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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet

Asian Network for Scientific Information

308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 15 (4): 177-185, 2012
ISSN 1028-8880 / DOI: 10.3923/pjbs.2012.177.185

Effect of Field History on the Cereal Leafminer *Syringopais temperatella* Led. (Lepidoptera: Scythrididae) and its Preference to Different Wheat and Barley Cultivars

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Abstract: Due to the importance of wheat and barley production in Jordan, prevention of the cereal leafminer, *Syringopais temperatella* Led. (Lepidoptera: Scythrididae) is of vital importance. The insect is a severe pest and plays an important role in limiting the production of these crops. The use of insecticides is neither economic nor sustainable, so that there is an urgent need to initiate a viable alternative to chemical control. Therefore, this study aimed at investigating the effect of crop rotation on *S. temperatella* and its preference to different wheat and barley cultivars. The field history experiment was conducted using five different crop rotations. For the preference experiments in the laboratory, two major experimental groups were conducted. The first was set up to measure the consumed leaf area and the second one to record the number of larval attaches. Each group consisted of four different subgroups; 6 wheat cultivars, 6 barley cultivars, two and one cultivar of each crop. The results indicated that the infestation percentage and number of larvae were significantly the lowest in the crop rotation, wheat/chickpea/wheat while the highest were recorded for barley/barley/barley. The preference results showed that wheat cultivar, Horani Nawawi is significantly the most preferred while Horani 27 is the least cultivar. In case of barley, Mutah was the most preferred cultivar and the least preference was recorded for Athroh. Also, wheat was significantly less preferred than barley. The wheat cultivars, Sham, Em-Qees and Acsad 65 had the highest number of attaches and Deer Alla the least. In contrast, the barley cultivar, Acsad 176 had the highest and Athroh and Rum 1 had the least attaches. Barley cultivars had higher attaches than wheat ones. There was a positive relation between the infestation percent and number of larvae, as well as the consumed area and number of attaches in all of the four subgroups. In conclusion, the crop rotation, wheat/chickpea/wheat should be followed and there is a preference variation among the tested wheat and barley cultivars.

Key words: *Syringopais temperatella*, cereal leafminer, control, field history, preference, barley, wheat

INTRODUCTION

Wheat and barley are major cereal crops in Jordan and important sources for human food and livestock feed. Abiotic and biotic factors play an important role in limiting the production of these two crops, therefore, the country is not self-sufficient in wheat and barley production and depends on imports to cover the national needs (Agricultural Statistics, 2010). Insect pests are major biotic factors that limiting the cereal production, in which many of them have been described on wheat and barley worldwide. while most of these insects cause insignificant damage, others annually cause serious yield and forage reduction (Harlan, 1992).

The cereal leafminer, *Syringopais temperatella* Led. (Lepidoptera: Scythrididae) is one of the most severe insect pests on wheat and barley and causes quantitative and qualitative damages (Al-Zyoud, 2007, 2008; Al-Zyoud *et al*., 2009, 2011) over the last ten years in Karak district of Jordan. Due to the frequent occurrence of drought and lack of proper rotations applied by farmers, *S. temperatella* feeds on the plant foliage, soon turning its leaves into yellow and eventually leads to a sharp decline in production (Al-Zyoud *et al*., 2009, 2011). Cereal fields were almost damaged in Karak district, even though the infested fields were sprayed with insecticides (Al-Zyoud, 2007). The pest has also been reported to cause quantitative damage to wheat and barley in many countries of our region (Borror *et al*., 1989; Daamen *et al*., 1989; Miller, 1991; Miller and Ghannoum, 1994; De Vrieze, 2002; Jemsi and Rajabi, 2003; ICARDA Annual Report, 2007).

Nevertheless, due to the importance of wheat and barley production in the country, suppression of *S. temperatella* is of vital importance. The use of insecticides became the predominant method of

S. temperatella control in Jordan and overshadowed programs of alternative methods of pest control (Al-Zyoud *et al*., 2011). Intensive application of chemical insecticides has been used since the first outbreak in 2001 to suppress *S. temperatella* in south of Jordan, but unfortunately until nowadays the infested areas by the pest are continuously increasing and most of the wheat and barley fields are left for grazing (Al-Zyoud, 2007, 2008; Al-Zyoud *et al*., 2009, 2011). Therefore, the use of insecticides is neither economic nor sustainable and expensive for farmers, as well as it poses a risk to human, animals, beneficial insects and environment (Debach and Rosen, 1991). Concomitantly, it is crucial to find other control measures than insecticides to suppress *S. temperatella* population. The use of Integrated Pest Management (IPM) has been proven to be a successful, sustainable and environmentally friendly control strategy for insect pests (NRC, 1996).

