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Significance of the Larval Population Size of the Cereal Leafminer *Syringopais temperatella* Led. (Lepidoptera: Scythrididae) and the Diapausing Depth in the Soil on the Yield Variables of Wheat and Barley

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ABSTRACT

The cereal leafminer, *Syringopais temperatella* Led. is one of the most serious insect pests of wheat and barley in the Near East countries and their neighboring. Deep ploughing has negative impacts on soil-inhabiting pests. Therefore, it was of vital important to know the soil depth at which the pest larvae diapause to determine the right ploughing depth to facilitate pest control. Soil samples were collected at four different soil depths from a highly infested field and these samples were used to plant wheat and barley seeds in pots. Results revealed that foliage infestation percentage and larval population size in plant leaves were higher on plants grown in soil taken from deeper soil depths than shallower ones. Barley yield in the control treatment was significantly higher than those in the four soil depths, while for wheat, there were no significant differences in the yield among the soil depths treatments including the control. There was a reduction in the grain yield and in the dry straw mass of plants that were planted in soils taken from deeper depths since they contain larger numbers of pest larvae which attacked plant leaves after getting out of dormancy. Results also showed that the leaf infestation percentage was positively correlated with the larval population size in the soil; meanwhile, the grain yield and the dry straw mass were negatively correlated with the larval population size.

Keywords: Cereal Leafminer, *Syringopais temperatella,* Diapause Depth, Larval Population Size.

INTRODUCTION

Biotic factors such as insect pests play an important role in limiting the production of wheat and barley (ICARDA, 2007). The cereal leafminer, *Syringopais temperatella* Led. (Lep., Scythrididae) is considered as one of the most serious insect pests of wheat and barley in the field, and causes economic damage to these crops in the countries of West Asia (Serghiou, 1975; Kaya, 1976; Daamen *et al.*, 1989; Miller and Ghannoum, 1994; Jemsi *et al.*, 2002; Vrieze, 2002; Jemsi and Rajabi, 2003; ICARDA, 2007; Al-Zyoud, 2007, 2008). The pest has been reported in Cyprus (Vakis, 1975; Melifronides, 1977), Turkey (Kaya, 1976), Iran (Jemsi *et al.*, 2002), Greece (Vrieze, 2002), Jordan (Al-Zyoud, 2007, 2008), and in Iraq (ICARDA, 2007). In Jordan, *S. temperatella* had a great significance damage on wheat and barley throughout the country (Al-Zyoud *et al.*, 2009, 2011), and outbreaks of the pest had mostly reported in Karak District in the southern region of the country since 2001. Wheat infestation in Karak District had reached up to

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70%, with a total infestation area of more than 25,000 dunums. Field observations indicated that larvae emerge from ground in early February and penetrated the leaf mesophyll of wheat and barley. The larvae gnaw mines between the two epidermal layers and live in the leaves for 2 months. After reaching a maximum growth in early April, the larvae enter the ground and pupate. Later on, adults activity begin to appear in flight in early May and egg laying takes place on cereal plants or in soil cracks. After larvae hatching in early June, they descended into the soil and formed cysts in which they aestivated during summer, autumn and part of the winter diapausing as first-instar larvae, thus, the insect has one generation a year (Al-Zyoud, 2007).

Studies conducted in Jordan dealing with this pest focused on its biological and ecological aspects (Al-Zyoud, 2007); susceptibility of host plant varieties to the insect (Al-Zyoud *et al.*, 2009), and sources of tolerance in the plant varieties as well (Madanat *et al.*, 2012). In addition, efficacy of certain insecticides against this pest was investigated under laboratory (Al-Zyoud, 2008) and field conditions (Al-Zyoud, 2013). Besides, *Bacillus thuringiensis* (Berliner) was bio-assayed as a preferable and promising bio-insecticide for suppressing the pest in the laboratory (Al-Zyoud *et al.*, 2011). A further study was done on the effect of crop rotation on infestation level (Al-Zyoud, 2012).

