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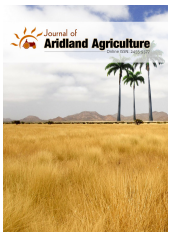

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Evaluation of resistance of some barley varieties to wheat stem sawfly (Hymenoptera: Cephidae) in Hama Governorate

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ABSTRACT

Wheat stem sawfly (Hymenoptera: Cephidae) is a significant pest on wheat and barley in Syria, and host plant resistance is one of the most effective mitigation of wasps damage.The preference for laying eggs among females of wheat stem sawfly (WSS) was studied in some cultivation barley varieties in Syria, and the reasons for this preference, by comparing the characteristics of plant height in the stages of early wasp propagation, phenological development stages synchronized with late propagation wasps stages that are known having attraction influence for female wasps to put eggs, within the natural conditions at the place of experimenting in Soran region, northern of Hama, about 20 km.The results showed a great variation in the infection rates between the studied barley varieties. Female of wheat stem sawfly WSS preferred to lay eggs in the barley cultivar Arabi Aswad, which was a susceptible variety for infection although it was not the highest plant during the early dates of wheat stem sawfly spread, or the less developed in the late dates of wheat stem sawfly spread, whereas the rest of the studied varieties (Furat 1, Furat 3, Furat 4, Furat 5, Furat 6, Furat 9, Arabi Abiad, and Arabi Abiad Mohsan) were distinguished by its relative resistance to the wheat stem sawfly. Our results suggest conducting other studies to reach the reasons for predilection preference or lack of preference and benefit from them later for reducing losses resulting from this injury.

KEYWORDS: Wheat stem sawfly, Barley, Phenological stages

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INTRODUCTION

Wheat stem sawfly Cephus spp., Trachelus spp. (Hymenoptera: Cephidae) is an extraordinary insect pest of wheat and barley in Europe, North America, North Africa, and Western Asia as well as the Middle East. The larvae feed on the stems of cultivated grass crops such as wheat, barley, oats, and wild herbs such as Agropyron, Bromus, and Elymus. Wheat stem sawfly leads to considerable losses in cereal crops around the world because the larva chews the stem of the host cereal crops like wheat, barley and oat, as the larval tunnels overlap with plant stem vessels, ending with reduction of number and weight of grains, and poor grains quality (Protein content). Stems dries and suffer from lodging , as a result of cutting its bottom by the larva, this increases the losses of falling grains number [1], and delays harvest time, raises amount of fuel and the need for special equipment to collect the lodged stems, and finally all these will consequently lead to increasing the cost of production [2]. Larvae spend their dormant period in the subsurface portions of the stems. The adults emerge in early spring during the growth period of grass crops. Males appear at the beginning, and most of the mating occur during the first day of the emergence of female adults. Females feed immediately after their emergence and then spend the rest of their lives searching for a suitable place to lay eggs in the stem of large grass crops [3].The pest has one generation per year, and its flight period varies from one week to approximately one month. Therefore, choosing the appropriate host for laying eggs is of great importance because the adults of the wheat stem sawfly live less than seven days after emergence [4], and the success of laying eggs requires placing them in a young, fast-growing, juicy green stem. Plants are susceptible to infection during a short period, and most eggs are laid between the stages of stem elongation to the stage of flowering [5]. The larvae feed inside the stem, moving up and down, and then moving down to the lower part of the stem when the plant matures. The larvae chew the internal part of plant stem in a V- shape furrow, so the internal part of stem will blocked because of the larva food residues under the furrow

and the sawyer above the larva. The furrows weaken the stems that usually break at this point, producing heels that remain underground, where the larvae spend the winter inside it [6].

