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# The Effects of Different Irrigation Systems on the Inundative Release of *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae) against *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae) in the Second Crop Maize

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**Abstract:** This study was conducted to determine the effects of different irrigation systems on the inundative release of the egg parasitoid *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae) against *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae) in the second crop maize in the Çukurova region of Turkey in 1999 and 2000. *O. nubilalis*, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) and *T. evanescens* were reared in a climatic room under constant temperature of  $25 \pm 1$  °C, relative humidity of  $65 \pm 10\%$ , and an appropriate light regime (16:8 LD). *Trichogramma evanescens* was applied twice at a rate of 75,000 parasitoid  $ha^{-1}$  at 10-day intervals at the beginning of the oviposition period of the third generation of *O. nubilalis* in the second crop maize. Irrigation was an important factor for the effectiveness of *T. evanescens* and significant differences between the 2 irrigation systems tested were observed. The efficiency of *T. evanescens* was higher under flood irrigation than sprinkler irrigation conditions. Egg parasitism was 81.0% and 84.3% with flood irrigation, and 66.3% and 69.2% with sprinkler irrigation in 1999 and 2000, respectively. The reduction rate of infested plants with *O. nubilalis* was 80.0% and 88.3% with flood irrigation, and 60.7% and 68.9% with sprinkler irrigation in 1999 and 2000, respectively. Yield increased approximately 1500-2000 kg  $ha^{-1}$  under flood irrigation as compared to sprinkler irrigation.

**Key Words:** Maize, *Ostrinia nubilalis*, *Trichogramma evanescens*, inundative release, irrigation systems

## İkinci Ürün Mısırdaki *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae)'e Karşı *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae)'in Kitle Salımı Üzerine Farklı Sulama Sistemlerinin Etkileri

**Özet:** Bu araştırma, Çukurova Bölgesinde mısırdaki *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae)'e karşı yumurta parazitoidi *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae)'in kitle salımı üzerine farklı sulama sistemlerinin etkilerinin belirlenmesi amacıyla 1999-2000 yıllarında yürütülmüştür. *O. nubilalis*, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) ve *T. evanescens*  $25 \pm 1$  °C sıcaklık, %  $65 \pm 10$  orantılı nem ve uygun ışık (16 saat aydınlık 8 saat karanlık) koşullarına ayarlı iklim odalarında üretilmiştir. *T. evanescens* ikinci ürün mısırdaki *O. nubilalis*'in üçüncü dölünün ovipozisyon periyodu başlangıcında 10 gün ara ile 75.000 parasitoid/ha oranında iki kez uygulanmıştır. Sulama *T. evanescens*'in etkinliği için önemli bir faktör olmuş ve iki sulama sistemi arasında önemli farklılıklar gözlenmiştir. *T. evanescens*'in etkinliği salma sulamada yağmurlama sulamadan daha yüksek bulunmuştur. Yumurtadaki parazitlenme oranı 1999 ve 2000 yıllarında salma sulamada sırası ile % 81.0 ve % 84.3 iken, yağmurlama sulamada sırası ile % 66.3 ve % 69.2 olmuştur. *O. nubilalis* ile bulaşık bitkilerde azalma oranı, salma sulamada % 80.0 ve % 88.3 iken, yağmurlama sulamada sırasıyla % 60.7 ve % 68.9 olarak bulunmuştur. Verim yağmurlama sulama ile kıyaslandığında salma sulamada yaklaşık 1500-2000 kg  $ha^{-1}$  artmıştır.

