Arthropods, 2019, 8(2): 53-66

Article

Integrated inhibition of citrus leafminer, *Phyllocnistis citrella* in Mazandaran Province, Iran

Narges Mohsenpour[1], **Mohammad Reza Damavandian**[1], **Fatemeh Shafiei**[2], **Mohammad Esmail Kamali Pasha**[3]

[1]Department of Plant Protection, Faculty of Cultural Sciences, Sari University of Agricultural Sciences and Natural Resources, Sari, Iran

[2]Department of Agricultural Extension and Education, Faculty of Cultural Sciences, Sari University of Agricultural Sciences and Natural Resources, Sari, Iran

[3]Department of Soil And Water Researches, Agriculture & Natural Resources Research Center of Mazandaran Province, Sari, Mazandaran, Iran

E-mail: m.r.damavandian@gmail.com

Received 24 January 2019; *Accepted 1 March 2019*; *Published 1 June 2019*

Abstract

In this research, the effect of irrigation management on the production of new shoots and leaves produced by citrus plants, and damage rate caused by citrus leafminer, *Phyllocnistis citrella* was investigated. The study was performed in a completely randomized design with 3 treatment and 5 replicates for two consecutive years (2014-2015) in Besat citrus orchard of Sari Fajr Company. Treatment included control (without irrigation), conventional irrigation and irrigating based on water requirements (WaterCrop). The number of shoots and leaves produced and damaged by *P. citrella* in each treatment were counted from the beginning to the end of the growing season and then compared statistically. According to the obtained results, during sampling after the leaf miner emerged, the maximum number of shoots produced and infected related to conventional irrigation. The mean leaves produced by each plant in WaterCrop, conventional and control treatments was 111a, 108.3a, and 51.7b, respectively, which of these, 2, 26.5 and 3.5 of leaves was produced at a time that *P. citrella* was active and damaged the leaves to 1.71, 21.6, and 4.31%, respectively. The results of this study showed that irrigation is effective in germinating and producing the leaves of citrus trees. As it is clear, over the year, the maximum and minimum leaves before and after emerging the pest have been produced by the trees that were irrigated by WaterCrop method, which because the lower number of the leaves produced during periods when the pest is active, these trees suffered the lowest damage without the use of common pesticides.

Keywords irrigation; Mazandaran; citrus leafminer; WaterCrop.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

The young larvae of the pest begin to feed under the epidermis of the leaf tissue (sometimes young branches and possibly fruits) immediately after hatching the egg and feed on the contents of the leaf, which causes their deformity and complexity (Garcia -Mari et al., 2002; Belasque et al., 2005). Helix mines caused by feeding this pest reduce the photosynthetic capacity of the leaves and increase their susceptibility to plant pathogens such as *Xanthomonas axonopodis* pv. *Citri,* which is the pathogen of citrus canker (Gottwald et al., 1997, 2002; Jesus Junior et al., 2006). The pest is more damaging on young shoots in nurseries, and preventing the spread of young leaves and sometimes causing their downfall (Diez et al., 2006).

So far, a wide range of chemicals has been tested to control this pest. Chemical control is an improper management approach against citrus leafminer for some reasons such as high control costs, increased resistance of citrus leafminer and other pests to insecticides, imbalance in the biological control of other citrus pests, the survival of pesticide residues in groundwaters and foods, undesirable effects on non-target living organisms and the environment and adverse effects on the health of workers in the long-term (Sarada et al., 2014). The insect has a long resistance history to insecticides and the resistance created by excessive use of insecticides has caused that chemical control is not effective against this pest (Legaspi et al., 2001). Biological control is often recommended as an economically and environmentally friendly method to manage this pest (Elekcioglu and Uygun, 2006).

As mentioned before, so far, many synthetic pesticides have been used to control this pest (Sarada et al., 2014). On the one hand, the continuous and prolonged use of these pesticides due to their low impact has been caused the outbreak of other pests (Damavandian and Kiaeian Moosavi, 2014) and on the other hand, also, environmental pollution and the disruption of the biological control balance of the pest was as a result of Pesticides application (Damavandian, 2007). Patsias (1996) has announced a crop operations as a complementary method to control citrus leafminer in Cyprus, Which it includes increased amount of chemical fertilizers, especially nitrogen before February, moderated irrigation during February and March, citrus pruning operations until early February, irrigating moderately citrus trees during the summer and autumn, and reduced use of fertilizer in these seasons (Patsias, 1996). Irrigation helps better output of fertilization programs. The germination of citrus trees starts from early spring and continues until the end of summer and early autumn (Kord Firoozjaei, 2012). On the other hand, the activity of the citrus leafminer begins in late June and lasts until the end of summer and autumn that damages to the shoots produced in spring and autumn (Jafari, 1998; Powell et al., 2007; Sarda et al., 2014). This study intends to provide conditions by irrigation management, which tree shoots appear when the pest is not active. Therefore, in this research, the effect of irrigation management in different seasons of the year on the activity of citrus leafminer was studied.

2 Materials and Methods

2.1 Research location

This research was carried out in Besat citrus orchard of Sari Fajr Company affiliated to Mostazafan Foundation with an area of approximately 60 ha located in Sari city (53º 6E, 36º 48N) in Mazandaran province, north Iran. The average temperature and rainfall of the research location during the course were 25.54 ºC and 1.65 mm, respectively. This study was conducted in two separate experiments. The first experiment was conducted during 2014 that studied on the number of shoots and the second experiment was conducted during 2015 that studied on the number of leaves of citrus trees. The operation method of the two experiments was similar.

2.2 Evaluation of irrigation management efficiency on citrus leafminer damage

Experiments were conducted in a completely randomized design with three treatments and five replications. Experiments were performed on a part of this orchard with three rows of trees and each row with 10 trees.

Citrus trees were 3-year-old Miagawa cultivars, *Citrus tangerine* (V.) var *unshiu* with an inter-row distance of approximately 5 m and the distance between trees within a row about 3 m. Treatments included control (without irrigation), conventional irrigation (35 liters of water per each tree with intervals of 3 days, from the late April to late September) and WaterCrop (irrigating three times on a week from the late April to 22nd July and Once in every two weeks, from the 23rd July to 7th October), which the content of irrigation was determined based on the plant's water requirement and Readily Available Water of soil. The water requirement of the plant in this treatment was calculated based on two-stage FAO method and using the CropWat software. The content of water needed for the plant was determined by the program, based on information such as tree age, tree cultivar, and soil type. Reference evapotranspiration was calculated based on FAO-Penman-Monteith method and using weather data of Sari city. Based on this software, the amount of water consumed per each tree at each time was obtained 45 liters, which was given a tree on a schedule every time.