[7] concluded that both antibiosis and antixenosis are involved in the resistance of barley to the WSS, but antibiosis seems to be more prevalent. Almost all of the barley lines had greater larval mortality than the hollow-stemmed wheat lines, and only a few barley lines had mortality as low as that observed in the solid stemmed wheat line. Since barley lines lack solid stems, it is apparent that barley has a different form of antibiosis. Some scientists results provided information about using barley in rotation to control the wheat stem sawfly which could provide a basis for identification of new approaches for improving wheat stem sawfly resistance in wheat. The results of [8] recommended to measure the wheat stem sawfly survival through barley cultivars, their results explained that standardizing with site-specific growing degree-days would provide stronger guidance on barley cultivars that hinder population growth of wheat stem sawfly and minimize economic losses.

Four species of wheat stem sawfly were recorded in Syria *Cephus pygmaeus* (L.), *Trachelus judaicus* (Konow), *T. libanensis* (Andre), and *T.tabidus* (Konow) [9], the most dangerous of which is the European wheat stem sawfly C. *pygmaeus* (L.), among all of the previous spreading species [10]. The most severe cases of wheat stem sawfly occur in the northern governorates of Syria including Idlib, Hama, and Aleppo [11], and the injury causes significant economic losses as it affects wheat, barley, oats, rye and several wild herbs [9]. High infection rates occurred in the governorates of Aleppo and Hama [9, 12, 13]. Existence of varieties resistant to wheat stem sawfly are currently the first strategy to manage this pest and to reduce its damage. The results of studies have shown that these varieties can reduce infection levels compared to susceptible varieties, while the resistant wheat varieties to wheat stem sawfly are characterized mainly by the solid stem, that causes the death of a big number of the larvae or leads to poor fertility of completed development adults [14], but these varieties are poorly productive. The characteristic of impermeability varies from season to another according to different environmental conditions [15].Therefore, the search focused on the non-preferred varieties by the wheat stem sawfly in order to increase the plants resistance to this insect. Some plant traits such as plant height, growth stage, and the smell of some chemical compounds released by plant, are playing attractive role in making insects choose specific plant to lay eggs. In general, the insect prefers to lay its eggs firstly in the taller and more developed plants when wasps begin to spread in the spring, then in the younger and less developed plants at the end of their spread during the developmental period of plants which are suitable for wasps to lay eggs, this period extends from the start of the stem elongation (Zadoks 33) until the time when grains start to dry (Zadoks 77) in barley [16].

The General Organization for Seed Multiplication distributes mainly the barley advanced varieties to Hama governorate farmers, and since this pest is critical and causes important economic losses, and because of the difficulties of chemical controlling which costs a lot, so the objective of this study was to assess the resistance of targeted barley varieties to this pest in field conditions.

MATERIALS AND METHODS

Plant Material

Ten local varieties of barley (*Hordeum vulgare* L.) provided by the General Organization for Seed Multiplication: Furat 1, Furat 3, Furat 4, Furat 5, Furat 6, Furat 7, Furat 9, Arabi Abiad, Arabi Abiad Mohsan, and Arabi Aswad were planted in this study (Table 1).

Targeted Pest

Adults of wheat stem sawfly which are naturally distributed in site of study.

Field Experiments

The experiment was conducted at Soran site, 18 km northern Hama city (36.74 E Longitude and 35.29N Latitude), and the altitude is 350 m, during the season (2019/2020) in a randomized complete block design RCBD with three replicates. Every replicate was divided into ten plots, the total area of each plot was 1m^2, with 2 m distance between plots. Each plot consisted of two rows of 1 m length, with 30 cm distance between rows, and 5cm between plants in the same row. Barley seeds were planted on 10 December 2019. All agronomic practices were applied according to the recommendations of Syrian Agrarian Ministry.

