The Russian Wheat Aphid, *Diuraphis noxia* (Kurdjumov) (Homoptera: Aphididae), and its Natural Enemies in Northern Syria.

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Abstract

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Russian wheat aphid, *Diuraphis noxia* (Kurdjumov) (RWA), is a serious pest of several small grain cereals in many countries. A survey of RWA infesting wheat and barley in northern Syria, and its associated natural enemies, was conducted at ICARDA's main research station near Tel Hadya, Syria. A wide range of predatory insects and parasites, including Coccinellidae, Syrphidae, Chamaemyiidae, and Braconidae were observed. In addition a chalcidoid hyperparasite of *Diaeretiella rapae* (M'Intosh) was observed. Natural enemies may exert an important regulatory role on RWA populations on wheat and barley.

Key words: Cereals, insects, predators, parasites, hyperparasite.

Introduction

Insect herbivore populations are usually maintained in nature in equilibrium where births and immigrations are compensated for by deaths and emigration. An important regulatory action on insect herbivore populations is exerted by natural enemies including predators, parasites, and parasitoids. In the absence of natural enemies, many insect herbivores would soon deplete their food resource, causing instability in the ecosystem ultimately resulting in extinction of the herbivore population. In the case of insect pest populations, which compete directly with man for the food source, intolerable economic and material damage would result.

The Russian wheat aphid, *Diuraphis noxia* (Kurdjumov) has recently gained widespread notoriety due to its devastating effect on small grain cereals, primarily wheat, *Triticum aestivum* L. and barley, *Hordeum vulgare* L. RWA first gained serious attention as a cereal pest in Syria in 1990, and its presence was confirmed in Lebanon in 1992 (8). It has also been observed in nearly every country of the Mediterranean rim, where it causes serious crop losses during periods of prolonged drought (12). RWA causes damage to cereals by direct feeding (4,10). Reaction to the aphid's salivary secretions, which are injected into the plant during feeding, causes longitudinal chlorotic streaking, convolute leaf curling, and stunting in the host plant that may result in lower grain yield, poor grain quality, and ultimately plant death (1,3,20).

Previous surveys of RWA on barley and wheat cultivars have concentrated on the identification and quantifying of RWA to estimate its impact on crop production. Few studies in Middle Eastern countries have examined the natural enemy complex associated with RWA or the potential for controlling RWA in the region by enhancing natural enemies. The objectives of this study were therefore to identify some of the natural enemies attacking RWA in northern Syria, and begin to examine the effectiveness of these natural enemies in controlling RWA populations.

Materials and Methods

RWA colonies were established from aphids collected in wheat and barley fields at ICARDA's main research station near Tel Hadya, Syria (elevation 284 m; 36° 01'N, 36° 56'E; 365 mm mean rainfall). Collected RWA were reared in cages on potted barley plants in a plastic house maintained between 15 to 25° C, approximately 65% relative humidity, and on a 16L:8D photoperiod regime. The RWA-susceptible barley cultivar Arabi Abiad, grown in 25 cm diameter plastic pots in a 2 soil:1 peat moss:1 sand mixture, was used as host for aphid cultures. RWA colonies were maintained on host plants for a minimum of three weeks. When field plots were ready to be infested with RWA, potted plants were cut at soil level and the aphids shaken from the leaves onto paper sheets covered with powdered talc for application onto plants in the field with an aphid bazooka (11,18).

Field trials were sown in late November as hill plots spaced at 0.5 m intervals with ten seeds sown per hill. Seeds sown were wheat and barley varieties developed by ICARDA's germplasm improvement program and screened specifically for RWA resistance (8,9). A 5 m wide border of triticale (X *Triticosecale* Wittmack) was planted around the area containing the hill plots. The entire field was treated with the herbicide U-46 (dimethylamine salt of CMPP 400 + dimethylamine salt of 2.4-D 100, Bayer) at 3 l/ha in February prior to tillering to control volunteer lentils.

Hill plots were infested with RWA on 17 Mar 1993 using an aphid bazooka when plants had attained growth stage 32 according to Zadoks *et al.* (22), approximately 127 days after planting. Prior calibration of the aphid bazooka by diluting the collected aphids with powdered talc insured that each hill received between 50 and 70 mixed RWA instars.

Field surveys of RWA and associated natural enemies were conducted from 3 May to 16 May on hill plots showing obvious symptoms of RWA infestation. Ten tillers each from 25 randomly selected hills of wheat and 25 hills of barley were examined for RWA, aphid mummies, and natural enemies. The number of infested tillers out of the total number tillers was recorded and all plants in the hill plot scored as a single unit for RWA damage according to infestation/plant damage scales described by DuToit (2). Zadoks (22) plant growth stage at the time of collection was determined for each hill plot.