**Anahtar Sözcükler:** Mısır, *Ostrinia nubilalis*, *Trichogramma evanescens*, kitle salımı, sulama sistemleri

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## Introduction

In Turkey, maize is grown on a total of approximately 700,000 ha and is the third most important cereal crop, following wheat and barley. With "The Second Crop Agricultural Research and Dissemination Project" administered by the Ministry of Agriculture in 1982, the amount of land used for maize production increased by putting uncultivated irrigated land into use. Maize is sown in Turkey as a first crop, generally between March and April, and as a second crop between June and July. Maize fields are usually irrigated by flood irrigation and rarely by sprinkler systems. The first irrigation is sometimes achieved with sprinklers in maize fields. Maize fields are irrigated at least 6 times in the second crop. Many insect pests cause damage to first and second crop maize in the Çukurova region. One of them is the European corn borer (ECB), *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae). The European corn borer is a serious pest and causes considerable yield loss in Turkish maize production. *O. nubilalis* has 4 generations in the Çukurova region. Two generations appear in the first crop and the other 2 generations occur in the second crop. ECB larvae damage maize plants in several ways: feeding and boring disrupts physiological processes, feeding involves direct damage to kernels, and larval tunnelling promotes stalk breakage, ear drop, and the entrance of stalk rot pathogens. ECB is responsible for yield losses and expensive control measures. Chemical control is not satisfactory because of the stem-tunnelling behaviour of this pest. For this reason, biological control has been given more emphasis than chemical control. In the biological control of ECB, *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) are widely used for inundative release in biological control programs (Wajnberg and Hassan, 1994). For the success of such control programmes, it is important to know the factors affecting the parasitisation efficiency of *T. evanescens*. There are a number of factors that will influence the success of an inundative release program using an egg parasitoid such as *T. evanescens*. Previous studies on *T. evanescens* focused on the effectiveness of releasing this parasitoid to control ECB in Turkey (Coşkuntuncel and Kornoşor, 1996; Melan et al., 1996; Uzun et al., 1996; Öztemiz and Kornoşor, 1999), but no studies have been conducted to determine the effect of irrigation systems on the released parasitoids.

The objective of this study was to compare the efficiency of 2 different irrigation systems (flood and sprinkler irrigation systems) on field performance of *T. evanescens* to control ECB.

## Materials and Methods

Mass production of the laboratory host *Ephesia kuehniella* Zell., major host *O. nubilalis* Hbn., and the egg parasitoid *T. evanescens* was carried out under laboratory conditions, in a continuous fashion (Hassan, 1981; Abbas et al., 1987). The field study was carried out on farmland belonging to the Agricultural Research Institute of Çukurova, with second crop maize in 1999 and 2000. The experimental plots were planted with the maize cultivar "Pioneer-3394" in June using 70-cm row spacing and plant densities of 70,000 plants ha<sup>-1</sup>. Experimental design was a 2-factor (irrigation systems and treated and untreated by *T. evanescens*), randomised, complete block design with 5 replications. Plots irrigated by flood and sprinkler systems, and untreated plots were determined. The parasitoid was not released in untreated plots. Each experimental plot was 0.5 ha and divided into 5 replications.

The adult population of the pest was observed by means of Robinson light traps located near the experimental plots to determine the release time of the parasitoid. When the first adult of *O. nubilalis* was captured in the light trap, egg masses were counted from 100 plants (5 plants each from 20 different plot locations) before releasing the parasitoid in each plot.

*T. evanescens* was released twice, 1 week apart, in plots irrigated with either flood or sprinkler systems at the beginning of the oviposition period of the third generation of *O. nubilalis* in August. At each release, 75,000 parasitoids ha<sup>-1</sup> were released. The distance between the 2 releasing points was 14 m. The parasitoid was released with a releasing bag, which included 1500 *E. kuehniella* eggs parasitised by *T. evanescens* (Hassan and Heil, 1980). Parasitoids were released from 5 points in each plot with releasing bags. After release, totally 200 plants were examined to determine parasitisation rate of the pest eggs. If the egg masses were parasitised, it was recorded, if they were not parasitised, the egg masses were marked and then observed until the eggs either turned black or larvae of *O. nubilalis* emerged from them. If parasitoids already emerged from the parasitised eggs, these eggs were not considered. The number of egg masses was examined twice during the week before the parasitoid was released and twice each week following release until harvesting time. Additionally, untreated plots were monitored at the same time until harvesting time.