Treatments

The date of first emergence of the Wheat stem sawfly, and the development of their numbers in the search area were determined via usage of the insect collection network, by conducting twenty random strikes near a wheat field nearby the experiment every week starting from the middle of March to the first of May in order to study the Synchronization between the wasps spreading period and the developmental stage of barley plants. The stem solidness determined for the tested cultivars in mid-April, according to the scale of [17], (1:hollow, 2: semi-hollow, 3: medium solid, 4: semi-solid, 5: solid), by performing a cross-section between the second and the third

Table 1: List of wheat genotypes used in this study

Variety	Syrian Zone of Stability	Rainfall / mm	Productivity (kg/h)
Furat 1	Second	250-350	2212
Furat 3	Third	250	1750
Furat 4	Second	250-350	3090
Furat 5	Third	250	2030
Furat 6	Second	250-350	2540
Furat 7	Third	250	1715
Furat 9	Third	250	2620
Arabi Abiad	Second/ Third	250-350/ 250	2000
Arabi Abiad Mohsan	Second	250-350	2725
Arabi Aswad	Third	250	1760

nodes, to estimate the degree of solidness for excluding the influence of the solidness factor on the survival rate of larvae and their cutting of the stems.

Studied Traits

Ten plants of each variety were chosen weekly during the period of naturally occurring spread of the wasps in the fields (from mid-March to the end- April) to study the plant traits that affecting the rate of infection of the wheat stem sawfly. Plant height measured by counting the average of the ten plant lengths, by measuring the height from the soil surface to the top of the tallest leaf at the beginning of spikes emerging, and from the soil surface to the top of a spike after heading.

The developmental stage of each variety was determined according to the scale of [18]. Plants were left under field conditions until the end of May (before harvest). The average percentage of infestation of each studied varieties in the three replicates was calculated using the formula:

Infestation rate = the number of plants which were cut by larvae / total number of plants per replicate.

Statistical Analysis

Results analyzed using SAS.9 analytical program depending on the least significant differences test L.S.D at 0.05 in studied traits.

RESULT

The spread of wheat stem sawfly in the search area coincided with the development stages of infection-susceptible barley plants, as the beginning of the emergence of the insect was recorded from 23th of March 2020, and were in small numbers. The numbers of the captured wasps increased until it reached the largest number on 11th of April, and they were still found in the search site until 24th of April (Figures 1. and 2.). The majority of the captured wasps belonged to *C.pygmaeus*, while only a few numbers belongs to the genus *Trachellus* recorded.

The results showed that the studied cultivars were all with hollow stems, so the solidness trait did not affect the percentage of infestation which was determined based on the percentage of cutting plants before harvest.

The results of the statistical analysis showed that there were significant differences in the infection rates between the studied varieties ($P < 0.05$).The infestation rates of the barley varieties ranged between 1.2% in cultivar Furat 9 to (46.2%) in Arabi Aswad (Table 2).

Female wasps preferred to lay their eggs in the stems of Arabi Aswad compared to the rest of barley varieties, followed by Furat 7, the infection rates were very high (46.2 and 30.5) % respectively, and the differences are large between these two verities and the rest of them. The infection rates were medium

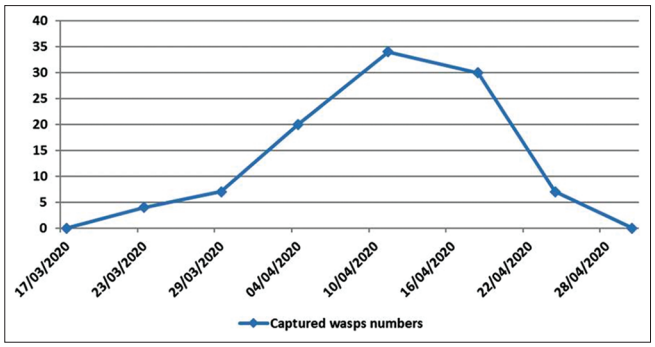

Figure 1: Change of wheat stem sawfly numbers in Soran site (Hama governorate) season (2020)