In establishing plastic house cultures, individual aphids were removed from infested tillers in the field with a fine artist's brush and immediately transported to the plastic house where they were placed on a potted barley plant covered with a fine mesh cloth cage. The barley variety used was Arabi Abiad. Aphid mummies were removed from the leaves as they were discovered and placed on a filter paper lining the bottom of a petri dish. A few drops of honey were placed on the filter paper as a food source for the emerged parasitoid. Petri dishes were maintained at 22 to 25° C and 55% relative humidity in a rearing room. Once parasitoids had emerged a representative sample was preserved in 95% ethanol for later identification. Unknown parasites were sent to Dr. Peter Stary, Czeck Academy of Sciences, for identification. All syrphids, coccinellids, and *Leucopis* spp. were removed from the tillers and preserved in 95% ethanol.

Once field surveys had been completed, an experiment was designed to examine the efficiency of the most common RWA parasitoid, *D. rapae,* at different aphid densities. Seven Arabi Abiad seeds were sown in each of 30 pots in a 2 soil:1 peat moss:1 sand mixture and later thinned to 5 plants/pot. Each pot was covered with a 90 cm high cage measuring 18 cm in diameter. A yellow sticky trap was suspended from the top of each cage to capture alate aphids and emerged parasitoids. Treatments consisted of 10, 50, 100, 150, 200, and 250 adult alate aphids placed on plants in each pot when plants had reached the three leaf stage, plant development stage 13 according to Zadoks *et al.* (22). Each treatment was replicated five times. One hour after introducing aphids onto the plants, two newly emerged adult female *D. rapae* were placed in each cage with an aspirator. Both were removed from the cage after 24 hours. Aphid mummies were collected after 24 hours and every 24 hours thereafter for 13 days. Collected mummies were placed on moistened filter paper within a petri dish with a few drops of honey and parasitoid identification was confirmed upon emergence. The entire experiment was conducted in a plastic house under conditions described previously.

It became obvious during the experiment that parasitoids were emerging and attacking the aphid population in the caged pots, suggesting that removal of the mummies from the cages once daily was insufficient. The experiment was therefore repeated with mummies being removed in the morning and afternoon.

Results and Discussion

The variety of RWA natural enemies collected in the field during this study was not as great as the number of different species reported from Mediterranean rim countries by other workers (Table 1). No parasitoids in the genera *Aphidius*, *Aphelinus*, *Praon*, *Lysephlebus* or *Ephedrus* were observed in this study, although *Praon* spp. and *Aphidius colemani* Viereck have been collected previously at Tel Hadya from RWA cultured in plastic houses (7). The predators collected in this study have also been reported in previous collections of RWA natural enemies made in Syria, Jordan, and Turkey (12,16,17).

There were some differences in RWA and RWA natural enemy occurrence on wheat and barley (Table 2). RWA plant ratings, which combined observations of RWA density and plant response to RWA toxins, were insignificant between the two plant species. The number of RWA observed on wheat and barley did not differ, nor did the number of predators. There were significant differences observed on wheat and barley in the total number of tillers per hill, the number of infested tillers per hill, and the number of *D. rapae* and *Leucopis* per ten tillers.

The manner in which data were collected from individual hills rendered intraspecific statistical analysis of differences in RWA on different cultivars improper. However, there were large differences in the number of RWA and parasitoids collected from the different lines in both wheat and barley. In wheat RWA densities per ten tillers ranged from 67 to 341,

Table 1. Natural enemies of RWA from Tel Hadya, Syria and from other Mediterranean rim countries.

Genus/ Species	Order:Family	Location
	Collected in Syria	
Syrphus sp.	Diptera:Syrphidae	Syria[1]
Leucopis sp.	Diptera:Chamaemyiidae	Syria[1]
Coccinella septempunctata L.	Coleoptera:Coccinellidae	Syria[1]
Coccinella sp.	Coleoptera:Coccinellidae	Syria[1]
Diaretiella rapae M'Intosh	Hymenoptera:Braconidae	Syria[1]
Praon sp.	Hymenoptera:Braconidae	Syria[2], Greece, France.
Aphidius colemani Viereck	Hymenoptera:Aphidiidae	Syria[2]
	Collected in other Mediterranean rim countries[3]	
Aphelinus asychis Walker	Hymenoptera:Encyrtidae	Turkey
Aphelinus nr. *varipes*	Hymenoptera:Encyrtidae	Turkey, France, Greece
Aphelinus spp.	Hymenoptera:Encyrtidae	France
Aphidius ervi Haliday	Hymenoptera:Braconidae	Greece
Lysiphlebus ambiguus (Haliday)	Hymenoptera:Braconidae	Greece
Aphidius matricariae Haliday	Hymenoptera:Braconidae	Turkey, Greece
Aphidius rhopalosiphi De Stephani Perez	Hymenoptera:Braconidae	Turkey, Spain
Aphidius uzbekistanicus Luzhetski	Hymenoptera:Braconidae	Greece
Aphidius spp.	Hymenoptera:Braconidae	France, Spain
Ephedrus plagiator (Nees)	Hymenoptera:Braconidae	Turkey, France
Praon gallicum Stary	Hymenoptera:Braconidae	France
Praon volucre (Haliday)	Hymenoptera:Braconidae	Turkey, France

[1]Present study; [2](7); [3](15,21).

and in barley ranged from 31 to 396. Parasitoid densities per 10 tillers in wheat ranged from 27 to 102 and from 4 to 103 in barley. Predator densities per ten tillers ranged from 0 to 8 in both wheat and barley.