Samples were taken from the soil of the orchard to determine the amount of fertilizer required and the fertilizer content was determined based on the soil testing results (Table 1). The fertilizers were sprinkled as top-dressing in the shade of the trees examined and then placed under the soil by using a shovel. From each tree, four branches in four different geographic directions were identified and marked, and the data were recorded with the emergence of the first shoots and new leaves in May. The number of shoots, leaves, and leaves infected by leafminer for each tree was counted weekly until the end of the growing season (early October). In order to prevent leafminer damage in the studied treatments, Imidacloprid (Confidor) insecticide was applied when the damage observed. According to the recommendation of pesticide manufacturer, 3 cc of confidor in 2 liters of water was consumed for each 3-year-old tree in soil at the base of the tree. The control was conducted in two stages, late June (first stage) and early August, 45 days after the first stage (second stage).

Table 1 Fertilizers used based on the results of the soil testing.

Fertilizer	Dosage
Ammonium Sulfate	0.5 kg in March+ 0.5 kg in April + 0.5 kg in May
Triple Superphosphate	150 g per tree
Potassium Sulfate	50 g per tree
Manganese Sulfate	75 g per tree
Zinc Sulfate	50 g per tree

2.3 Statistical analysis

Data were analyzed using nonparametric tests. In order to study the effect of irrigation on the germinating and foliating trees, Kruskal-Wallis test was used and in case of rejecting the assumption of equality of means to determine the difference between treatments, Mann-Whitney U test with SPSS software was used and the treatments were compared pairwise.

3 Results

3.1 First experiment: the number of shoots

In the first year, before 20th July due to the high irrigation content in WaterCrop (based on water requirement) and conventional treatments, there was no significant differences between these two treatments in the number of leaf shoots of trees, although there was a significant difference between the two treatments and control (χ^2=6.466, p=0.039). Pest damage has also been seen after the above date. According to Table 2, the assumption of equality of the mean of control with WaterCrop and conventional treatments is rejected ($p<0.05$). Although there was no significant difference between two treatments, WaterCrop, and conventional irrigation, the Ranking comparison of the average of these two treatments indicated that the ranking average of conventional irrigation (8.75) was higher than that of WaterCrop treatment (8.25).

Table 2 The results of Man Whitney U test on 20th July 2014.

Characteristic	Treatments compared	Z	Asymp. Sig. (2-tailed)	Exact Sig. (2*(1-tailed sig.))
No. shoots	Control and WaterCrop	-2.899	0.004*	0.01b
	Control and Conventional	-2.557	0.011*	0.038b
	WaterCrop and Conventional	-2.14	0.831	0.878b

Comparison of the number of leaf shoots of trees for three treatments on 2nd August 2014 (χ^2=10.835, p = 0.004) shows that there is a significant difference between these three treatments ($p<0.05$). As regards, the probability of significance of the test in both asymptomatic and precise cases is less than 0.05 (Table 3), so, the assumption of equality of the mean of control treatment with two treatments, WaterCrop, and conventional irrigation is rejected ($p<0.05$). Although there was no significant difference between two treatments, WaterCrop, and conventional irrigation, the ranking comparison of the average of these two treatments indicated that the ranking average of conventional irrigation (10.13) was higher than WaterCrop treatment (6.88).

Table 3 The results of Man Whitney U test on 2nd August 2014.

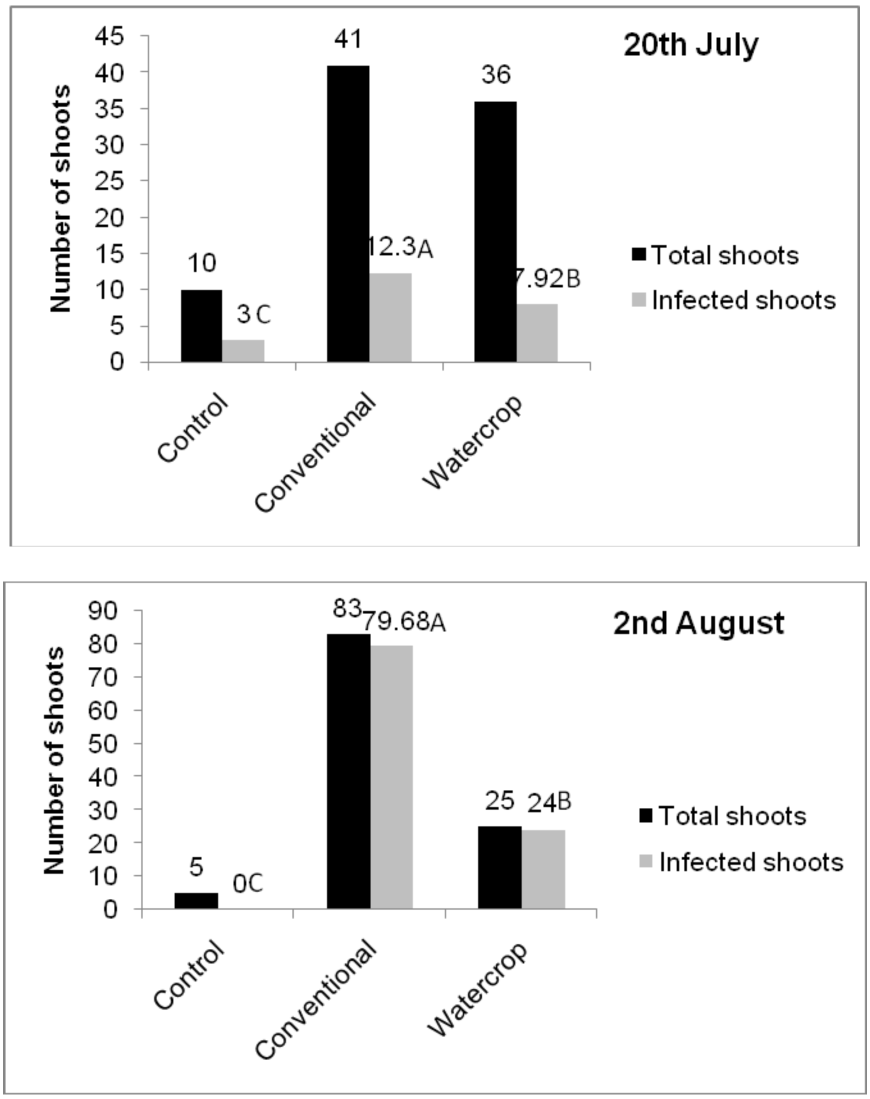
Characteristic	Treatments compared	Z	Asymp. Sig. (2-tailed)	Exact Sig. (2*(1-tailed sig.))
No. shoots	Control and WaterCrop	-2.899	0.004*	0.01b
	Control and Conventional	-2.896	0.004*	0.01b
	WaterCrop and Conventional	-1.38	0.168	0.195b