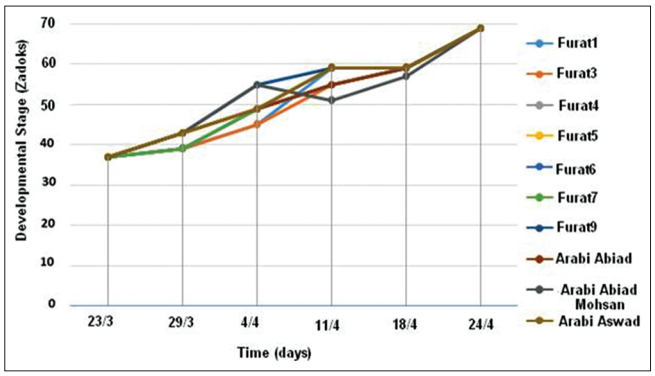

Figure 2: Phenological development stages of the tested barley varieties during the propagation of wheat stem sawfly in Soran site in season 2020

in Furat 4 and Arabi Abiad Mohsan 13.2% for both of them, while weak in the rest of the varieties (Furat 1, Furat 3, Furat 5, Furat 6, Furat 9, and Arabi Abiad), which were (4, 7.6, 1.4%, 4.6, 1.2 and 8) % respectively. There were no clear significant differences in plant height between varieties in early infestation dates with the high and low infestation. The most susceptible variety to wheat wasps Arabi Aswad wasn't superior in plant height during early growth dates, whereas some cultivars with low infestation rates, such as Furat 1, were superior in plant height during all early dates.

There were no significant differences with other varieties such as Furat 5 at the beginning of the wasps spread, the variety Furat 4 in the second week, the variety Furat 6 and Furat 9 in the third week, and both varieties Furat 5 and Furat 9 in the fourth week.

The sensitive variety Furat 7did not show significant differences in plant height except at the beginning of the wasps spread on 23March, while these differences were not found concerninig the varieties with a low infestation in the remaining dates (Table 2).

In the fifth week after start of infection, the same phenological stage (full emergence of spike) was for all varieties with no differences, and the same in the sixth week all varieties were in flowering stage. The varieties differed in maturity stage in the fourth date; the two sensitive varieties Arabi Aswad and Furat 7 were in the full emergence of spike stage, as were as the less

significant varieties Furat 1, Furat 9, and Arabi Abiad Mohsan, While the rest of varieties which were less significant infected than the two susceptible varieties (Furat 3, Furat 4, Furat 5, Furat 6, and Arabi Abiad) were all in half emergence of spike stage which means a less developed stage (Table 3).

DISCUSSION

Many researches were conducted in the world about host plant resistance (Wheat and Barley) to wheat stem sawfly for finding resistant cultivars because of difficulty to control this pest chemically. Our study considers as the first Syrian study with the aims of searching for barley varieties resistant to wheat stem sawfly in Syria, and trying to determine the causes of their resistance.

the study of resistance due to non-preference was focused only in this paper, host plant resistance that is due to the presence of solid pith in the stem can be relatively successful [19], solid stems may be compromised by environmental effects on pith expression [20] and relative expression of the trait in different backgrounds [21].

The Antixenosis of the tested barley cultivars by wheat stem sawfly were determined based on the average percentage of cut stems by the larvae at the end of their development, and not by the average number of eggs placed in each cultivar, and this evaluation is accurate since all the varieties with hollow stems and do not cause the death of the hatched larvae [22, 19].

Number of cut stems varied depending on cultivar, indicating oviposition preference for certain cultivars. We found that both cultivars Arabi aswad and Furat 7 had the greatest cut stems (Table 2, 3). This indicates that Arabi Aswad and Furat 7 has traits similar to those reported for wheat, that are more attractive to foraging *C. cinctus* females [23, 24], although the cause of preference in barley is unknown. In in contrast, the percentages of the cut stems were relatively small in the rest of the tested varieties, and this indicates that they were less attractive to the females to lay eggs.