However, in many wheat- and barley-based systems cultural control methodologies where agronomic practices (i.e., resistant cultivars, crop rotation) are used to maintain pest populations below the economic threshold are of vital importance. Resistant plant cultivars are considered one of the most economically effective and environmentally friendly control measures. Moreover, crop rotation is an important measure to control *S. temperatella*, since the pest has a very limited host plant spectrum. These two control methods will maintain natural balances within the ecosystem. Importantly, the crop rotation used in our region usually includes fallow periods, when large areas remain unsown. These fallows offer a great opportunity to produce forage legume crops such as grass pea and chickpea. Because of the relatively low emphasis on insect pests in wheat- and barley-based systems, cultivars possessing resistance to insect pests have for the most part lagged behind the development of high-yielding and pest-resistant cultivars (Lin *et al*., 1995).

There is an urgent need to initiate such a work in Jordan in order to reduce the reliance of Jordanian farmers on chemical insecticides, provide farmers with a viable alternative to chemical control that will be sustainable and minimize impacts on environment and human health and increase wheat and barley production in the country, which will in turn increase farmers' incomes. However, up to date and to the best of our knowledge, no attention has been paid on research on field history (crop rotation) and preferences of this pest in Jordan and the world as well. Therefore, this study aimed at investigating the effect of crop rotation on *S. temperatella* population and the pest preferences to different cultivars of wheat and barley. It is hoped that this valuable information will open the door for plant breeders to start investigating the least preferred cultivars aiming to produce a type of resistance to *S. temperatella* as well as for farmers to start applying crop rotation in their farmers.

MATERIALS AND METHODS

Effect of field history on *Syringopais temperatella* infestation

Experimental site conditions: The field history experiment was conducted in 5 different open fields in Al-Rabba city/Karak district of Jordan (Karak city has Latitude of 31°11" and Longitude of 35°42"). The experiment was carried out in well known annual infested areas with *S. temperatella* during the 2009/2010 cropping season. All the fields were under rain-fed conditions and neither insecticides nor fertilizers were used. All the pre- and post-stand establishing managements; land preparation, plowing and cultivation were done as required. The experimental sites are characterized by a semi-arid condition with a relatively moderate rainfall (300 mm long-term annual average). The location is suitable for cultivating a wide crop spectrum, especially wheat, barley and legumes and it is located at 920 m above the sea level.

Crop rotation: Five different fields were selected to represent five different crop rotations. The crop rotations were: barley/fallow/wheat, fallow/fallow/barley, wheat/chickpea/wheat, barley/barley/barley and barley/vetch/barley. In all the five different fields, *S. temperatella* larvae started infesting cereal crops (wheat or barley) in late February and early March. The collected time of plant leaves, to be tested, from all of the five different fields was taken place in March 25th when the insect' larval damage on wheat and barley leaves is clearly seen. From each field, five plots (replicates) were randomly selected and each plot consisted of an area of one meter square. All plants were harvested from the fields; in total 25 plots and 5 plots per each crop rotation. The plants of each plot were separately kept in a paper bag and brought to the laboratory. In the laboratory, data were recorded for the number of total plants/plot, number of infested plants/plot and number of larvae/plot. A Binocular microscope was used to count the larvae. To ensure that the selected crop rotations are correct, many criteria were used such as (a) our experience in the surrounding fields to the Faculty of Agriculture since 2005, because we have conducted many researches and brought thousands of the pest larvae from the fields which required from us to make frequent visits to them and (b) the information which was obtained with the cooperation of the agricultural center in Al-Qasr/Karak and from the farmers who own the fields.