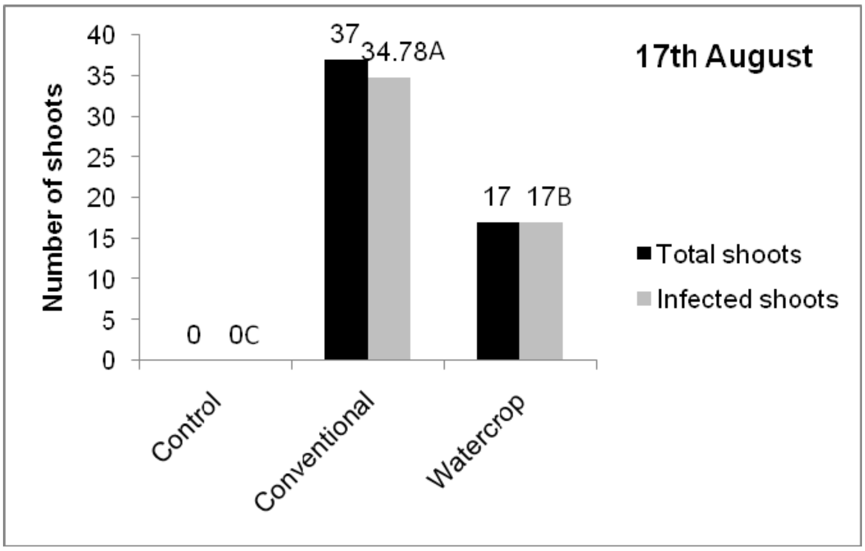
Due to reduced irrigation from 23rd July, germination in WaterCrop treatment has been associated with the density or number of shoots reduced on 2nd August. Also, comparing the density of shoots in two treatments of conventional and WaterCrop shows that the number of shoots in conventional treatment (n=83) was much higher than that in WaterCrop treatment (n=25). Therefore, irrigation cut off has reduced the germination of trees in the WaterCrop treatment. As it is known, conventional irrigation will result in a greater number of shoots when the pest is active, will provide an opportunity for the pest outbreak and severe damage to trees.

The results of germination comparison on 17th August 2014 show that p-value is greater than 0.05 and the assumption of equality of means is not rejected and there is not a significantly different between the treatments

(χ^2=3.396, p=0.183). The analysis of data on 15th September 2014 showed that there is not a significant difference between the three treatments studied (χ^2=2.293, p=0.318) and the assumption of the equality of the means is not rejected ($p<0.05$). Also, the new shoot was not found in any of the treatments on 31st August and 1st October.

In 2014, the exact time of observation of the pest in the plot of the orchard was on 20th July and its approximate time in the total 60 ha was the last decade of June. The graphs presented in Fig. 1 showed the total number of shoots and the infected shoots after the damage of the pest in the orchard. As can be seen, on July 20, 22.2, 30 and 30% of the total shoots were infested in the WaterCrop, conventional and control treatments, respectively. There was a significant difference between the treatments on this date (20th July). On 2nd August, 96% of the total shoots were infested in both conventional and WaterCrop treatments. Of course, it is noteworthy that the number of shoots in conventional treatment was much higher than that in WaterCrop treatment. There was a significant difference between the treatments based on the number of infected shoots on this date (2nd August).





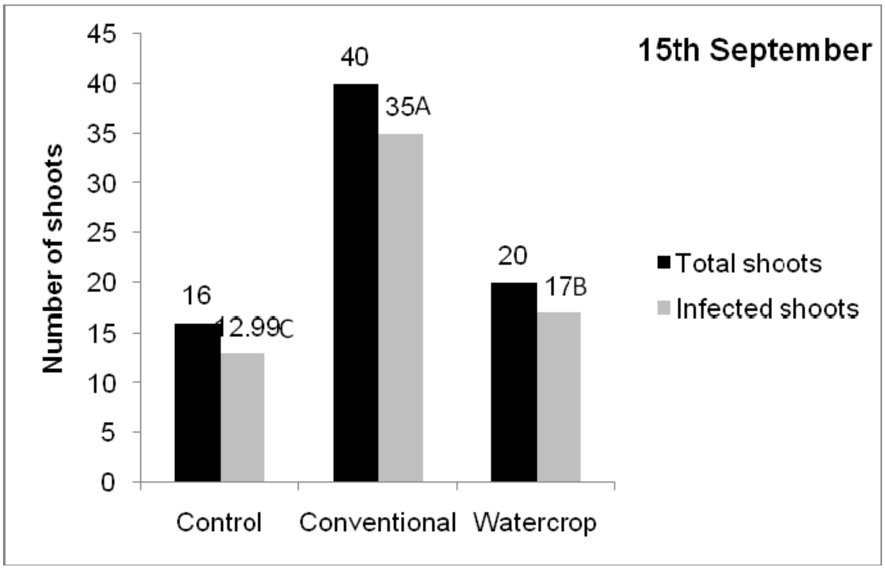


Fig. 1 Comparison of the infected sprouts from the total treated sprouts on 20th July, 2nd August, 17th August and 15th September 2014 **(**Capital letters indicate a significant difference between treatments in terms of the number of infected sprouts).