Cultural methods were in use for pest control since long, though the action of these practices was slow and not spectacular, it is a safe technique, with less expenditure, was the main reason to follow. The interest in cultural methods for control is renewed since the new hazards and problems created by the inception of new toxic pesticides (Gerson and Cohen, 1989; Debach and Rosen, 1991), and now cultural practices forms an important part of integrated pest management. For the adoption of successful cultural methods for control, it is necessary to have a good knowledge of pest life-cycle, biology and ecology (Al-Zyoud, 2007). Cultural practices like deep ploughing influence directly the survival of soil inhabiting pests. So, the determination of the soil depth at which the pest larvae diapause is necessary to determine the right ploughing depth. It is to be noted that the pest will only be brought to the surface if the soil is ploughed at the right depth, otherwise the pest may remain undisturbed and lay in wait ready to attack the target crop. It is obvious that the majority of the cereal farmers in Jordan have not ploughed their fields at the right depth under the pretext of conserving the soil moisture; therefore, the pest is annually infesting cereal fields. In Iran, ploughing treatment done up to late August with disking was effective in decreasing the pest infestation, provided that the depth of ploughing must be deeper than 15 cm, because larvae diapause at a depth of 15-30 cm (Jemsi and Rajabi, 2003). Furthermore, one- and two-time ploughing gave larval mortalities of 4% and 30% (Fard, 2000). Moreover, a single deep ploughing in summer was not effective against larvae, but gave a slight reduction in the pest population (Serghiou, 1975). However, there is an urgent need to initiate cultural control methods in Jordan in order to reduce the reliance of farmers on chemical insecticides. Concomitantly, this study was conducted to determine the depth of diapaused larvae in the soil to promote the best-bet ploughing depth that should be applied. It is hoped that the outcomes of this study could suggest an appropriate low-cost and environmentally sound control approach to the pest.

MATERIALS AND METHODS

Experimental Conditions and Growing Plants

The experiments were conducted at Al-Raba District, Karak/Jordan (latitude of 31°11", longitude of 35°42", and altitude of 980 m). The experimental site is characterized by semi-arid conditions with relatively moderate long-term annual average rainfall of 300 mm. Generally, rainfall is irregular with intra- and inter-seasonal variability. The study was carried out on potted wheat and barley plants during 2012/2013 cropping season. Routine cultural practices (i.e. weeding and irrigation) were conducted throughout the season. Plants were left without fertilization and no pesticides were applied during the whole experimental period. Wheat cultivar of Horani 27 and barley cultivar of Mutah were grown in plastic pots of 32 cm in diameter and 45 cm in height. The cultivars were obtained from the National Centre of Agriculture Research and Extension/Jordan. The potted plants were kept under natural field conditions.

Experimental Procedure

To fill the experimental pots for planting, soil samples were collected from a field known always with a high *S. temperatella* infestation in Al-Qasr area/Karak (5 km north of the Faculty of Agriculture, Mutah University). The samples were collected from the field on December 10th, 2012 from four different soil depths; 0-10 cm, 11-20 cm, 21-30 cm and 31-40 cm. The samples were kept in the pots, and the treatments have been replicated four times (four pots/each soil depth). Five seeds of each cultivar of wheat or barley were sown per pot. In addition, a control treatment was set up consisting of 4 pots of each crop, in which the soil of the control treatment was brought from the field of Faculty of Agricultural Station which is free of the pest infestation. A distance of 5 m was kept between the control and the other treatments in order to prevent dispersant of the pest larvae among treatments. The experimental design was complete randomized design.

The *S. temperatella* larvae started coming up from the soil in the pots and infesting the foliage of wheat and barley plants at early March, 2012. At late March, data were taken visually and by using a lens (10 ×) on larval number on plant foliage which reflects the larval population size in the soil. The numbers of larvae/pot at the four soil depths for both crops were recorded. The percentage of *S. temperatella* infestation was recorded for all pots at early April, 2012 when the pest' larval damage was clearly seen on wheat and barley leaves. The percentage of infestation has independently estimated three times within the same day, and the average values were calculated. At the harvesting stage, the plants of each pot were separately collected, kept in a paper bag and brought to the laboratory. Hereafter, data were recorded for grain yield weight and dry straw mass/pot using a digital balance. Rates of grain yield and dry straw mass loss of wheat and barley resulted from *S. temperatella* infestation at the different soil depths were calculated. The loss rate was expressed as:

Loss rate (%) = [100-(treatment*100)/control].