Multi-choice laboratory experiments on the preference of *Syringopais temperatella* to different species and cultivars of wheat and barley acquisition and maintenance of *Syringopais temperatella* and plant species: The stock culture of *S. temperatella* was initiated from thousands newly emerged first larval instars that collected from wheat and barley fields in Al-Rabba city of Karak district and maintained on potted wheat and barley plants. The infested wheat and barley plants were kept in meshed cages of 50×50×80 cm (height, width, length) under laboratory conditions of 20±5°C temperature, 50±10% relative humidity and 12:12 h (L:D) photoperiod at the Faculty of Agriculture, Mutah University. The meshed cages were sealed with gauze from their sides and tops to provide adequate ventilation. For the purpose of *S. temperatella* rearing and conducting experiments, the rearings were kept in three meshed cages, in which the first cage contained all the wheat cultivars tested and the second one had all the barley cultivars while the third one had all of the wheat and barley cultivars. This step was done to reduce the possibility that *S. temperatella* might get adapted to a particular plant species or cultivar. To maintain adequate host-plants supply for *S. temperatella* rearing, many potted plants from each cultivar of both crops were grown and frequently placed inside the cages whenever needed. Wheat and barley plants were grown with neither fertilizers nor insecticides usage in small pots of 12×12 cm (diameter, height) in an air-conditioned glasshouse and were frequently replaced whenever needed to maintain adequate host-plant supply.

Obtaining the appropriate larval instars of *Syringopais temperatella*: The third larval instars (L_3) of *S. temperatella* were used in the laboratory experiments. In order to obtain this larval instar, the newly collected first larval instars from the field have singly transferred into Petri dishes (5 cm in diameter and 1 cm in height) containing food as wheat and barley leaves and monitored daily for molting the successive larval instars. Hereafter, the criterion used to select the third larval instar was the molting of the larvae since the larvae were daily checked in the petri dishes.

Experimental conditions, arenas and design: All preference experiments were conducted in a climatically controlled chamber at a temperature of 25±2°C, a relative humidity of 60±10% and a photoperiod of 12:12 (L: D) h in 2010 at the Faculty of Agriculture, Mutah University. All the experiments were set up in Petri dishes of 11 cm in diameter and 3 cm in height. The Petri dishes were partially filled with 0.5 cm thick layer of wetted cotton pad and the lid of each Petri dish had a hole closed with organdie fabric for ventilation. The preferences of 12 wheat and barley cultivars by *S. temperatella* were comprehensively investigated in multi-choice experiments, in which six cultivars of each crop were used. The wheat cultivars were Sham, Acsad 65, Horani Nawawi, Em-Qees, Horani 27 and Deer Alla, whereas the barley cultivars were Mutah, Athroh, Acsad 176, Yarmuk, Rum 1 and Rum 2. All cultivars were obtained from the gene bank collection that belongs to the National Centre of Agriculture Research and Extension (NCARE)/Jordan. Two major groups of experiments were conducted. The first group was conducted to measure the consumed area by *S. temperatella* larvae and the second group was set up to record the number of attaches by the insect larvae. Each experimental group is consisted of four different subgroups, in which the first one consisted of all the above mentioned 6 wheat cultivars, the second one had all the fore-mentioned 6 barley cultivars, the third one consisted of two cultivars of each crop (wheat: Sham and Acsad 65; barley: Mutah and Athroh) and the fourth one had one wheat cultivar (Sham) and one barley cultivar (Mutah). The experimental design was Randomized Complete Design (RCD). A minimum of ten replicates was used in each of the four subgroups in the first group of experiments (measure the consumed area) and a minimum of 125 larvae was used in each of the four subgroups in the second group of experiments (number of larval attaches).

Preference of *Syringopais temperatella* for wheat and barley cultivars: Freshly picked leaves were punched from the different uninfested cultivars using a blade and were together placed above the cotton pads in a labeled petri dish with one third instar larva (L_3)/petri dish as mentioned before in the four different subgroups to measure the consumed area by *S. temperatella* larvae. Subsequently, the petri dishes were kept under the previously mentioned laboratory conditions for a period of 2 days. Hereafter, the larval individuals were removed and the leaf area consumed was recorded by measuring the width and length of the mines, since the feeding behavior of the larva has a distinguish pattern, in which the larva starts with a known width and keeps feeding horizontally. For the second group which was set up to record the number of attaches (visits) by the insect larvae, ten L_3 were kept as mentioned above in each petri dish in the previously mentioned four subgroups for a period of

24 h. Hereafter, the number of attaches by the insect larvae was recorded. The number of attaches was counted when feeding symptoms were clearly seen on the leaves.

