian rice cultivars, Tarom and Shiroudi were used, previously reported as susceptible (Amouoghli Tabari et al., 2005) and tolerant (Mohadesi et al., 2009) to *C. suppressalis,* respectively. From the agronomic point of view, these cultivars are respectively characterized as early and medium maturity cultivars (Oskou, Nasiri, Omrani, & Zare, 2016). Through classical plant breeding method by crossing two rice cultivars (Tarom Dilmani × Khazar), the cultivar Shiroudi was introduced by the Iranian Rice Research Institute, known as a resistant to blast disease with high performance (Mohadesi et al., 2009). Tarom, a susceptible cultivar to *C. suppressalis*, has a lower performance than Shiroudi and known as a native and odorous rice, widely cultivated in the north of Iran (Tabari et al., 2017).

The use of chemical insecticides has been the main *C. suppressalis* controlling strategy in Iran and majority parts of the world so far (Mirhaghparast, Zibaee, Sendi, Hoda, & Fazeli-Dinan, 2015). Among the examined insecticides in present study, cypermethrin has not yet been registered for controlling of rice pests, although its use is common in paddy fields (Singh & Singh, 2020). Cypermethrin, as a synthetic pyrethroid insecticide, is a long-lasting and environmentally hazardous insecticide with residual effect on rice husk (Teló et al., 2017). Diazinon, as a common organophosphate insecticide, has a long history of use in the paddy fields of northern Iran to control *C. suppressalis* (Mirhaghparast et al., 2015). In Mazandaran province, it widely enters water and environment and causes contamination in food chain (Won & Yang, 2015). In recent years, tebufenozide has been introduced as a specific and ecdysone agonist insecticide against lepidopteran pests including *C. suppressalis* (Roscoe, Forbes, Lamb, & Silk, 2020). Tebufenozide interferes with the hormonal control and molting of lepidopteran larvae, while it has low toxicity to non-target organisms (Roscoe et al., 2020).

In the current circumstance that increasing of crop production through expanding the cultivated area of crops, especially rice, has faced with limitation of climatic, social and financial resources in Iran, it is necessary to improve an integrated rice striped stem borer management relying on available and common resources to reduce pest damage. The aim of present research was to evaluate the efficacy of four common insecticides in controlling of the striped stem borer on Tarom and Shiroudi cultivars in Amol paddy fields using examination of biological and damage indices.

MATERIAL AND METHODS

The current research was conducted in the Rice Research Institute of Iran, Deputy of Mazandaran, Department of Plant protection, located in Amol county (longitude: 52° 23' E latitude: 36° 28' N and height: 23.7 meters above sea level) in 2019, based on the factorial randomized complete block design. The first factor consisted of Tarom and Shiroudi rice cultivars and the second one included the insecticides cypermethrin (EC 40%, Golsam company of Gorgan[1]), Tebufenozide (SC 20%, Nippon Soda Company of Japan[2]), Diazinon emulsion (EC 60%, Golsam company of Gorgan), Diazinon granule (G 10%, Golsam company of Gorgan) and the control (water only). The experiments were performed in semi-field conditions inside the screen-confined pots in 5 replicates.

Culturing of the host-plants

The seeds of Tarom and Shiroudi were obtained from Iran Rice Research Institute, Deputy of Mazandaran and were used in transplanting nursery for planting. 15% salt water solution was used to remove unhealthy rice seeds. After thoroughly rinsing with water, the seeds were soaked in water for 24 h. Disinfection of seeds was performed using carboxin thiram (40% FS) at 3 $ml.kg^{-1}$seed for 24 h. The seeds of Shiroudi and Tarom were kept in a hothouse at 35±1°C for 3 to 5 days, respectively. The germinated seeds were transferred to the nursery to prepare transplants. Transplants were planted in plastic pots with 30 cm diameter and 10 L volume (Tabari et al., 2017). Three seedlings with 3 to 4-leaves (25 to 30-day old transplants) in a pot were regarded as an experimental unit. After drying and crushing, the soil originally collected from the paddy fields of surrounding area was used to fill the pots up to a 5 cm from their surfaces. Agronomic cares were carried out based on the technical recommendation

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[2]Imported by Raha Andish Kavan Chemical Office Address: No. 18, North Khazar St. Elahiyeh, Tehran, Iran.

of the Iranian Rice Research Institute. Irrigation was done every other day until the middle of plant ripening. Weeding was done manually at intervals of every 15 days. Fertilization was carried out using urea (46% N_2), triple superphosphate (46% P_2O_5) and potassium sulfate (K_2O 50%) at the rate of respectively 3, 3 and 4 $g.pot^{-1}$ mixed with soil before transplanting. Furthermore, 25 days after transplanting, top-dressing was done with 3 $g.pot^{-1}$ of urea and 40 days later with 3 $g.pot^{-1}$ of each of urea and potassium sulfate fertilizes. (Majidi-Shilsar, 2015). The experimental pots were covered by net and kept outside in field conditions with a distance of 100 cm until the end of experiments.