The efficiency of the parasitoid was evaluated by assessing the percentage of parasitism throughout the growing season (Bigler, 1986; Rawensberg and Berger, 1986) and counting the number of damaged plants, corncoobs, larvae, kernels, and 1000 kernel weight in the treated and untreated plots irrigated by flood and sprinkler systems. From each plot, 200 plants were taken at random, and were cut and examined. The infestation rate was calculated by means of Abbott's formula (Karman, 1971).

## Results

When the first adult of *O. nubilalis* was captured in the light trap, egg masses were counted in both plots and only one egg mass, which included 13 eggs, was found to be unparasitised before parasitoid release in 1999. After finding the first egg in the plots, *T. evanescens* was released in both plots twice, on August 3 and 11.

In the plots irrigated by flood, parasitisation rates were low at the beginning of the season, but high at the end of the season. After the first release, parasitisation rates of *O. nubilalis* eggs ranged from 35.4% to 84.6%; after the second release, the rates were 54.2%-100% in the replications. The average parasitisation rates among the replications were 60.7%, 78.2%, 84.3%, 88.7%, and 93.3% (Table 1).

In the plots irrigated by sprinkler, after the first and second releases, parasitisation rates were 23.2%-59.9% and 52.9%-81.1%, respectively. Parasitisation rates in the plots irrigated by sprinkler were lower than those in

the plots that were flood irrigated, and increased at the end of the season in the plots irrigated by flood. As a result, parasitisation rates were 56.6%, 64.0%, 76.6%, 76.9%, and 58.1% in the replications, (Table 1).

In the untreated plots irrigated by flood system, there were no parasitised eggs (Figure 1), whereas, in those treated by sprinkler system, the parasitisation rate was very low (2.19%-3.13%) (Table 1).

As a result, the parasitisation rate was 81.0% and 66.3% in plots irrigated by flood and sprinkler, respectively, and in untreated plots irrigated by flood and sprinkler the rate was 0.00% and 0.42%, respectively (Figure 1).

However, eggs of the other major pest of maize, the cornstalk borer *Sesamia nonagrioides* were parasitized by *T. evanescens* a rate of about 24.6%. At harvest, 68.8 and 86.0 plants were infested by *S. nonagrioides* were in the plots irrigated by flood and sprinkler systems, respectively, whereas 138.4 and 147.6 plants were infested in the untreated plots irrigated by flood and sprinkler systems, respectively. The numbers of cornstalk borer larvae were 136.4 and 166.4 in the plots irrigated by flood and sprinkler systems, and was 208.2 and 239.2 in untreated plots, respectively. The numbers of infested plants, corncoobs, and larvae were 50.3%, 56.8%, and 34.5% lower in the released plots irrigated by flood system, and 41.7%, 44.9%, and 30.4% lower in the released plots irrigated by sprinkler system compared to the untreated plots in 1999, respectively.

Table 1. The parasitisation rate of *Ostrinia nubilalis* eggs by *Trichogramma evanescens* under 2 irrigation systems in the Çukurova region in 1999.

Repetition	Release Plots						Control Plots					
	Flood Irrigation			Sprinkler Irrigation			Flood Irrigation			Sprinkler Irrigation		
	No. of Eggs	No. of Par. Eggs	Parasitisation Rate (%)	No. of Eggs	No. of Par. Eggs	Parasitisation Rate (%)	No. of Eggs	No. of Par. Eggs	Parasitisation Rate (%)	No. of Eggs	No. of Par. Eggs	Parasitisation Rate (%)
I	433	263	60.73	556	315	56.65	611	0.00	0.00	678	0.00	0.00
II	459	387	84.31	503	322	64.01	609	0.00	0.00	683	0.00	0.00
III	434	385	88.70	455	350	76.92	649	0.00	0.00	575	18	3.13
IV	469	438	93.39	622	477	76.68	698	0.00	0.00	864	19	2.19
V	505	395	78.21	545	317	58.16	510	0.00	0.00	702	0.00	0.00