Statistical analysis: The statistical analysis was performed using the proc GLM of the statistical package SigmaStat version 16.0 (SPSS, 1997). The data were analyzed by one way ANOVA to detect any differences among the different cultivars and crop rotations (Zar, 1999). When significant differences were detected, differences among several means were compared using LSD at $p<0.05$ (Abacus Concepts, 1991). T-test was used for comparisons between two means (Anonymous, 1996). Also, the correlation between the percentage of infestation and the mean number of larvae per plot in the field history experiment as well as between the consumed area and the number of attaches by the larvae was calculated by Spearman's correlation method (Zar, 1999).

RESULTS

Field history: Mean percent of infestation caused by *S. temperatella* larvae and the number of larvae/plot in the five different crop rotations are presented in Fig. 1 a, b). The results indicated that the infestation percent was significantly the lowest in the crop rotation, wheat/chickpea/wheat with a mean of 34.04% (Fig. 1a). The infestation increased to 52.34% in the fallow/fallow/barley, 56.80% in the barley/vetch/barley and 59.88% in the barley/fallow/wheat and all of them were at par with each other and no significant differences were detected among them. The highest infestation was significantly recorded for barley/barley/barley with a mean of 67.64% ($F = 1.69$; 4, 20 df; $p<0.05$). The mean number of *S. temperatella* larvae was significantly also the lowest in the crop rotation, wheat/chickpea/ wheat with a mean of 21.4 larvae/plot (Fig. 1b). The number of the larvae increased in barley/fallow/wheat crop rotation with a mean of 25.8 larvae/plot, which was significantly lower than in barley/vetch/barley (39.0 larvae/plot) and fallow/fallow/barley (39.4 larvae/plot). The highest number of larvae was significantly reported in barley/barley/barley crop rotation with a mean of 69.8 larvae/plot ($F = 9.21$; 4, 20 df; $p = 0.000$). There was a significant positive correlation of ($r = 0.59$, $p = 0.001$) between the percent of infestation and the mean number of larvae per plot.

Preference

Leaf area consumed by *Syringopais temperatella* larvae: Mean leaf area consumed by *S. temperatella* larvae by

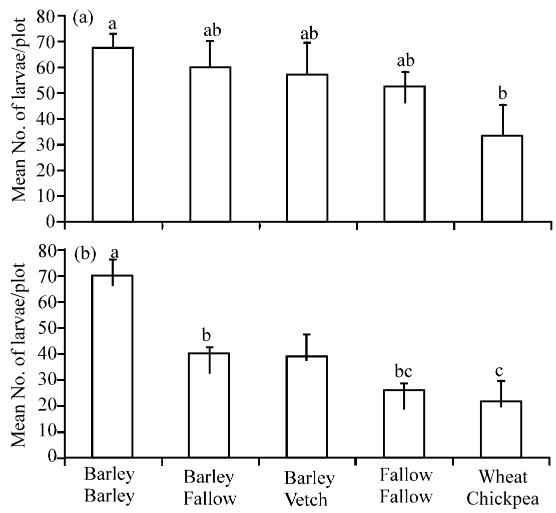

Fig. 1(a-b): (a) Mean±SE infestation percentage caused by *Syringopais temperatella* larvae and (b) Mean±SE number of larvae in five different crop rotations during the cropping season 2010 at Al-Rabba area. Different small letters above bars indicated significant differences among the different crop rotations or number of larvae at $p<0.05$ (one-factor analysis of variance)

feeding together upon different wheat, barley or mixed cultivars of wheat and barley for a period of two days at 25±1°C is summarized in Fig. 2. The results showed that the wheat cultivar, Horani Nawawi is significantly the most preferred by the larvae recording total consumed leaf area of 10.99 mm^2 while Horani 27 with only a mean leaf area of 4.39 mm^2 represented significantly the least preferred cultivar ($F=0.87$; 5, 48 df; $p<0.05$). The wheat cultivars, Acsad 65 (5.83 mm^2), Deer Alla (6.10 mm^2), Em-Qees (6.77 mm^2) and Sham (7.09 mm^2) were at par with each other and no significant differences were detected among them. In case of barley, the larvae consumed significantly more from Mutah (8.93 mm^2) representing the most preferred cultivar and the least consumption was recorded for Athroh (4.53 mm^2) ($F = 1.11$; 5, 49 df; $p<0.05$). The barley cultivars, Yarmuk (5.84 mm^2), Acsad 176 (6.02 mm^2), Rum 1 (6.45 mm^2) and Rum 2 (7.98 mm^2) showed a moderate preference by the larvae.