Rearing of rice striped stem borer larvae

Male and female insects were collected from Amol paddy fields using light traps and settled on Fajr rice cultivar .The use of this cultivar in insect culture was due to prevention of the rice striped stem borer adaptation to the experimental cultivars of Tarem and Shiroudi. The egg masses were obtained in laboratory as described by Majidi-Shilsar (2015). Newly-hatched larvae were used for infestation of the experimental rice seedlings.

Experiments Implementation

Two weeks after transplanting, 15 newly-hatched larvae per rice seedling (totally 45 larvae per pot) were transferred on the leaf auricle so that they had access willingly to the feeding area. To ensure the larvae settlement and escaping prevention, a cylindrical mesh cage (30 × 90 cm) was laid on each seedling for 24 h (Tabari et al., 2017). One week after artificial infestation, i.e. 21-day post-transplanting, insecticidal treatments were performed using a 2 L handheld sprayer. The insecticides were applied according to the manufacturer recommendations as 0.175 $L.ha^{-1}$ of cypermethrin, 0.75 $L.ha^{-1}$ of tebufenozide, 2 $L.ha^{-1}$ of diazinon emulsion and 15 $kg.ha^{-1}$ of diazinon granule. The diazinon granule was applied as mixed with dry sand into water of pots for optimal coverage as well as better absorption by the roots.

Measurement of Insecticidal efficacy and damage indices

In the vegetative stage of rice plant, 21 days after artificial infestation of host plants with larvae, one of the three seedlings of experimental pots was excised at the soil level. The number of tillers with dead heart symptoms (Dh) was counted and recorded as percentage using the equation, Dh%=(No. of Dh/total No. of tillers) ×100 (Mahapatra & Nanda, 1996). The number and weight of live larvae were also recorded. Moreover, the percentage of larval mortality in each seedling was recorded compared to the initially artificial infestation.

In reproductive stage of rice plant, following excision of the second seedling, the number of tillers with whitehead symptoms (Wh) was counted and recorded as percentage using the equation Wh%=(No. of Wh/total No. of tillers) ×100. The number and weight of live larvae and the mortality percentage compared to the initial plant infestation with larvae were recorded. At this phenological stage, the number of pupae on the seedling was also counted.

The efficacy of insecticide treatments was assessed using Abbott's formula, by which the percentage of the damage indices and larval mortality were corrected compared to the counterpart data in control (Abbott, 1925).

Data analysis

Prior to the statistical analysis, the normality and homogeneity of variances were subjected to Jarque-Bera Test (Jarque & Bera, 1987) and Levene's Test (Levene, 1960), respectively, and if necessary, the data were converted to $(x+1)^n$. Analyses of variance (ANOVA) were performed on all biological and damage indices in factorial randomized complete block design. Comparisons of means were made using Fisher's protected least significant difference (LSD) procedure. Pearson correlation analysis was performed between indices of damage and biological characteristics. All statistical analyses were performed using SAS software version 9.4 (SAS Institute, Inc, 2004).

RESULTS

Assessment of plant damage and biological characteristics in the vegetative stage of rice

The results of ANOVA in the vegetative stage of the rice plant demonstrated that the main effects of cultivar and insecticide on dead heart ($F=25.26$; $df=13,36$; $P\leq0.0001$), the number of live larvae ($F=45.1$; $df=13,36$; $P\leq0.0001$), live larvae weight ($F=47.23$; $df=13,36$; $P\leq0.0001$) and larval mortality ($F=39.33$; $df=13,36$; $P\leq0.0001$) were significant. The block effect and the interaction effect of cultivar × insecticide on all variables were not significant ($P>0.05$). The results of main effects of cultivar revealed that the dead heart percentage, the number of survived larvae and the larval weight were significantly higher in Tarom than those in Shiroudi (Table 1).

Table 1. The main effect of cultivar on the biological characteristics of *C. suppressalis* larvae and their damage indices (Mean±SE) [β] in the vegetative stage of rice plant [€].