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 using one way ANOVA to detect the differences in the variables studied. The variables are: larval population size infesting plant foliage, leaf infestation percentage, grain yield and dry straw mass for both wheat and barley at the different soil depths inhabiting different larval population sizes of the pest (Zar, 1999). When significant differences were detected, means were separated using LSD at 0.05 probability level (Abacus Concepts, 1991). In addition, correlations' analysis among the four different variables studied was conducted using Spearman's correlation method (Zar, 1999).

RESULTS

Results revealed that the number of diapaused larvae increased with increasing soil depth, and this result was confirmed by the percentages of plant infestation (Figure

1 A and B). The infestation percentage and number of larvae were higher for both wheat and barley plants grown in soils taken from deeper field soil depths. The percentage of infestation due to larvae diapaused in 31-40 cm depth (30%) was significantly higher than the other depths for barley ($F_{4,15}$=3.876; P<0.05), while the other three depths were at par with each other (11-14%). Regarding wheat, infestation percentage due to larvae diapaused in 31-40 cm depth (23%) was also significantly higher than the other depths ($F_{4,15}$=3.629; P<0.05), and the infestation percentage in the two middle depths (11-20 cm: 12% and 21-30 cm: 16%) was not significantly differ from each other (Figure 1A). It is clear that the control with zero infestation was significantly different compared with the four studied soil depths for both crops. For barley, the numbers of larvae were significantly higher at the four soil depths as compared with the control with a zero larva ($F_{4,15}$=1.812; P<0.05), and there was no significant difference in number of larvae among the four depths (Figure 1B). On the contrary, the two marginal depths (0-10 and 31-40) were significantly different from the two middle depths (4-5 larvae) for wheat in the number of larvae attacked plants (Figure 1B) ($F_{4,15}$=3.846; P<0.05).

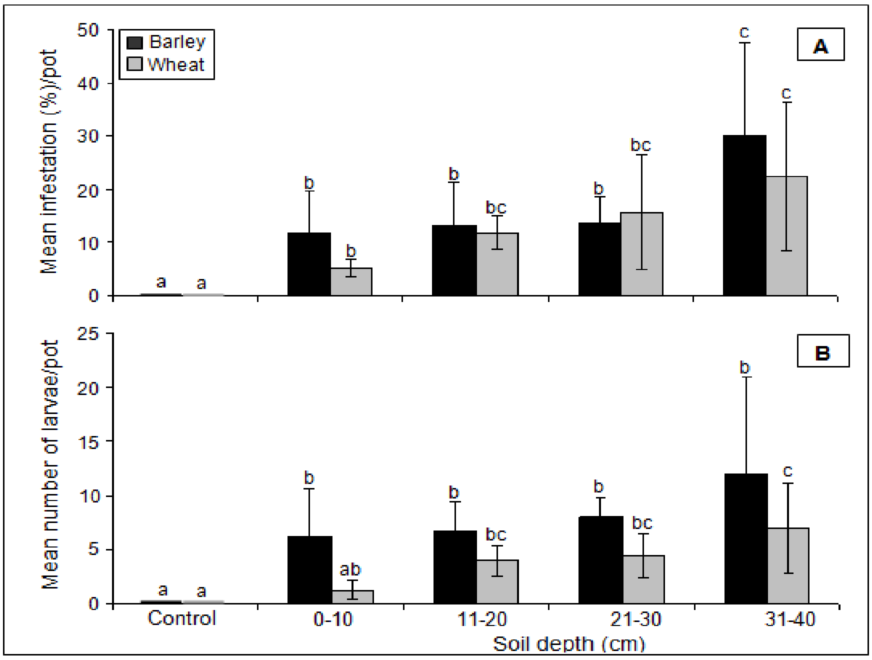

Fig. 1. Effect of larval *Syringopais temperatella* diapause depth in the soil on the infestation percentage (A) and the number of larvae infesting foliage (B) of potted wheat and barley plants. *Different small letters* above bars indicated significant differences among the different soil depths including the control within the same crop at p<0.05 (one-factor analysis of variance).