In the third subgroup when *S. temperatella* larvae were provided with only two different cultivars of each wheat and barley, the results indicated that the wheat cultivar, Sham (4.89 mm^2) was significantly less preferred. In contrast, the barley cultivar, Mutah (8.56 mm^2) was significantly the most preferred ($F=1.3$; 3, 57 df; $p<0.05$) while the wheat cultivar, Acsad 65 (6.13 mm^2) and the

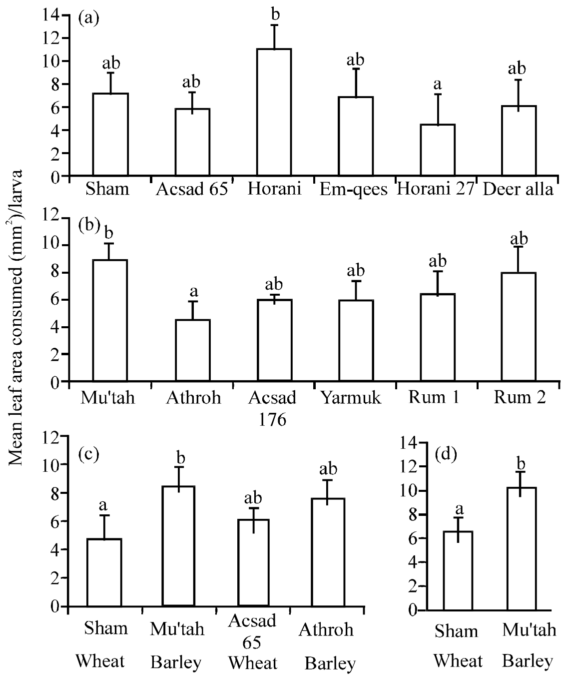

Fig. 2 (a-d): Mean±SE leaf area (mm^2) consumed by *Syringopais temperatella* larvae by feeding together upon different (a) wheat, (b) barley or (c-d) mixed cultivars of wheat and barley for a period of two days at 25±1°C, Different small letters above bars indicated significant differences among the different wheat and/or barley cultivars at $p<0.05$ (one-factor analysis of variance)

barley cultivar, Athroh (7.64 mm^2) had a moderate preference by the larvae. Also, when the larvae were only provided with one cultivar from each wheat and barley, the results showed that also the wheat cultivar, Sham (6.45 mm^2) is less preferred than the barley, Mutah (10.11 mm^2) ($F = 2.97$; 1, 33 df; $p<0.05$).

Number of attaches by *Syringopais temperatella* larvae: Mean number of attaches by *S. temperatella* larvae by feeding together upon different wheat, barley or mixed cultivars of wheat and barley for a period of 24 h at 25±1°C is summarized in Fig. 3. The results of wheat cultivars showed that Sham, Em-Qees and Acsad 65 were the most attached cultivars with 24 times. Then, the number of attaches decreased to 23 times for Horani Nawawi and 21 times for Horani 27. The least number of attaches was recorded for Deer Alla with only 13 times. In case of barley cultivars, Acsad 176 with 29 attaches was the highest, then it followed by Rum 2 (24 times), Yarmuk (22 times) and Mutah (20 times). The least attaches by the larvae were recorded for Athroh and Rum 1 with 15 times for each. When the larvae were provided with two