Rice cultivar [¥]	Dead heart (%)	Live larvae gain (per seedling)		Mortality (%)
		Number	Mass (mg)	
Shiroudi	10.67±1.08 b	7.48±0.73 b	144.32±14.35 b	50.13±4.87 a
Tarom	23.76±2.23 a	8±0.74 a	203.44±19.23 a	46.67±4.94 a

[SE] Standard Error
[β] Within each rice cultivar, all insecticide-treated data (Including control) were pooled (n=25).
[€] Sampling made at 14-day post-insecticide application (35 day post-transplanting).
[¥] Each 14-day old seedling (3 seedings per pot) was infested by 15 newly-hatched larvae.
Means followed by the same letters in each column are not significantly different (LSD Test, P<0.05).

The main effects of insecticide indicated that the control- and cypermethrin- treated plants had respectively the highest (30.74%) and lowest (7.52%) percentages of dead heart. The lowest number (3.6) and weight of survived larvae (80.2mg) on plants were achieved through the cypermethrin application. The highest percentage of larval mortality was associated with cypermethrin treatment (76%) (Table 2).

Table 2. The main effect of insecticide on the biological characteristics of *C. suppressalis* larvae and their damage indices (Mean±SE) [β] in the vegetative stage of rice plant [€].

Treatment [¥]	Dead heart (%)	Live larvae gain (per seedling)		Mortality (%)
		Number	Mass (mg)	
Tebufenozide (Sc)	16.64±2.62 b	7.5±0.22 b	168.7±10.83 b	50±1.49 c
Diazinon (Ec)	15.03±2.32 b	6.4±0.31 c	142.2±10.18 c	57.33±2.04 b
Diazinon (G)	16.14±2.44 b	6.9±0.28 bc	154.3±10.57 bc	54±1.85 bc
Cypermethrin (Ec)	7.52±1.15 c	3.6±0.22 d	80.2±7.52 d	76±1.47 a
Control	30.74±3.72 a	14.3±0.15 a	324±17.3 a	4.67±1.02 d

[SE] Standard Error
[β] Within each insecticide-treated experimental unit, all rice cultivars data were pooled (n=10).
[€] Sampling made at 14-day post-insecticide application (35 day post-transplanting).
¥ Each 14-day old seedling (3 seedings per pot) was infested by 15 newly-hatched larvae.
Means followed by the same letters in each column are not significantly different (LSD Test, P<0.05).

Cypermethrin possessed the highest percentage of efficacy in decreasing the dead heart percentage and the survived larvae weight on rice plants, followed by diazinon emulsion. Tebufenozide represented the least insecticidal efficacy (Fig. 1).

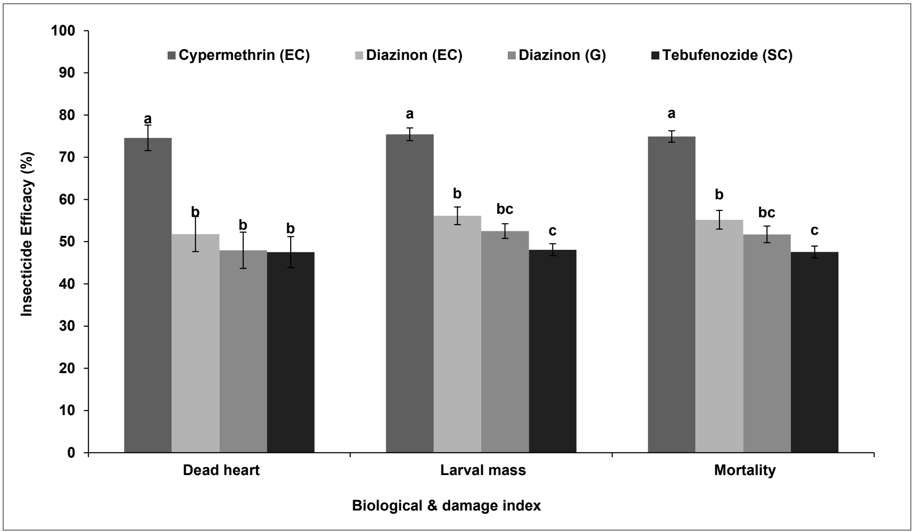

Figure 1. The percentage of insecticide efficacy (mean ± SE) at vegetative stage of the rice plant in terms of damage indices of *Chilo suppressalis* larvae. Within each insecticide-treated experimental unit, all rice cultivar data were pooled (n=10). The insecticide efficacy was calculated as corrected-damage in control using Abbott's formula (1925). (Within each damage index, columns carrying different letters are significantly different (P≤0.05, LSD Test).