The results also showed that the yield for barley in the control treatment (~18 gm/pot) is significantly higher than those in the four treatments (3.5-5.2 gm/pot) ($F_{4,15}$=76.39; P<0.05). For wheat, there were no significant differences in the yield (3.3-4.3 gm/pot) among the treatments including the control ($F_{4,15}$=0.442;

P>0.05). The yield in both wheat and barley has not been significantly affected by the larval population size at the different depths of the soil (Figure 2A). With the same trend of results, in case of barley, the larval population size in the soil did not significantly affect the straw biomass at the different depths (3.3-5.5 gm/pot), while the control (14 gm/pot) was significantly higher than the four treatments ($F_{4,15}$=20.017; P<0.05). There was significant differences in the straw biomass for wheat among the different treatments, in which the highest was in the control and the 0-10 cm depth (7.5-8.3 gm/pot), while the lowest (4-5 gm/pot) was at the deepest two depths ($F_{4,15}$=3.494; P<0.05) (Figure 2B).

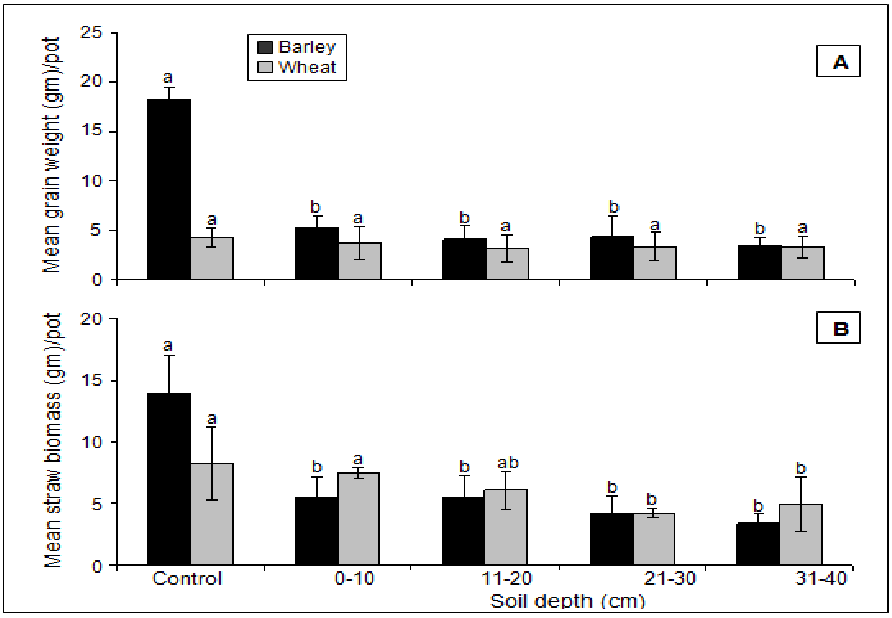

Fig. 2: Effect of *Syringopais temperatella* diapause depth in the soil on grain weight (A) and straw biomass (B) of potted wheat and barley plants. *Different small letters* above bars indicated significant differences among the different soil depths including the control within the same crop at *p*<0.05 (one-factor analysis of variance).

As a general trend, the results indicated that there was a decrease in the grain yield and straw weights with increasing the depth of the soil due to the increase in the population size of the pest larvae. For wheat and barley, the yield loss ranged from 11.5 - 25% (aver. 20%) and 71 - 81% (aver. 76%), respectively. Straw loss was 9.6 - 48.9% (aver. 31.2%) for the wheat and 60.7 - 76.1% (aver. 67%) for the barley. Nevertheless, both yield and straw losses were greater 3.8 and 2.2-fold in barley than in wheat (Table 1). It is worthy to mention that larval population size of the pest in the soil play an important role in plant's yield and straw biomass.

Table 1. Rates of yield and straw losses of wheat and barley resulted from infestation by *Syringopais temperatella* at different soil depths.