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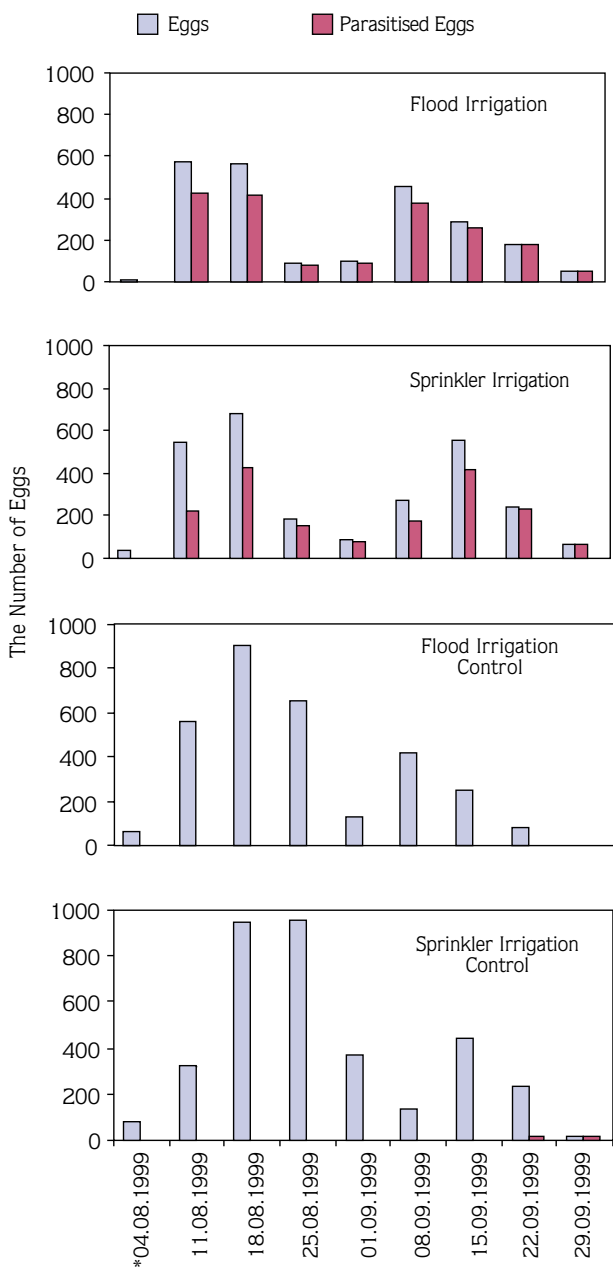


Figure 1. The number of parasitised and unparasitised *Ostrinia nubilalis* eggs under 2 irrigation systems, Çukurova, Turkey, 1999. \*Previous counting.

In 2000, the same method was applied against ECB. The parasitisation rate was low at the beginning of the season, but high at the end of the season in the flood irrigated plots. After the first release, the parasitisation rate of *O. nubilalis* eggs was 63.6%-81.8%. After the second release of the parasitoid, it was 77.2%-95.5% in