On 17th August, 100 and 94% of the shoots were infested in WaterCrop and conventional treatments, respectively, which the difference between them was significant. Whereas, the number of shoots in the conventional treatment was almost twice the number of shoots in the WaterCrop treatment. Also, the study of the graph on September 15 shows that the highest percentage of infestation is related to conventional treatment with 87.5% of the total shoots, which had the highest total number of shoots among the treatments. In the WaterCrop, 85% of the total shoots were infected. On the other hand, mean comparison of the number of infected shoots shows that treatments have a significant difference with each other (Fig. 1). As it is known, on the 20th July, WaterCrop treatment had the highest number of infected shoots (7.92) due to higher irrigation rates than other treatments, while in the other sampling dates, conventional treatment had the highest number of the infected shoots.

The analysis of the graphs shows that irrigation cut off in WaterCrop treatment after 20th July decreased the number of shoots compared to conventional treatment, and Also, the pest activity was severe, why so, on average, more than 80% of the buds produced in All three treatments were damaged during sampling. Also, by examining the graphs on different dates, it is concluded that at all sampling dates after emergence and activity of citrus leafminer, the most germination has belonged to conventional treatment, and the highest infection have been observed on the trees of this treatment.

3.2 Second experiment: the number of leaves

In the second year, the effect of irrigation on leaf production rate was investigated. Comparison of leaf production for three treatments studied on 5th May 2015 showed that there was a significant difference between the treatments (χ^2=8.746, p=0.013). The results of Mann-Whitney U test and probability of significance in Table 4 indicate that there is a significant difference between WaterCrop and control treatments ($p<0.05$) and the assumption of the equality of mean in these two groups is rejected. On the other hand, there was not a significant difference between control and conventional treatment, as well as between the WaterCrop and conventional treatments ($p>0.05$).

Table 4 The results of Man Whitney U test on 5th May 2015.

Characteristic	Treatments compared	Z	Asymp. Sig. (2-tailed)
No. leaves	Control and WaterCrop	-2.426	0.015*
	Control and Conventional	-1.699	0.089
	WaterCrop and Conventional	-1.601	0.109

The average number of leaves produced for control, conventional and WaterCrop treatments in the mentioned date were 48.2, 81.8 and 102.9, respectively. There is little difference between the above treatments because the foliating on trees at this time is influenced by early spring rainfall, which the number of leaves produced is high in all three treatments. It is also observed that despite the irrigation rate in WaterCrop treatment was lower than that in conventional treatment, the number of new leaves in WaterCrop was higher than conventional treatment and in the control treatment, due to no irrigation, the number of leaves produced in it was lower than both treatments.

It should be noted that on dates of 22nd May, 5th June and 22nd June 2015, no new leaves have been seen in any of the trees. The results of the comparison of leaf production in the three treatments studied on 6th July 2015 indicate that there is not a significant difference between treatments and the assumption of equality of mean is not rejected (χ^2=4.037, p=0.133). The average of leaves produced on this date for control, conventional and WaterCrop treatments were zero, 5.9 and 3.7, respectively. Also, Similar results were obtained on 23rd July 2015, which showed that there was not a significant difference between treatments (χ^2=2.000, p=0.368).

The comparison results of leaf production for three treatments studied on 6th August 2015 using Kruskal-Wallis test (χ^2=14.169, p=0.001) showed that there was a significant difference between the treatments and the assumption of the equality of means was rejected ($p<0.05$). The average leaves produced at this date for control, conventional and WaterCrop treatments were 2.2, 11 and 2, respectively. The results of the Mann-Whitney U test (Table 5) shows that there is a significant difference between the control and conventional irrigation as well as WaterCrop and conventional irrigation.

Table 5 The results of Man Whitney U test on 6th August 2015.

Characteristic	Treatments compared	Z	Asymp. Sig. (2-tailed)
No. leaves	Control and WaterCrop	-0.018	0.986
	Control and Conventional	-2.829	0.005*
	WaterCrop and Conventional	-2.829	0.005*

According to the results obtained on 23rd August 2015 (χ^2=4.316, p=0.604), there was not a significant difference between the three treatments (p>0.05). The average leaves produced for control, conventional and WaterCrop treatments at this date were zero, 1.6 and 0.3, respectively. The evaluation of the trees on 6th September 2015 showed that no new leaves were found in the selected plots. While, Comparing the results of leaf production on 23rd September 2015 for three treatments (χ^2=8.204, p=0.017) shows that there was a significant difference between the treatments (p<0.05). The average of leaf production in control, conventional and WaterCrop treatments at this date was 1.3, 10.4 and 0, respectively. Also, the results of the Mann-Whitney U test in Table 6 shows that there is a significant difference between the two treatments of conventional and WaterCrop (p=0.042).

Table 6 The results of Man Whitney U test on 23rd September 2015.

Characteristic	Treatments compared	Z	Asymp. Sig. (2-tailed)
No. leaves	Control and WaterCrop	1.000	0.317
	Control and Conventional	-1.399	0.162
	WaterCrop and Conventional	-2.038	0.042*

According to Fig. 2, the highest number of leaves produced by trees before the pest attack was in the WaterCrop treatment. As can be seen, the average number of leaves produced per tree at the beginning of the period was 102.9, 81.8 and 48.2 for WaterCrop, conventional and control, respectively. Of course, there was a significant difference between the two treatments of WaterCrop and conventional.

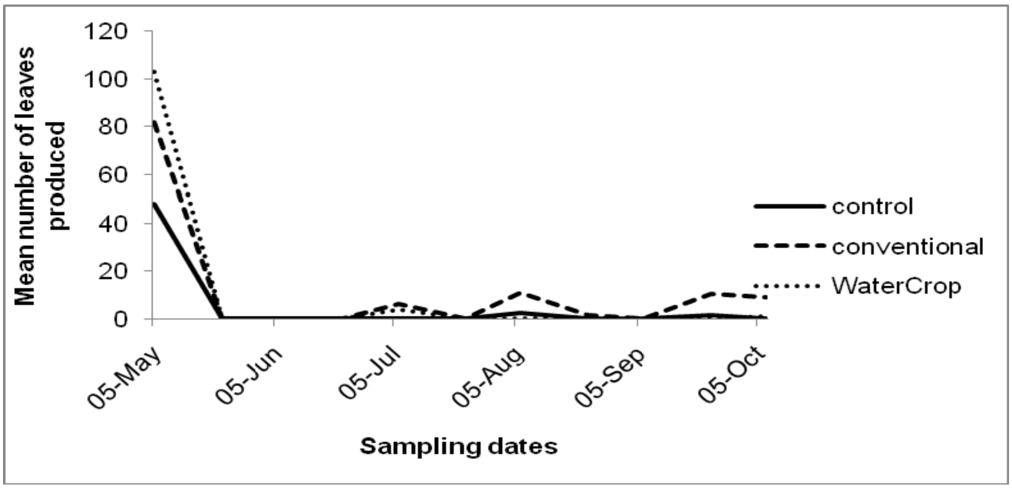


Fig. 2 Mean total leaves produced in the studied treatments over sampling dates.