Assessment of plant damage and biological characteristics in the reproductive stage of rice

The results of ANOVA in the reproductive stage of the rice plant showed that the main effects of cultivar and insecticide on whitehead (F=67.99; df=13,36; P≤0.0001), the number of live larvae (F=56.06 ; df=13,36; P≤0.0001), weight of live larvae (mg) (F=32.62; df=13,36; P≤0.0001), larvae mortality (F=42.64; df=13,36; P≤0.0001) and the number of pupae (F=42.13; df=13,36; P≤0.0001) on the rice plant were significant. The effects of block and cultivar × insecticide interaction were not significant on the all studied features (P>0.05). The results of main effect of cultivar revealed that the whitehead percentage and the larval weight were significantly higher in Tarom than those in Shiroudi (Table 3).

Table 3. The main effect of cultivar on the biological characteristics of *C. suppressalis* larvae and their damage indices (Mean±SE) β in the reproductive stage of rice plant €.

Rice cultivar ¥	Whitehead (%)	Live larvae gain (per seedling)		Mortality (%)	Pupa (No. seedlings-1)
		Number	Mass (mg)		
Shiroudi	17.73±1.86 b	4.84±0.92 a	195.84±37.32 b	67.73±6.13 a	4.12±0.96 a
Tarom	44.47±5.09 a	5.24±0.94 a	260.12±47.08 a	65.07±6.26 a	4.6±1.01 a

SE Standard Error
β Within each rice cultivar, all insecticide-treated data (Including control) were pooled (n=25).
€ Sampling made at 69 and 44 days post-insecticide application in Shiroudi and Tarom, respectively.
¥ Each 14-day old seedling (3 seedinligs per pot) was infested by 15 newly-hatched larvae.
Means followed by the same letters in each column are not significantly different (LSD Test, P<0.05).

The main effects of insecticide indicated that the control- and cypermethrin- treated plants had respectively the highest (62.16%) and lowest (13.77%) percentages of whitehead. At the end of the experiment, the lowest number (1.1) of survived larvae and their weight (54.1mg) were detected on the plants sprayed with cypermethrin. However, the number of pupae on the tebufenozide-sprayed plants was not significantly different from that on cypermethrin-sprayed plants. (Table 4).

Table 4. The main effects of insecticide on the biological characteristics of *C. suppressalis* larvae and their damage indices (Mean±SE) β in the reproductive stage of rice plant €.

Treatments ¥	Whitehead (%)	Live larvae gain (per seedling)		Mortality (%)	Pupa (No. seedlings-1)
		Number	Mass (mg)		
Tebufenozide (Sc)	20.88±3.23 c	2.9±0.18 c	119±9 c	80.67±1.2 b	0.8±0.2 c
Diazinon (Ec)	29.67±4.08 b	3.7±0.15 b	170.8±10.49 b	75.33±1.02 c	3.5±0.22 b
Diazinon (G)	29.01±4.64 b	3.6±0.16 b	165.8±11.66 b	76±1.09 c	3.1±0.18 b
Cypermethrin (Ec)	13.77±1.93 d	1.1±0.18 d	54.1±9.76 d	92.67±1.2 a	0.7±0.15 c
Control	62.16±9.48 a	13.9±0.18 a	630.2±27.62 a	7.33±1.2 d	13.7±0.21 a

SE Standard Error
β Within each insecticide-treated, all rice cultivars data were pooled (n=10).
€ Sampling made at 69 and 44 days post-insecticide application in Shiroudi and tarom, respectively.
¥ Each 14-day old seedling (3 seedings per pot) was infested by 15 newly-hatched larvae.
Means followed by the same letters in each column are not significantly different (LSD Test, P<0.05).

Cypermethrin was represented by the highest efficacy in terms of decreasing the whitehead percentage and the survived larvae weight on the rice plant, followed by tebufenozide treatment (Fig. 2).

The positive and significant correlations were detected between dead heart percentage and larval weight in the vegetative (r=0.917) and reproductive (r=0.766) stages of rice plants (P≤0.0001). Furthermore, there were negative and significant correlations between whitehead percentage and larval mortality in the vegetative (r=-0.699) and reproductive (r=-0.771) stages of rice plants (P≤0.0001).