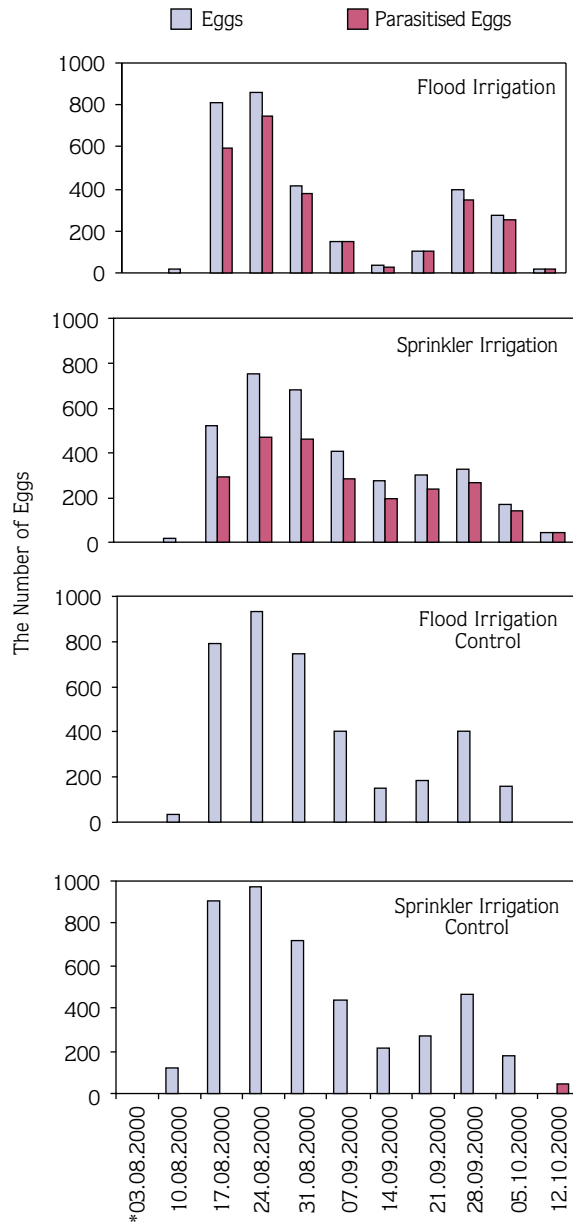


Figure 2. The number of parasitised and unparasitised *Ostrinia nubilalis* eggs under 2 irrigation systems, Çukurova, Turkey, 2000. \*Previous counting.

the replications. Parasitisation rates for replications 1-5 were 74.5%, 87.3%, 92.2%, 88.3%, and 79.0%, respectively (Table 2).

In the plots irrigated by sprinkler system, after the first and second parasitoid releases, parasitisation rates were 50.9%-66.1% and 55.2%-69.9%, respectively.

Table 2. The parasitisation rate of *Ostrinia nubilalis* eggs by *Trichogramma evanescens* in 2 irrigation systems in the Çukurova region in 2000.

Repetition	Release Plots						Control Plots					
	Flood Irrigation			Sprinkler Irrigation			Flood Irrigation			Sprinkler Irrigation		
	No. of Eggs	No. of Par. Eggs	Parasitisation Rate (%)	No. of Eggs	No. of Par. Eggs	Parasitisation Rate (%)	No. of Eggs	No. of Par. Eggs	Parasitisation Rate (%)	No. of Eggs	No. of Par. Eggs	Parasitisation Rate (%)
I	645	481	74.57	791	502	63.46	705	0.00	0.00	820	0.00	0.00
II	483	422	87.37	762	523	68.63	761	0.00	0.00	878	0.00	0.00
III	704	622	88.35	706	547	77.47	785	0.00	0.00	894	0.00	0.00
IV	675	623	92.29	633	455	71.87	804	0.00	0.00	836	20	2.39
V	581	459	79.00	578	375	64.87	748	0.00	0.00	853	25	2.93

Parasitisation rates for replications 1-5 were 63.4%, 68.6%, 77.4%, 71.8%, and 64.8%, respectively (Table 2), and the parasitisation rate was lower than that for the flood irrigation system. In the untreated plots irrigated by flood system there were no parasitised eggs (Figure 2), whereas in those irrigated by sprinkler system, the parasitisation rate was very low (2.4%-2.9%) (Table 2).

As a result, the parasitisation rate was 84.3% and 69.2% in plots irrigated by flood and sprinkler systems, respectively, and 0.0% and 1.2% in untreated plots irrigated by flood and sprinkler systems, respectively (Figure 2).