The obtained results show that in conventional treatment, which irrigation is constantly carried out throughout the season, the new shoots have been observed throughout the season. At the beginning of the season, leaf production was maximum in the WaterCrop treatment due to the high irrigation content and since late July, the production of leaves has decreased sharply in conventional treatment due to decreasing the irrigation rate. This is also true for the control treatment in the entire season, to wit, the irrigation cut off has caused the density or number of new shoots and leaves on the trees of control reach to zero.

Comparison of the total number of leaves produced during the sampling showed that there were a significant difference between the WaterCrop, conventional and control treatments (F=10.09, df=2, p=0.0005) and the mean number of leaves for treatments was 111a, 108.3a, and 51.7b, respectively.

As regards, the first symptoms of citrus leafminer damage has observed on 6th August, the effect of irrigation on the control of citrus leafminer is studied after 6th August. In this date, the highest mean of new leaves produced related to conventional treatment that there was a significant difference between conventional treatment and WaterCrop and control (F=3.81, df=2, p=0.035) (Fig. 3). It should be noted that the infected leaves have observed in the conventional treatment on this date (Fig. 3). On 23rd September, the results showed that the highest mean number of total and infected leaves was observed in conventional treatments, and no new leaves were produced in the WaterCrop treatment and therefore no infected leaf was observed in this treatment. Analysis of variance showed that there was a significant difference between the treatments at this date (F=3.4, df=2, p=0.024) (Fig. 3).

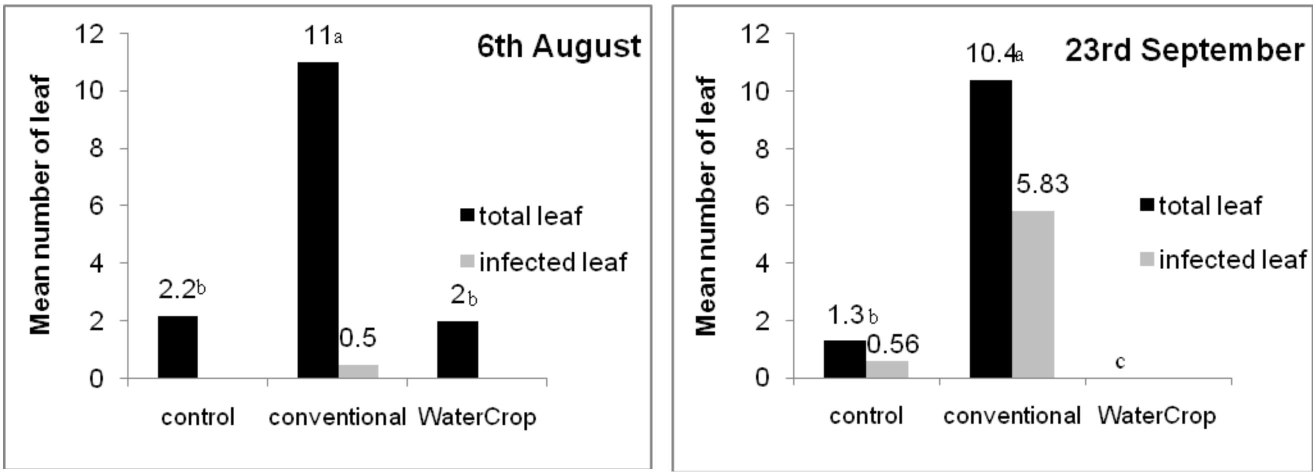


Fig. 3 Mean comparison of leaves infected to citrus leafminer on the treated trees on 6th August and 23rd September 2015 (Different letters indicate a significant difference between treatments in terms of the number of leaves).

Fig. 4 shows the percentage of leaves produced for each treatment before (5th May to 6th August) and after (6th August to 7th October) the observation of pests in the orchard. Analysis of variance showed that there was a significant difference between treatments before and after pest attack (F_{before}=3.6, df=2, p=0.019; F_{after}=4.6, df=2, p=0.020). As seen in Fig. 4, in the WaterCrop treatment, 98.29% of the leaves produced at the beginning of the season when the irrigation content was high, and only about 2% of the leaves were produced at a time that the pest was active in the orchard. In conventional treatment, which had constant irrigation content throughout the season, 21.08% of the new leaves were produced after the pest emergence in the orchard, and approximately most of these leaves were infected and destroyed by *P. citrella*.