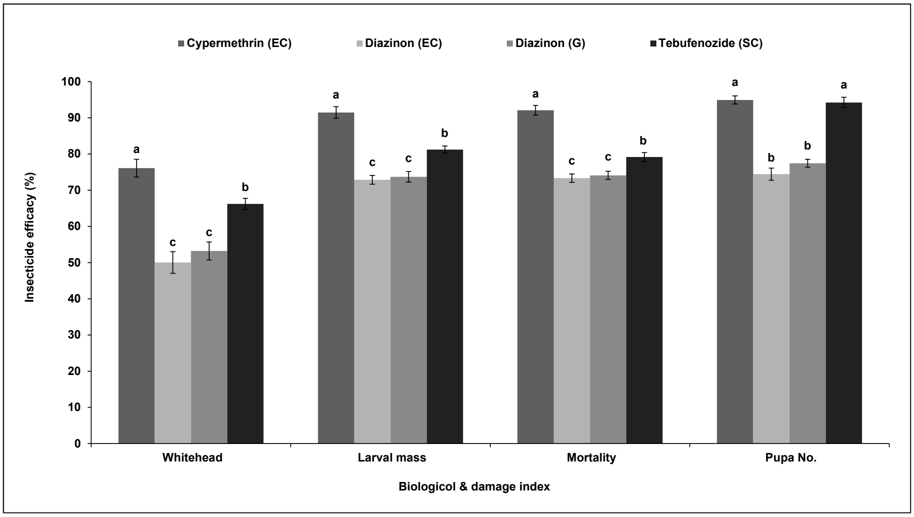

Figure 2. The percentage of Insecticide efficacy (mean ± SE) at reproductive stage of the rice plant in terms of damage indices of *Chilo suppressalis* larvae. Within each insecticide-treated experimental unit, all rice cultivar data were pooled (n=10). The insecticide efficacy was calculated as corrected-damage in control using Abbott's formula (1925) (Within each damage index, columns carrying different letters are significantly different (P ≤ 0.05, LSD Test).

DISCUSSION AND CONCLUSION

The current study represented that the cultivar × insecticide interaction effect on *C. suppressalis* larvae was not significant in all of the examined features (P>0.05). Wilson et al. (2020) in their research on the interaction effects of cultivar, nitrogen fertilization and insecticide on sorghum field infested with the sugarcane aphid, *Melanaphis sacchari* (Zehntner, 1897), showed that the interaction effect of sorghum cultivars on the aphid during the application of Flupyradifurone insecticide in South Carolina was not significant. In contrast, many researchers have demonstrated that the interaction effect of insecticides application and relative resistant plants on piercing-sucking insects such as aphids led to a decrease in the pesticides concentration for the pest controlling on resistant cultivars (Heinrichs, Fabellar, Basilio, Wen, & Medrano, 1984; Kea, Turnipseed, & Carner, 1978; Taksdal, 1992). Reduction in amount of insecticide application against the reared insects on the cultivars with relative resistance, ultimately elicits costs reduction (Heinrichs et al., 1984), a reduction in detrimental environmental effects on natural enemies (Van Emden, 1990) and predation reinforcement (Nicol, Wratten, Eaton, & Copaja, 1993), reducing insecticides resistance to pests (Mohamad & Van Emden, 1989) and a possibility of delaying resistance-breaking in pest-resistant cultivars (Van Emden, 1991). Contrary to the above-mentioned researches, no interaction effect was observed between insecticide and rice cultivar, presumably owing to low difference in resistance between rice varieties, particularly in the semi-field conditions of the present study.

The results revealed that at the end of the experiment the number of *C. suppressalis* pupae on the rice plants was higher on Tarom cultivar than Shiroudi, even though the difference was not statistically significant (Table 4). According to Tabari et al. (2017), Shiroudi with more tillers showed higher antibiosis resistance to *C. suppressalis* compared to Tarom cultivar. Shiroudi was recommended as a useful rice cultivar in integrated pest management (IPM) as well as breeding programs. Ghaninia and Amooghli-Tabari (2016) also demonstrated that the tendency of *C. suppressalis* adults toward Shiroudi is less than Tarom.

The main effects of insecticide in the rice reproductive stage represented cypermethrin with the highest mortality and lowest larval biomass on rice plants (Table 4) and accordingly the highest efficacy compared to other insecticides (Figure 2). Horgan, Peñalver-Cruz, & Almazan (2021) in greenhouse conditions showed that cypermethrin decreased oviposition of the brown plant hopper, *Nilaparvata lugens* (Stal) in resistant and susceptible rice cultivars, leading to high controlling effect on nymph population. Nevertheless, Horgan et al. (2021) pointed out the adverse effects of cypermethrin including phytotoxicity, reduction of rice yield and tillers (Horgan et al., 2021). Cypermethrin was also reported as a carcinogenic and hazardous substance for environment in some countries (Singh & Singh, 2020). Thus, despite the high efficacy of cypermethrin on larvae in the present study, considering the reports of its adverse effects on health and environment in the literature, the use of this insecticide is not advised in the paddy fields.