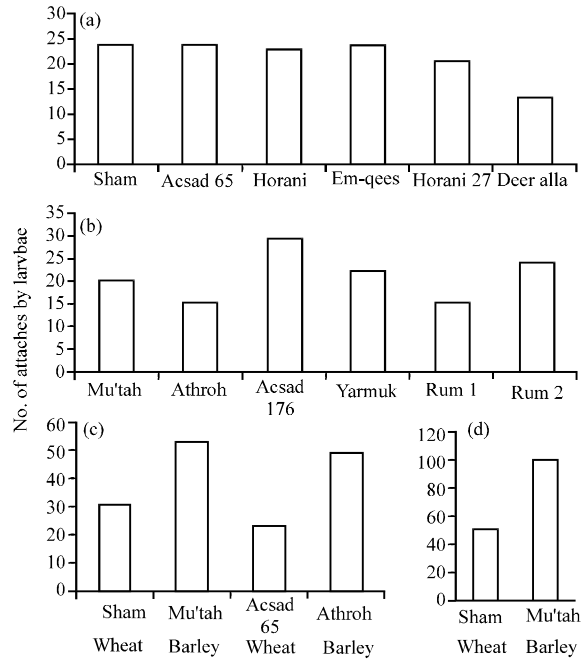

Fig. 3 (a-d): Mean number of attaches by *Syringopais temperatella* larvae by feeding together upon different (a) wheat, (b) barley or (c-d) mixed cultivars of wheat and barley for a period of 24 h at 25±1°C

different cultivars of each wheat and barley, the results indicated that the barley cultivars, Mutah (53 times) and Athroh (49 times) were attached more than the wheat cultivars, Sham (31 times) and Acsad 65 (23 times). Also, when the larvae were provided only with one cultivar from each wheat and barley, the results demonstrated that also the barley cultivar, Mutah with 102 times was more attached than the wheat cultivar, Sham with only 51 times. There was a positive correlation between the consumed area and the number of attaches (visits) by the pest larvae in all of the four different subgroups investigated. A weak positive correlation of $r = 0.27$ and $r = 0.23$ was recorded for wheat and barley cultivars, respectively. However, there was a strong positive correlation ($r = 0.85$) between the consumed area of the two cultivars of each wheat and barley and the number of attaches by the larvae. In contrast, there was a complete positive correlation ($r = 1$, $p = 0.000$) between the consumed area of the two cultivars of wheat and barley and the number of attaches.

DISCUSSION

Wheat and barley are the most grown cereal crops in Jordan, but their yearly average yield is still very low (Agricultural Statistics, 2010). Several abiotic and biotic factors limit their yields (Weltzien and Fischbeck, 1990;

ICARDA Annual Report, 2007). Most of agricultural pests are not easily controlled with conventional pest management strategies (i.e., chemical control) and due to the low amount of inputs on wheat and barley in Jordan, adequate resources are not available in a timely fashion. However, one of the major problems to the production of wheat and barley in Jordan and neighboring countries has been *S. temperatella* (Jemsi and Rajabi, 2003; (ICARDA Annual Report, 2007; Al-Zyoud *et al.*, 2009, 2011).

In Jordan, *S. temperatella* larvae emerge from ground in February and penetrate the leaf mesophyll of wheat and barley. The larvae live in the leaves about 2 months and gnaw mines between the two epidermal layers. After reaching maximum growth in late March to early April, the larvae enter the ground and pupate. Later the adults begin to appear in flight at late April to early May. Laying of eggs takes place on the wheat and barley or in cracks in the soil and after hatching at the beginning of June the larvae descend into the soil and form cysts in which they aestivate from summer to early winter as first-instar larvae (Al-Zyoud, 2007). Because of completely lack of proper crop rotation, outbreaks of *S. temperatella* have mostly occurred in the south of the country (Karak district) for the last ten years (ICARDA Annual Report, 2007; Al-Zyoud, 2007).

The cereal leafminer has chemically been controlled in many countries of our region, i.e., fenitrothion, diazinon and chlorpyrifos in *Cyprus* (Serghiou, 1975), diazinon and chlorpyrifos in Turkey (Duran *et al.*, 1979), diazinon and cypermethrin in Iraq (ICARDA Annual Report, 2007), diazinon and chlorpyrifos in Iran (Fard, 2000; Jemsi and Rajabi, 2003) and diazinon and chlorpyrifos in Jordan (Al-Zyoud, 2008). The use of insecticides has been adopted in Jordan since the first outbreak of *S. temperatella* in 2001, but in spite of that the infested area had a continuous increasing since that time (Al-Zyoud, 2007), suggesting that the use of pesticides is not an efficient and sustainable control measure (Debach and Rosen, 1991). Consequently, chemical insecticides must be decreased and/or eliminated if possible and the idea that pest control could be founded on sound ecological principles was resurrected. However, in many wheat- and barley-based systems, cultural control methodologies as a part of IPM where agronomic practices (i.e., crop rotation and resistant cultivars) used to maintain pest populations below the economic threshold are of paramount importance (NRC, 1996). Therefore, this study is the first to tackle some of IPM measures of this pest such as crop rotation and cultivars preference by the pest.