Crop	Item	Soil depth (cm)				Overall loss rate
		0-10	11-20	21-30	31-40	
Wheat	Yield loss (%)	11.56	25.00	22.20	21.73	20.12
	Straw loss (%)	09.55	26.24	48.85	40.15	31.20
Barley	Yield loss (%)	71.47	77.65	76.01	80.99	76.53
	Straw loss (%)	60.73	60.95	70.31	76.11	67.03

Correlations' analysis among the different variables investigated (larval population size on the plant foliage, infestation percentage, yield and straw biomass) is presented in Table 2. Results indicated that the larval population size and the infestation percentage are correlated negatively with the yield and straw biomass for both crops ($r = (-0.629)$ to (-0.931)). The larval population size was correlated positively and significantly with the infestation percentage for the wheat ($r = 0.99$, $P < 0.05$) and barley ($r = 0.98$, $P < 0.05$).

Table 2. Correlations' analysis among the different variables studied (larval number, infestation percentage, yield and straw biomass) due to *Syringopais temperatella* infestation on potted wheat and barley plants.

Correlated variables	Correlation (r)	
	Wheat	Barley
Larval population size vs. Yield	- 0.695	- 0.817
Larval population size vs. Straw biomass	- 0.784	- 0.931*
Infestation percentage vs. Yield	- 0.629	- 0.801
Infestation percentage vs. Straw biomass	- 0.825	- 0.844*
Number of larvae vs. infestation percentage	+ 0.990**	+ 0.979**

**Correlation is significant at 0.01 probability level. *Correlation is significant at 0.05 probability level.

DISCUSSION

Most previous studies dealing with *S. temperatella* have focused on the evaluation of many chemical pesticides for its control. Few studies were concerned with the economic importance of such pest and its various manifestations of damage as well as information that serve its control. Hence, this study provided a part of such important information. It is well known from the literature that *S. temperatella* distribution is nearly restricted to the Near East countries and their neighboring countries including Turkey (Kaya, 1976), Iran (Jemsi *et al.*, 2002), Iraq (ICARDA, 2007), and Jordan (Al-Zyoud, 2007), where wheat and barley originate. Nowadays, more attention is paid for alternative measures rather than insecticides to suppress *S. temperatella* in the countries threatened. Timing and distribution of rainfall which characterized by high variability in term of amount and distribution over the entire growing season, and that rainfall is concentrated mainly in December and January promoted the cereal leafminer hazards in Jordan (Madanat *et al.*, 2012). It is well known that the extent of the infestation by *S. temperatella* depends on the rainfall, if it is regularly over the season; the infested plants regain strength and continue to develop in spite of the insect damage (Al-Zyoud, 2007). The leafminer is considered as a key pest especially in southern region of Jordan. The current results indicated that the pest caused grain damage reached up to 20% for wheat and 76% for barley. Generally, barley is more susceptible to the pest than wheat. Such higher damage to barley than wheat is most likely related to the lower leaf oxalic acid content in the barley than wheat (Al-Zyoud *et al.*, 2014). In Turkey, the damage was estimated in the fields to be 40-60% (Kaya, 1976), and 22% (Duran *et al.*, 1979), while in Iraq, it was estimated at 20% (Abu-Yaman, 1971). Furthermore, Kaya (1976) reported that the economic threshold level for *S. temperatella* was determined when over 20% infestation is observed. So, the cereal leafminer requires control action in areas stricken in Jordan since the yield loss exceeded such a set threshold.

The current results revealed that the number of diapaused larvae increased with increasing soil depth, and this result confirmed by the percentage of plant infestation. The infestation percentage and larval population size on leaves were higher for both wheat and barley plants grown in soil taken from the two deeper field soil depths (21-40 cm) than shallower ones (0-20 cm). In this regard, in Iran, Jemsi *et al.* (2002) reported that *S. temperatella* larvae diapause at 15-30 cm soil depth, which is partially in agreement with the present results. Furthermore, ploughing treatment done in Iran up to late August with disking was effective in decreasing the pest infestation and increasing the wheat yield, provided that the depth of ploughing must be deeper than 15 cm (Jemsi and Rajabi, 2003). While in Cyprus it was found that a single deep ploughing in summer was not effective against larvae, but gave a slight reduction in the pest population on barley (Serghiou, 1975). Based on such result, ploughing at soil depth up to 40 cm will be of great benefit in the pest control; since it will bring up the larvae to the soil surface and they will be exposed to natural mortality factors such as birds and other predators, and to unfavorable environmental conditions, as well as it will disturb the niche of the diapaused larvae. Straw of both crops is no less important for the farmers than the grain itself, because of its importance as a dry feed for livestock. Thus, results of this study showed that at deeper depths, about one third of the wheat straw was lost due to the pest infestation, while two-third were lost for the barley. This huge loss in crop straw especially for barley reflects the larger larval population size at this depth of soil and the voracious feeding of insect larvae as well.