The efficacy of tebufenozide particularly in the rice reproductive stage was more than 66% in terms of biological and plant damage indices (Figure 2). Tebufenozide has less detrimental effects on environment, especially against honeybees (Abramson, Squire, Sheridan, & Mulder Jr, 2004). He et al. (2008) demonstrated that populations of the 4th-instar *C. suppressalis* larvae were susceptible to tebufenozide in four regions of China, but in some regions, partial resistance to diazinon was detected. Roscoe et al. (2020) stated that tebufenozide act mainly in the molting stage of lepidopteran larvae. Tebufenozide needs more time to be effective on insect larvae (He et al., 2008). Moreover, in the present study, the slow effectiveness of this insecticide was revealed by comparing the results of biological and damage indices between the phenological rice stages (Figures 1 and 2). This insecticide belongs to the benzoylurea group, recommended for controlling the rice stripe stem borer (He et al., 2008; Yu et al., 2016). From this group, hexaflumuron was also suggested as an alternative insecticide to diazinon in paddy fields (Mirhaghparast et al., 2015). Additionally, the environmental compatibility of Tebufenozide and its safety for non-target arthropods have been reported (Roscoe et al., 2020).

According to the studies of Mirhaghparast et al. (2015), the efficacy of diazinon emulsion gradually decreased during the long-term application, probably due to selection pressure in repeated use of organophosphorus pesticides in paddy fields. Emphasizing the lack of *C. suppressalis* larvae resistance to diazinon in their studies, Alhosseini et al. (1998) indicated that the efficacies of diazinon granule were 79.7 and 64.01%, in terms of dead heart and whitehead percentages, respectively

(Alhosseini, Heidari, & Mostofi-Pour, 1998). In the present study under semi-field conditions, the efficacies of 47.97 and 53.23% on *C. suppressalis* larvae were achieved for diazinon granule in terms of the respective criteria at 14-day post-infestation. Hassani, Hajiqanbar, Jalaeian, Moharramipour, & Moharramipour (2022) reported an effectiveness of 60.92% under natural field conditions for diazinon granule in terms of dead heart at 12 days after insecticide application. The efficacy of diazinon granule based on the reduction of whitehead percentage was more than its emulsion formulation (Figure 2). In contrast, under natural field conditions and rice-based double-cropping system, Amiri et al. (2017)reported less efficacy of diazinon granule based on the same criteria compared to its emulsion formulation. Comparing the efficacies of diazinon between phenological stages of rice plants (Tables 2 and 4), the results indicated that diazinon caused to increase total larval biomass on plants at reproductive stage. Nevertheless, due to environmental and health hazards of diazinon formulations as well as their role in insecticidal resistance development in insect pests (Mirhaghparast et al., 2015)., their application have recently been prohibited in Iran (Plant_Protection_Organization, 2021) and some other countries (Won & Yang, 2015).

In order to assess plant damage or plant tolerance to C. *suppressalis* larvae, percentage dead heart and/or whitehead indices, preferably the latter, have been widely proposed (Amooghli-Tabari et al., 2015). In the present study, based on the index of white head percentage, the relative resistance of the Shiroudi cultivar to C. *suppressalis* larvae compared to Tarom was revealed (Table 3), confirming the previous findings (Ghaninia et al., 2016; Tabari et al., 2017)

Significant relationships were demonstrated between biological characteristics of larvae and damage indices. Likewise, Amooghli-Tabari et al. (2015) reported a positive and significant correlation between the whitehead percentage and the larval density on the seedling (Amooghli-Tabari et al., 2015). Hosseini, Babaeian, Bagheri, Khademian, & Hasan (2011) reported a negative and significant correlation between the number of tillers and the whitehead percentage.

In conclusion, the effects of different insecticides on rice cultivars to control *C. suppressalis* larvae were evaluated. The tolerance of Shirodi cultivar to the damage of larvae was indicated to be greater compared to Tarom. The insecticide tebufenozide, regarding its relatively high efficacy and the previous reports of environmental compatibility, is suggested to be assessed further for integrated *C. suppressalis* management in the field conditions.

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