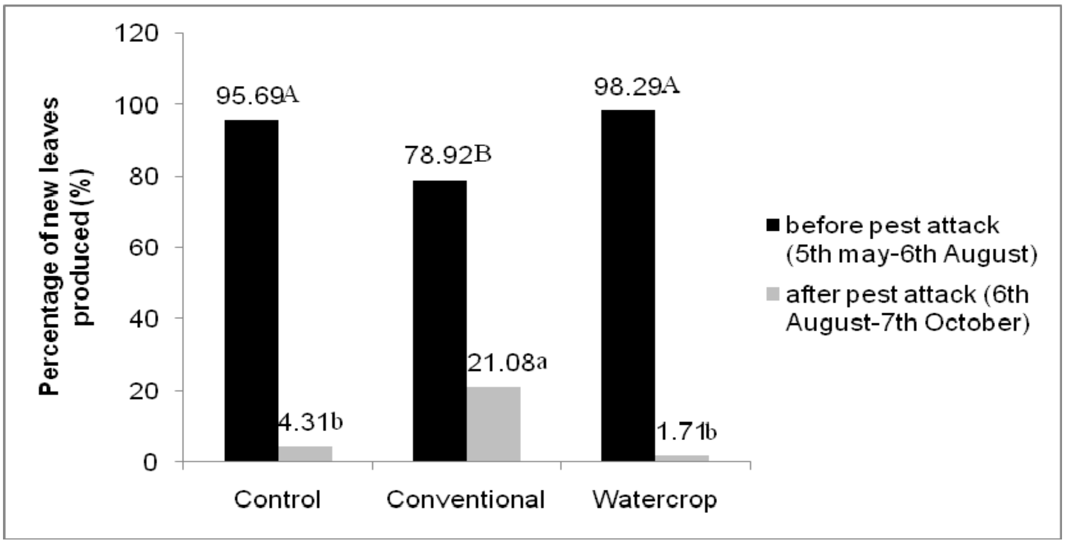


Fig. 4 Comparison of percent new leaves produced before and after emerging of citrus leafminer (Uppercase and lowercase letters showing significant differences between treatments before and after the pest attack, respectively).

4 Discussion

Based on the results obtained in the first year (Fig. 1), the highest number of produced and infected shoots was related to conventional treatment. WaterCrop treatment had less infected shoots compared to conventional treatment due to fewer shoots produced during pest activity. On the other hand, the results of sampling in the second year (Fig. 3) showed that the most produced leaves during the citrus leafminer attack, belong to conventional treatment and also the highest infected leaves related to the same treatment. In the WaterCrop treatment, there were almost no new leaves in the WaterCrop treatment at the time of damage, and no damage was observed. The obtained results indicate that the irrigation using WaterCrop method in the second year greatly prevents the damage to treated trees, and because the number of leaves produced in the trees at the time of pest activity has been very low, practically no infection was observed in the trees during the sampling period, and the trees were healthy and without damage. Also, it should be noted that irrigation content in conventional and WaterCrop treatments during the irrigation period was 1995 and 1986 liters per each tree, respectively. As it is known, the amount of water consumed per tree in conventional treatment is more than that in WaterCrop.

Some researchers achieved this conclusion that insufficient water would reduce plant growth. In contrast, excessive use of water may cause other effects such as loss of soil nutrients, placing the plant root under flood conditions, the salinity of water and soil, and the development of pests and diseases. It is expected that optimizing water consumption using an appropriate irrigation program has the results such as conservation of water resources, reduced production costs, increased growth (Fereres, 1997; Abbas and Fares, 2009; Pereira and Villa Nova, 2009; Al-Yahyai, 2012). As the results of this study showed, consumption of adequate water based on the water requirement of the plant (WaterCrop) caused the proper growth of the shoots and leaves before the emergence of the pest, which is consistent with the results of the above studies.

Ghasemnezhad et al. (2014) stated that the highest number of leaves was observed in Thomson Navel seedlings which were irrigated once every two days, but no significant difference was observed between the other irrigation intervals (4, 6 and 8 days). The results of the above study and the results of Cohen and Goell (1988), Davies and Zalman (2002) and Shao et al. (2008) were consistent with the results of this study. Because in the present study, the number of leaves produced was more by decreasing the irrigation intervals to the one stage at a week(once every two days) from 21st April to 22nd July.

Colella et al. (2014) in a two-year field experiment showed that reducing irrigation content significantly reduced the infection rates of pests such as *Trialeurodes vaporariorum* Westwood, *Macrosiphum euphorbiae* Thomas and *Frankliniella occidentalis* Pergande in tomato plants. Charlet et al. (2007) stated that the proper moisture content provided during the growing season reduced the larval density of sunflower stem pests such as *Pelochrista womonana* Kearfott in stems. The results of the above study are consistent with the results of the present study regarding the effect of reducing the content of irrigation and providing adequate moisture on reducing pest damage.

In a study identified that magnesium and calcium, leaf thickness and area were negatively correlated with the population of citrus leafminer larvae, while potassium, rainfall, and relative humidity were positively correlated with citrus leafminer population (Mustafa et al. 2014). According to the results of experiments in Mazandaran province (north of Iran), it was found that 80 percent of branches from all branches produced of citrus seedlings from spring to the end of summer could be maintained by managing irrigation, fertilization and application of mineral oil instead of confidor (Kord Firoozjaei, 2012). The results of the above studies, as well as the results of the present study, show the effective role of appropriate irrigation in producing shoots and leaves as well as managing to reduce the damage of citrus leafminer.

The results of Radjabi's study showed that there is a significant relationship between the growing conditions of the trees and the rate of pest attack, which irrigation, the amount of water supplied to trees, irrigation intervals, and irrigation methods were the most important among different growing factors (Radjabi, 2011). The results of the above study are consistent with the results obtained in this study. Control of *P. citrella* has been reliant on synthetic insecticides since the past times (Diez et al., 2006), although their long-term use leads to inefficiency, damage to beneficial factors, and the outbreak of other pests (Beattie et al., 1995). Patsias (1996) has announced a crop operation as a supplementary method for controlling Citrus leafminer that can be mentioned mild irrigation during the months of January, February and March, as well as mild irrigation of citrus during the summer and autumn, and reducing the use of chemical fertilizers in these Seasons. Other researchers argued that proper fertilization and irrigation can reduce the damage severity of pests such as citrus leafminer (Krajewski and Krajewski, 2011). The results of the above studies and the results of this study confirmed the role of irrigation and its management in reducing the damage of citrus leafminer.

The results obtained from Tahrir Adabi et al. (2013) showed that irrigation periods (4, 8 and 12 days) had a significant effect on red poplar leaf beetle, *Chrysomela populi* Linnaeus, and popular flat headed borer beetle, *Melanophila picta* Pallas densities ($p < 0.05$). The highest density of *C. populi* was observed in the 4 and 8 days of irrigation and the highest density of *M. picta* was observed in the period of 8 and 12 days. They concluded that in order to reduce the damage of *C. populi* and *M. picta*, the irrigation interval should be increased and reduced, respectively. The results of the above study are consistent with the results of the present study due to the effect of the irrigation period on pest damage.