Furthermore, it was determined that *S. nonagrioides* eggs were parasitised by *T. evanescens* at a rate of about 20.5%. At harvest, the number of the plants infested with *S. nonagrioides* was 59.2 and 74.0 in plots irrigated by flood and sprinkler systems, respectively, and 134.4 and 140.2 in untreated plots irrigated by flood and sprinkler systems, respectively. The number of larvae was 116.4 and 136.6 in the plots irrigated by flood and sprinkler, respectively, and 196.0 and 214.4 in untreated plots irrigated by flood and sprinkler systems, respectively. In the untreated plots, the percent reduction in the number of infested plants, corncobs, and larvae was 55.5%, 57.5%, and 40.6% in flood system plots, and 47.2%, 52.8%, and 36.3% in sprinkler system plots.

In both years, the differences between the 2 irrigation systems at harvest were statistically significant. The numbers of infested plants, corncobs, and larvae were

higher in plots irrigated by sprinkler than in plots irrigated by flood (Tables 3 and 4). It was found that sprinkler irrigation affected the parasitoids negatively, especially during pollination, and reduced insemination by causing damage to tassels. For this reason, infestation was high in the plots irrigated by sprinkler system.

## Discussion

In the plots irrigated by flood system, the parasitisation rate was low at the beginning of the season, but high at the end of the season. It is known that the life cycle of *Trichogramma* spp. from egg to adult is typically completed in 7-10 days (longer in cooler weather). This short life cycle allows for nearly 30 generations per season, with rapid increases in *Trichogramma* spp. populations. For that reason, parasitism increased at the end of the season (Pak and Oatman, 1982; Brower, 1988; Croft, 1990).

In the plots irrigated by sprinkler system, the parasitisation rate was lower than in the plots irrigated by flood system, and increased at the end of the season, similarly to flood-irrigated plots. It was thought that sprinkler irrigation affected flight and walking activities of adult parasitoids because of moisture on the surface of maize leaves. For this reason, the search capacity of parasitoids was decreased and the host eggs were hatched before parasitisation. Hence, the parasitisation rate was lower in sprinkler irrigation than in flood irrigation. It is reported that, at night, dew formation on plant foliage

Table 3. The effects of *Trichogramma evanescens* release on parasitisation rate, pest population, and yield in both irrigation systems in 1999 in Çukurova, Turkey.

Parameter	n	1999			
		Release*		Control*	
		Flood	Sprinkler	Flood	Sprinkler
Parasitisation Rate (%)	5	81.06 ± 12.67 <sup>a</sup>	66.37 ± 9.68 <sup>b</sup>	0.00 ± 0.00 <sup>c</sup>	0.42 ± 0.99 <sup>c</sup>
Yield (kg ha <sup>-1</sup> )	5	9040.0 ± 43.7 <sup>a</sup>	7574.0 ± 30.1 <sup>b</sup>	6498.0 ± 19.2 <sup>c</sup>	6084.0 ± 15.3 <sup>c</sup>
1000 grain Weight (g)	5	390.24 ± 1.43 <sup>a</sup>	309.08 ± 2.74 <sup>b</sup>	280.14 ± 1.56 <sup>c</sup>	260.01 ± 1.57 <sup>c</sup>
No. of Infested Plants	5	18.00 ± 2.82 <sup>a</sup>	48.00 ± 1.58 <sup>b</sup>	90.00 ± 2.12 <sup>c</sup>	122.20 ± 1.30 <sup>d</sup>
No. of Larvae	5	16.00 ± 1.73 <sup>a</sup>	60.40 ± 1.51 <sup>b</sup>	122.00 ± 0.70 <sup>c</sup>	164.00 ± 3.16 <sup>d</sup>
No. of Infested Corncobs	5	2.00 ± 1.22 <sup>a</sup>	8.00 ± 1.41 <sup>b</sup>	19.00 ± 1.00 <sup>c</sup>	25.00 ± 0.70 <sup>d</sup>

\* Means within a row followed by the same letter are not significantly different at P ≤ 0.01 (LSD).