The current results indicated that the infestation percent and number of *S. temperatella* larvae were significantly the lowest in the crop rotation, wheat/chickpea/wheat. In contrast, the crop rotation, barley/barley/barley showed significantly the highest infestation percent and number of larvae. To the best of knowledge there were no previous studies on the effect of crop rotation on the cereal leafminer. However, Duran *et al.* (1979) reported that the survival of *S. temperatella* larvae in the soil could be affected by the type of plant present (cereal crop or fallow). Moreover, they reported that larval populations began to decline if the interval between sowing of susceptible crops was longer than 18 months. This finding is in line with our results, since we found that when barley was continuously grown three years, the infestation and the number of larvae were the highest. Whereas when the field was left for two years without growing any crop and then followed by barley (fallow/fallow/barley), the infestation percent and the number of the larvae/plot were reduced.

Yaman (1971) in Iraq concluded that the larval density is not the only factor affecting the plant damage indicating by a weak positive correlation. This conclusion is so clear in this study, since the correlation between the infestation percent and number of larvae in the crop rotation experiment was a moderate positive correlation ($r = 0.58$) and the correlation between the leaf area consumed and number of attaches by the larvae in the preference experiment was a weak positive correlation in wheat ($r = 0.27$) and barley ($r = 0.23$) cultivars. This confirms that the high density of the larvae is not only the factor that causes the high infestation or more leaf area consumed. Nevertheless, other factors can play a part in determining the infestation percent of the plant such as soil conditions, rainfall, plowing, predation, parasitism, sowing date and species and cultivar of plant present (Yaman, 1971; Duran *et al.*, 1979; Fard, 2000; Jemsi and Rajabi, 2003; Al-Zyoud, 2007; Al-Zyoud *et al.*, 2009, 2011). In this regards, in Jordan Al-Zyoud, (2007) reported a total parasitism by the parasitoid, *Anilastus* sp. Förster (Hym., Ichneumonidae) reached up to 49% which is high enough to make a sufficient reduction in the pest infestation. Furthermore, in Iran, plowing treatment done up to late August with disking was effective in decreasing the pest infestation, provided that the depth of plowing must not be lower than 15 cm, because *S. temperatella* diapauses at a depth of 15-30 cm (Jemsi and Rajabi, 2003). Also, in Iran, two-time plowing and burning of stubble reduced the infestation by 30 and 100% as compared to the control, respectively (Fard, 2000). In Turkey, it was found that changing the sowing time of cereals from autumn to spring, especially to after mid-March, reduced the larval population considerably (Duran *et al.*, 1979).

Moreover, it was reported that the relative number of live larvae is 1.6 times more in the control treatment and 3.3 times more in the chisel treatment compared with the zero tillage treatment (ICARDA Annual Report, 2007). In addition, since the plant capacity for compensation depends on the availability of moisture during the growing season, the less preferred accessions might compensate for insect infestation by producing more leaves and stems (Madanat *et al*., 2011).

In the current preference experiments on leaf area consumed when *S. temperatella* larvae were together provided with one or two different cultivars of each wheat and barley, the results indicated that the barley cultivars were significantly more preferred than the wheat cultivars by the pest. Also, the current results on number of larval attaches indicated that the barley cultivars had higher attaches (2-fold) than the wheat cultivars. Overall, the larvae consumed significantly more barley than wheat. Our results are in accordance with those of Al-Zyoud (2007) who offered wheat, barely and wild barely together to *S. temperatella* and reported that the larvae preferred significantly wild barely to barely and wheat and more barley than wheat. In addition, Al-Zyoud *et al*. (2009) found also that barely is significantly more susceptible to leafminer larval feeding than wheat when both crops were separately offered to *S. temperatella*. It might that wheat leaves are harder and thicker than barley ones, therefore, the larvae could gnaw mines easier and faster in barely leaves rather than wheat.