Staley et al. (2006) and Mody et al. (2009) stated that water stresses reduce or increase the sensitivity of plants to insects. Daane and Williams (2003) and Perfect et al. (2006) identified regulating the irrigation period as one of the most important and effective factors on pest management.

Radjabi (2011) in an experiment conducted on the two pests, *Sphenoptera davatchii* Descarpentries and *S. kambyses* Obenberger on cherry trees in Karaj during three years stated that the trees that were irrigated with irrigation interval of more than eight days were gradually ready for acceptance these two pests. In the trees with irrigation intervals of four and eight days, the infection was almost negligible.

In a study on a potato plant has been identified that young potato plants, due to their active and growing tissues, cause mortality of more than 80% of *Liriomyza huidobrensis* Blancard eggs, while egg mortalities in mature plants was about 17%. Therefore, if there are young plants in the fields at the peak of flying and laying of leafminer adult insects, the damage will be much less compared to when potato plants are mature (Videla and Valladares, 2007).

As *P. citrella* only damages to young citrus leaves, if the number of young citrus leaves decreases during the pest activity, the damage can be minimized. In fact, the irrigation program causes the lack of concurrency between plant development stages and pest activity that it's called ecological resistance or host escape. Among the strategies applied in integrated pest management programs, plant resistance to insects can be explored as a complementary control method (Santos et al., 2011). A small change in the phonological adaptation between insects and their suitable host plants can have a profound effect on the survival and reproduction of insects (Hunter et al., 2012).

The results of this study during two consecutive years showed that irrigation is effective in germination and production of citrus leaves. Since citrus leaf miner attacks new citrus leaves and shoots and influences them, can by managing the irrigation program in young citrus orchards in the beginning of the growing season, On the one hand, it prevents the production of new leaves and shoots when the pest emerges and, on the other hand, by producing the majority of leaves when the pest is not active, causes enough and satisfactory growth throughout the year. Therefore, the chemical control needs to be reduced due to the lack of the production of new leaves or a sharp decline in producing them in during *P. citrella* activity.

Acknowledgments
In this way, the authors thank and appreciate the University of Agricultural Sciences and Natural Resources of Sari for supporting and cooperating by offering research facilities.

References

Abbott WS. 1925. A method of computing the effectiveness of insecticide. Journal of Economic Entomology, 18(2): 265-267

Aronson AI, Beckman W, Dunn P. 1986. *Bacillus thuringiensis* and related insect pathogens. Microbiological Reviews, 50: 1-24

Arshad M, Suhail A, Arif MJ, Khan MA. 2009. Transgenic Bt and non-transgenic cotton effects on survival and growth of *Helicoverpa armigera*. International Journal of Agriculture and Biology, 11(4): 473-476

Bravo A, Gomez I, Conde J, Munoz-Garay C, et al. 2004. Oligomerization triggers binding of a *Bacillus thuringiensis* Cry1Ab pore-formingtoxin to aminopeptidase N receptor leading to insertion into membrane microdomains. Biochimica et Biophysica Acta, 1667: 38-46

Damgaard PH, Hansen BM, Pedersen JC, Eilenberg J. 1997. Natural occurrence of *Bacillus thuringiensis* on cabbage foliage and in insects assoc Abbas F, Fares A. 2009. Best management practices in Citrus production. Tree and Forestry Science and Biotechnology, 3: 1-11

Al – Yahyai R. 2012. Managing irrigation of fruit trees using plant water status. Agricultural Science, 3: 35-43

Amiri-Besheli B. 2004. The survey of the effect of some insecticides and mineral oils against citrus leafminer *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) in Sari district. Journal of Agricultural Sciences and Natural Resources, 4: 53-62

Amiri-Besheli B. 2008. Efficacy of *Bacillus thuringiensis*, mineral oil, insecticidal emulsion and insecticidal gel against *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae). Plant Protection Science, 44: 68–73

Beattie GAC, Somsook V, Watson DM, Clift AD, Jiang L. 1995. Field evaluation of *Steinernema carpocapsae* (Weiser) (Rhabditida: Steinernematidae) and selected pesticides and enhancers for control of *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae). Journal of Australian Entomological Society (Brisbane), 34: 335-342

Belaque JJ, Parra-Pedrazzoli AL, Rodrigoues Neto J, Yamamoto PT, Chagas MCM, Parra JRP, Vinyrad BT, Hratung JS. 2005. Adult citrus leafminer (*Phyllocnistis citrella*) are not efficient vectors for *Xanthomonas axonopodis* pv *citri*. Plant Disease, 89(6): 590-594

Charlet LD, Aiken RM, Meyer RF, Gebre-Amlak A. 2007. Impact of irrigation on the larval density of stem-infesting pests of cultivated sunflower in Kansas. Journal of Economic Entomology, 100: 1555-1559

Cohen P, Goell J. 1988. Fruit growth and dry matter accumulation in grapefruit during periods of water withholding and after irrigation. Journal of Plant Physiology, 15: 633-639

Colella T, Candida V, Campanelli G, Camele I, Battaglia D. 2014. Effect of irrigation regimes and artificial mycorrhization on insect pest infestation and yield in tomato crop. Phytoparasitica, 42: 235-246

Daane KM, Williams LE. 2003. Manipulating vineyard irrigation amounts to reduce insect pest damage. Ecological Applications, 13: 1650-1666

Damavandian MR. 2007. Laboratory and field evaluation of mineral oil spray for the control of citrus red mite, *Panonychus citri* McGregor. Acta Agriculturae Scandinavica, Section B-Soil and Plant Science, 57: 92-96

Damavandian MR, Kiaeian Moosavi SF. 2014. Comparison of mineral spray oil, confidor, dursban, and abamectin used for the control of *Phyllocnistis citrella* (Lepidoptera: Gracillaridae), and an evaluation of the activity of this pest in citrus orchards in northern Iran. Journal of Plant Protection Research, 54: 156-163

Davies FS, Zalman GR. 2002. Fertilization, rootstock, growth and yield of young Rhode red Valencia orange trees. Proceeding of Florida State Horticultural Society, 115: 14-17

Diez PA, Pena JE, Idalgo Pf. 2006. Population dynamics of *Phyllocnistis citrella* (Lepidoptera: Gracillaridae) and its parasitoids in Tafi Viejo, Tucuman. Argentina'Florida Entomologist, 89: 327-335