Female wasps preferred the variety Arabi Aswad for laying eggs, despite that in the early development stage of barley plants, the existence of other varieties that are higher than it, and other varieties equal with it in the plant height with no significant differences. Although there were less developed varieties in the late stage of the evolution of barley plants, and this also applied to the variety Furat 7, which had a high incidence of infestation compared to the rest of the varieties. It does not agree with some

Table 2: Plant height of studied barley varieties at early dates and average infestation of wheat stem sawfly

Variety	Plant height from the beginning spread to the maximum spread of the wasps (cm)				Infection rate %
	First date 23-3- 2020	Second date 29-3-2020	Third date -44-2020	Fourth date 11-4-2020	
Furat 1	39.5^{b}	52.6^{ab}	66.96^{a}	101.43^{a}	0.040^{de}
Furat 3	25.16^{e}	41.667^{fg}	53.5^{c}	71.26^{d}	0.076^{cd}
Furat 4	26.36^{de}	50.86^{abc}	58.5^{bc}	86.46^{b}	0.132^{c}
Furat 5	34.26^{c}	54.73^{a}	66.83^{a}	86.53^{b}	0.014^{e}
Furat 6	28.96^{d}	44^{efg}	57.4^{bc}	71.1^{d}	0.046^{de}
Furat 7	44.63^{a}	51.8^{abc}	60.53^{ab}	86.73^{b}	0.305^{b}
Furat 9	28.06^{de}	40.33^{g}	56.93^{bc}	77.67^{bcd}	0.012^{e}
Arabi Abiad	37.133^{bc}	49.4^{bcd}	61.2^{ab}	74.26^{cd}	0.080^{cd}
Arabi Abiad Mohsan	26.86^{de}	44.1^{efg}	61.8^{ab}	80.73^{bcd}	0.132^{c}
Arabi Aswad	35.4^{c}	47.63^{cde}	56.93^{bc}	88.33^{b}	0.462^{a}
Mean	32.63	47.71	60.06	82.45	0.131
LSD (5%)	3.28	4.42	7.03	10.26	0.05
CV %	5.87	5.40	6.82	7.25	22.68

Where: Means within a column followed by different letters are significantly different (ANOVA followed by Fisher pairwise comparison:$P<0.05$), LSD least significant differences, CV coefficient of variance

Table 3: The development stage of late dates and average incidence of wheat stem sawfly for the tested barley cultivars

Variety	Phenological stage of plants of different barley varieties during April (Zadoks scale)				Infection rate %
	Third date 4-4-2020	Fourth date 11-4-2020	Fifth date 18-4-2020	Sixth date 24-4-2020	
Furat 1	45	59	59	69	0.040^{de}
Furat 3	45	55	59	69	0.076^{cd}
Furat 4	49	55	59	69	0.132^{c}
Furat 5	49	55	59	69	0.014^{e}
Furat 6	49	55	59	69	0.046^{de}
Furat 7	49	59	59	69	0.305^{b}
Furat 9	55	59	59	69	0.012^{e}
Arabi Abiad	49	55	59	69	0.080^{cd}
Arabi Abiad Mohsan	55	59	59	69	0.132^{c}
Arabi Aswad	49	59	59	69	0.462^{a}

Where: Means within a column followed by different letters are significantly different (ANOVA followed by Fisher pairwise comparison: $P<0.05$)

researchers results, as some of the reasons for the preference of wheat stem sawfly for specific varieties of wheat and barley are related to the characteristic of plant height in the early stage of infection, and the less developed plants in the late stage of infection [25,23].

Concerning growth stages in barley, females of wheat stem sawfly were attracted to less mature stems and tillers in barley plants, due to the plants losing their insect-attracting scent [16].

Our results agreed with the results of researchers that indicated the egg-laying process of wheat stem sawfly is a complex process, which depends on several signals in wheat. Many studies have proven the role of semiochemicals compounds in the host plant on female's preference to lay their eggs in some wheat varieties as release large amounts of several compounds, including (Z)-3-hexenyl acetate [26, 27, 28], and (E)- and (Z)-β-ocimene [29].

our results need deeper studies to search for these compounds and confirm their role in attracting female wasps.

CONCLUSION

According to our results, we recommend to apply more researches concerning the using of the susceptible variety Arabi Aswad as a hunter plant by farmers to protect the farmers-favored barley varieties in the affected sites of wheat stem sawfly in Syria

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