Table 4. The effects of *Trichogramma evanescens* release on parasitisation rate, pest population, and yield in both irrigation systems in 2000 in Çukurova, Turkey.

Parameter	n	1999			
		Release*		Control*	
		Flood	Sprinkler	Flood	Sprinkler
Parasitisation Rate (%)	5	84.31 ± 7.28 <sup>a</sup>	69.26 ± 5.64 <sup>b</sup>	0.00 ± 0.00 <sup>c</sup>	1.06 ± 1.46 <sup>c</sup>
Yield (kg ha <sup>-1</sup> )	5	9412.0 ± 331.3 <sup>a</sup>	7984.0 ± 227.7 <sup>b</sup>	6807.2 ± 142.5 <sup>c</sup>	6501.2 ± 183.2 <sup>c</sup>
1000 grain Weight (g)	5	436.32 ± 5.58 <sup>a</sup>	354.82 ± 12.73 <sup>b</sup>	294.92 ± 15.18 <sup>c</sup>	277.82 ± 10.65 <sup>c</sup>
No. of Infested Plants	5	14.40 ± 1.81 <sup>a</sup>	51.20 ± 1.78 <sup>b</sup>	123.20 ± 0.83 <sup>c</sup>	164.40 ± 2.70 <sup>c</sup>
No. of Larvae	5	16.00 ± 2.54 <sup>a</sup>	65.60 ± 0.70 <sup>b</sup>	142.40 ± 2.88 <sup>c</sup>	174.80 ± 2.28 <sup>c</sup>
No. of Infested Corncobs	5	1.00 ± 1.22 <sup>a</sup>	1.00 ± 0.70 <sup>b</sup>	36.00 ± 1.58 <sup>c</sup>	41.00 ± 3.67 <sup>c</sup>

\* Means within a row followed by the same letter are not significantly different at P ≤ 0.01 (LSD).

prevents *Trichogramma* spp. from walking on the leaves (Boldt, 1974). Laboratory testing revealed that *T. exiguum* (Pinto and Platner) avoided walking on wet substrates, such as damp paper towelling; thus their activity in the field was probably restricted in places where dew occurs, both at night and in the early morning (Keller, 1985). Physical factors such as temperature, humidity, dew, and wind were also found to influence the movements of parasitoids, and walking activity of parasitoids changed with an increase in temperature (Kot, 1964).

Furthermore, eggs of the other major pest of corn, the cornstalk borer *Sesamia nonagrioides*, were

parasitised by *T. evanescens*. It was determined that *T. evanescens* parasitised the *S. nonagrioides* eggs as an alternative host, especially at the end of the season when parasitism was high, and the population of ECB eggs was reduced. It was reported that the parasitisation rate of *S. nonagrioides* eggs by *T. evanescens* ranged from 49.50% to 85.80% (Bayram and Kornoşor, 1999).

A low parasitism rate was observed in the untreated plots because *Trichogramma* spp. was passively spread by wind. The distance between the treated and untreated plots was 80 m. It has been reported that the distance between parasitoid-treated plots and untreated plots

could range from 50 to 100 m (Hassan, 1981; Yu et al., 1984; Keller and Lewis, 1985; Bigler and Brunetti, 1986; Tran and Hassan, 1986).

Our results are in good agreement with other studies reported by Manolache and Tien (1971), Voegelé et al. (1975) and Zanaty and Shenishen (1991). In the present study, 2 releases of *T. evanescens* at weekly intervals (75,000 parasitoid ha<sup>-1</sup>) to control *O. nubilalis* on corn irrigated by sprinkler system resulted in 89.1%

parasitism and a 63.6% reduction in the number of infested plants (Öztemiz and Kornoşor, 1999).

In conclusion, irrigation was an important factor for the effectiveness of *T. evanescens*, and significant differences in the 2 irrigation systems were observed. The efficiency of *T. evanescens* was greater with flood irrigation than with sprinkler irrigation. With respect to yield and parasitisation rate, flood irrigation is a better system than sprinkler irrigation.

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