Elekçioğlu NZ, Uygun N. 2006. The parasitoid complex of the citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) in the East Mediterranean region of Turkey and Their Role in Biological Control. Turkish Journal of Zoology, 30(2006): 155-160

Fereres E. 1997. Irrigation scheduling of horticultural crops. *Acta* Horticulturae, 449: 253-258

Garcia-Mari F, Granda C, Zaragoza S, Agusti M. 2002. Impact of citrus leafminer (Lepidoptera, Gracillariidae) on leaf area development and yield of mature citrus trees in the Mediterranean area. Journal of Economic Entomology, 95: 966-974

Ghasemnezhad M, Momenpour A, Abdollahpour AR, Sheikh Shakoori AR. 2014. The effect of irrigation interval on some growth characteristics of Thomson-Novel orange grated on three citrus rootstocks. Journal of Horticultural Science, 3: 416-426

Gottwald TR, Graham JH, Schubert TS. 1997. An epidemiological analysis of the spread of citrus canker in urban Miami, Florida, and synergistic interaction with the Asian citrus leafminer. Fruits, 52: 371-378

Gottwald TR, Graham JH, Schubert TS. 2002. Citrus Canker: The pathogen and its impact. Online. Plant Health Progress (DOI 10.1094/php-2002-0812-01-rv)

Hunter MD, Ohgushi T, Price PW. 2012. Effect of Resource Distribution on Animal-Plant Interactions. Academic Press, New York, USA

Jafari ME. 1995. Introduction of New Pest in Mazandaran Citrus orchards named Citrus Leafminer, *Phyllocnistis citrella*. 12th Iranian Plant Protection Congress. Karaj Agricultural College, India

Jafari ME. 1996. Citrus Leafminer, Phyllocnistis citrella Stainton in Near East. Syria Workshop Report. Department of Pest and Plant Disease Research, Mazandaran Agricultural and Natural Resources Research and Education Center, Sari, Iran

Jafari ME. 1998. Investigation of the effect of several new insecticides on citrus leafminer in the treasury and 1-5-year-old trees. The Final Report, Mazandaran Agricultural and Natural Resources Research and

Education Center, Sari, Iran

Jesus Junior WC, Júnior JB, Amorim L, Christiano RSC, Parra JRP, Filho AB. 2006. Injuries Caused by Citrus Leafminer (*Phyllocnistis citrella*) Exacerbate Citrus Canker (*Xanthomonas axonopodis* pv. *citri*) Infection. Fitopatologia Brasileira, 31: 277-283

Kord Firoozjaei Z. 2012. Study of the possibility of controlling the citrus leafminer, *Phyllocnistiscitrella* without the use of synthetic insecticides. Dissertation, Sari University of Agricultural Sciences and Natural Resources, Sari, Iran

Krajewski AJ, Krajewski SA. 2011. Canopy Management of Sweet Orange, Grapefruit, Lemon, Lime and Mandarin Trees in the Tropics: Principles, Practices and Commercial Experiences. Acta Horticulture, 894: 65-76

Legaspi JC, French JV, Zuniga AG, Legaspi BC. 2001. Population Dynamics of the Citrus leafminer *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae), and Its Natural Enemies in Texas and Mexico. Biological Control, 21: 84-90

Mody K, Eichenberger D, Dorn S. 2009. Stress magnitude matters: different intensities of pulsed water stress produce non-monotonic resistance responses of host plants to insect herbivores. Ecological Entomology, 34: 133–143

Mustafa IM, Arshad A, Ghani I, Ahmad AB, Muhammad Raza F, Saddique S, Asif M, Riaz Khan H, Ahmed H. 2014. Population dynamics of citrus leafminer on different varieties of citrus in correlation with abiotic environmental factors in Sargodha District, Punjab, Pakistan. Phytoparasitica, 42: 341-348

Patsias AN. 1996. The status of citrus leafminer *Phyllocnistis citrella* Stainton in Cyprus. Citrus Journal, 11

Pereira AR, Villa Nova NA. 2009. Transpiration of irrigated Tahiti acid lime trees with different canopy areas, reference evapotranspiration and water balance for precision irrigation schemes. Tree Forest Science Biotic, 3: 87-91

Perfect TJ, Thresh JM, Evans LT, Tanton TW. 2006. Irrigation as a Factor Influencing the Management of Agricultural Pests [and Discussion]. Philosophical Transactions of the Royal Society of London, 316: 347-354

Powell C, Burton MS, Pelosi R, Ritenour M, Bullock R. 2007. Seasonal Abundance and Insecticidal Control of Citrus Leafminer in a Citrus Orchard. Hortscience, 42: 1636-1638

Radjabi GR. 2011. Harmful insects of cold fruit trees of Iran (and their management in accordance with ecological realities). The Research Institute of Plant Protection Publication, Tehran, Iran

Santos MS, Vendramim JD, Lourencao AL, Pitta RM, Martins ES. 2011. Resistance of citrus genotypes to *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae). Neotropical Entomology, 40: 489-494

Sarada GK, Gopal T, Gouri Sankar L, Mukunda Lakshmi V, Gopi T, Nagalakshmi T, Ramana KTV. 2014. Citrus Leaf Miner (*Phyllocnistis citrella* Stainton, Lepidoptera: Gracillariidae): Biology and Management: A review. Journal of Agriculture and Allied Sciences, 3: 39-48

Shao HB, Chu LY, Jalel CA, Zhao CX. 2008. Water deficit stress induced anatomical change in higher plants. Comptes Rendus Biologies, 331: 215-225

Staley JT, Mortimer SR, Masters GJ, Morecroft MD, Brown VK, Taylor ME. 2006. Drought stress differentially affects leaf-mining species. Ecological Entomology, 31: 460-469

Tahriri Adabi S, Sadeghi SE, Bagheri R. 2013. Effect of irrigation intervals and poplar clones on the density of *Chrysomela populi* (Col. Chrysomelidae) and *Melanophila picta* (Col. Buprestidae) in Karaj area. Iranian Journal of Forest and Range Protection Research, 10: 108-117

Videla M, Valladares G. 2007. Induced resistance against leafminer eggs by extrusion in young potato plant. International Journal of Pest Management, 53: 259-262