It is worth to mention that larval population size of leaves could greatly affect plant’s yield and straw biomass. The results of this study indicated that larval population size is negatively correlated with grain yield and dry straw mass, and positively correlated with the infestation percentage of plants of both crops. Our results are in line with the findings of Al-Zyoud (2012), who reported a positive correlation between the infestation and the number of larvae, and also Serghiou (1975) who reported a negative correlation between the size of the pest larval population and the grain yield. Furthermore, Abu-Yaman (1971) in Iraq concluded that the larval density is not the only factor affecting the plant damage with a weak positive correlation. Nevertheless, other factors can play a part in determining the infestation percentage of plants such as soil conditions, rainfall, plowing, predation, parasitism, sowing date, and species and cultivar of plants (Abu-Yaman, 1971; Duran *et* *al.*, 1979; Fard, 2000; Jemsi and Rajabi, 2003; Al-Zyoud, 2007; Al-Zyoud *et al.*, 2009, 2011).

In conclusion, ploughing fields to a depth not less than 40 cm is of great importance in reducing the diapausing community of larvae in the soil, thereby reducing injury to plant leaves later.

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أهمية حجم وعمق بيات مجتمع يرقات صانعة أنفاق أوراق الحبوب في التربة على متغيرات الإنتاج لمحصولي القمح والشعير

فراس أحمد الزيود[1] وإيهاب حسني غبيش[2]✉

ملخص

صانعة أنفاق أوراق الحبوب (*Syringopais temperatella*) هي واحدة من الآفات الحشرية الأخطر على القمح والشعير. تأثر الحراثة العميقة بشكل مباشر على بقاء الآفات التي تقطن التربة على قيد الحياة. وبالتالي كان من الأهمية معرفة عمق بيات يرقات صانعة أنفاق أوراق الحبوب في التربة وذلك لتحديد عمق الحراثة المناسب لتحفيز المكافحة. جمعت عينات من التربة على أربعة أعماق مختلفة من حقل عرف بشدة إصابته بالآفة، ووضعت العينات في أصص حيث زرعت فيها بذور نباتات القمح والشعير. بينت النتائج أن نسبة إصابة أوراق النباتات وعدد يرقات الآفة على الأوراق كانت أعلى في النباتات التي زرعت في الترب المأخوذة من أعماق أكبر منها في الترب ذات الأعماق الأقل. وكان العائد في نباتات الشاهد لمحصول الشعير أعلى معنوياً من تلك النباتات الموجودة في أعماق التربة الأربعة الأخرى، في حين أنه لم تكن هناك فروق معنوية في عائد القمح بين أعماق التربة المختلفة وبما في ذلك الشاهد. وكانت هناك انخفاضات في ناتج الحبوب وناتج القش للنباتات التي زرعت في التربة المأخوذة من أعماق أكبر وذلك لاحتوائها على أعداد أكبر من يرقات الآفة والتي تهاجم أوراق النباتات بعد الخروج من البيات. وأظهرت النتائج ارتباط نسبة الإصابة في أوراق النباتات بعلاقة طردية مع حجم مجتمع يرقات الآفة الموجود في التربة، في حين أن ناتج الحبوب وناتج القش ارتبطا بعلاقة عكسية مع حجم مجتمع يرقات الآفة في التربة.

الكلمات الدالة: صانعة أنفاق أوراق الحبوب، *Syringopais temperatella* ، عمق البيات، حجم مجتمع اليرقات.

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