Because of the relatively low emphasis on insect pests in wheat- and barley-based systems, wheat and barley cultivars possessing a type of resistance to insect pests have for the most part lagged behind the development of high-yielding, pest-resistant cultivars (Lin *et al*., 1995). In addition, in order to develop improved wheat and barley cultivars that resistance to the pest and could be a cost-effective and practical method of reducing the pest damage, wheat and barley cultivars were, therefore, screened over one season at laboratory. However, the current preference results showed that the wheat cultivar, Horani Nawawi is significantly the most preferred cultivar by the larvae while Horani 27 representing significantly the least preferred cultivar. It is to be mentioned that the 6 wheat cultivars used in this study were together offered in the same Petri dish, however, in a study conducted by Al-Zyoud *et al*. (2009) to investigate the susceptibility of wheat cultivars to this pest, where the cultivars were separately offered to the larvae, indicated that Horani Nawawi is significantly the most susceptible cultivar to the pest larvae which is completely in agreement with the results of the current study. In a study in Iraq it was found a variation in the susceptibility of wheat cultivars to *S. temperatella*, in which the wheat cultivar, Sham 6 often had less infestation than Om Rabee, Karunyia or Tell After 3 cultivars (ICARDA Annual Report, 2007). In addition, under field conditions in Jordan, Madanat *et al*. (2011) stated that out of 308 bread wheat accessions tested, 1% was resistant, 11% were moderately resistant and 88% were susceptible to the pest. In case of barley in the current study, Mutah cultivar was the most preferred cultivar and the least preferred was recorded for Athroh. The barley cultivars, Yarmuk, Acsad 176, Rum 1 and Rum 2 showed a moderate preference by the larvae. When the barley cultivars offered separately to the larvae (Al-Zyoud *et al*., 2009), the pest larvae consumed significantly more from Acsad 176 and Rum 2 and least consumption was recorded for Athroh. Our results are completely in agreement with the results of Al-Zyoud *et al*. (2009), in which Athroh is the least preferred cultivar by the pest either when it was offered separately or together with other barley cultivars. Under field conditions in Jordan, Madanat *et al*. (2011) mentioned that out of 193 barley accessions tested, 12.4% were highly resistant, 4.1% were moderately resistant and 83.5% were susceptible to *S. temperatella*. Our results agreed with the previous ones, in which the cereal leafminer preferred some accessions/cultivars of wheat and barley upon others. The preferences of the leafminer larvae for a certain cultivar over another may be due to differences in natural materials which affect the larvae test or in morphological characteristics of plants which affect larvae behavior and make it more attractive and acceptable. However, the preference of the cereal leafminer for a plant species (wheat or barley), a cultivar or an accession upon another might be due to physical factors (i.e., hairiness, hardiness and thickness) of the leaves, as well as to differences in chemical composition of the leaves (Al-Zyoud *et al*., 2009).

In conclusion, the current study provides basic information on preferences by the cereal leafminer and effect of crop rotation on *S. temperatella* which is useful for the cereal farmers. This initial study showed interesting differences in the infestations of *S. temperatella* depending on cultivar of wheat and barley. These results suggest that cultivar selection can be useful in reducing leafminer damage and the least preferred wheat and barley cultivars found in this study should be grown instead of the most preferred ones. This would likely be useful in reducing both cereal leafminer infestation and the number of sprays currently used on wheat and barley to control this pest in Jordan. The data may support the conclusion that wheat in general is more tolerant to cereal leafminer than barley. Furthermore, the wheat and barley cultivars identified in this study as being less or moderately preferred by *S. temperatella* could harbor various sources of resistance and so could make an important contribution to future breeding programs aiming to produce a type of resistance to *S. temperatella*.

However, further research is warranted to be paid to analyze the leaf factors of wheat and barley cultivars/accessions associated with such a resistance/susceptibility. The ongoing studies on cultural methods and resistant cultivars should be intensified. More emphasis should be placed on regional and inter-regional cooperation in order to control this pest. Also, determining the economic injury level and the economic threshold level of the pest, study of the dynamics of the insect population in comparison with the phonological development of host plants to optimize planting and harvesting dates and monitor natural enemies to increase their impact on the pest population are of vita important. These future studies together with the present results and results of the previous studies (Al-Zyoud, 2007, 2008; Al-Zyoud *et al*., 2009, 2011) are expected to form the foundation of IPM for *S. temperatella* in Jordan. Finally, controlling of cereal leafminer by IPM method will increase yields, reduce variability in production and lower costs, resulting in increased farm income and reduce the hazards in rural areas associated with insecticide use as well as will contribute to improve food security in the country.

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