Data from pooled collections from wheat and barley are shown in Table 3. The overall parasitism rate of all RWA observed was about 23%, with nearly 55% of the aphid mummies collected being infested by a chalcidoid hyperparasite. All of the remaining parasitoids were identified as *D. rapae*. Nearly half of the mummies collected appeared dead, with no parasitoids or hyperparasites emerging from them in the laboratory. Among the predators, *Syrphus* spp. was the most numerous, followed by *Leucopis* spp. and *Coccinella* spp., respectively. *Leucopis* has gained much attention as a potential biocontrol agent for RWA since the larva is small enough to pursue it into the tightly rolled leaves that result from RWA feeding and which provide a safe refuge against most other aphid predators and parasitoids. The potential of syrphid flies as RWA biocontrol agents has largely been ignored. The ratio RWA to predators was about 90:1, decreasing to 67:1 if only living RWA were considered.

Some biologically and statistically significant correlations were observed between RWA and plant

Table 2. Comparison of RWA, parastoid, and predator performance on wheat and barley at Tel Hadya, 1992. Shown are mean values for each variable and results of t-tests (N = 25).

Variable	Barley	Wheat
RWA Plant Rating	3.72	3.80ns
Total tillers per hill	32.16	39.36**
Infested tillers per hill	15.24	11.52*
RWA/10 tillers	204.52	185.28ns
Predators/10 tillers	2.28	3.64ns
D. rapae/10 tillers	16.48	10.56**
Hyperparasites/10 tillers	15.76	17.56ns
Syrphus/10 tillers	1.04	1.44ns
Leucopis/10 tillers	0.64	1.00**
Coccinella/10 tillers	0.36	1.20ns

ns = $P > 0.05$; * = $P \leq 0.05$; ** = $P \leq 0.01$;

Table 3. Numbers of RWA, natural enemies, and hyperparasites collected at ICARDA, Tel Hadya, Syria. Means are based on pooled collections from 10 tillers/hill of what and barley.

Group	Mean±SE	Total
RWA and RWA Mummies		
Living RWA Counted	194.0±10.6	9745
Aphid Mummies		
D. rapae	13.5±1.3	676
Hyperparasites	16.7±1.3	833
Total Live Mummies		1509
Total Dead Mummies	29.4±2.5	1472
Total Mummies		2981
Total RWA Observed		12726
Predators		
Syrphus	1.2±0.2	62
Leucopis	0.8±0.2	41
Coccinella	0.8±0.2	39
Total Predators		142

variables monitored during this study (Table 4). The correlation of the number of tillers per hill with Zadoks plant development stages and the number of infested tillers, while statistically significant, means that older plants are likely to have more tillers than younger plants, and that plants having higher RWA densities will likely have a greater percentage of their tillers infested by RWA.

RWA numbers were negatively correlated with RWA plant ratings. While this is surprising at first glance, the plant damage scale used in this study is primarily based on visual symptoms of plant damage due to aphid toxins, rather than RWA density. RWA densities are weighted more heavily than plant symptoms only in the lowest steps of the rating scale, which would normally be encountered during low RWA infestations or during the initial stages of RWA infestation when plant symptoms are not pronounced. RWA densities may also level out on the plant during the course of RWA infestation and as the leaf area available for aphid colonization is restricted by severe curling. When RWA densities increase, RWA move to other tillers, perhaps in a density dependent response to overcrowding suggested by the significant correlation of RWA density with the number of infested tillers.

The number of *D. rapae* was significantly correlated with the number of infested tillers and the RWA density, but was negatively correlated with the number of predators. This may suggest a competition effect between predators and parasitoids, although the simple correlations between *D. rapae*, *Syrphus*, *Leucopis* and *Coccinella* were not significant at $P \leq 0.05$.

The number of hyperparasites was significantly correlated with Zadoks plant development, the number of tillers per hill, and RWA density, but not with the number of emerged *D. rapae*. Hyperparasites attack RWA mummies, and are influenced by the number of RWA present on the plant. Plant infestation by aphids and aphid mummification by parasitoids is likely well along by the time that hyperparasites become active in the field. The positive correlation with plant development suggests that their appearance is regulated by the status of their own physiological development.

The highly significant correlations between *Syrphus*, *Leucopis*, and *Coccinella* with predator numbers is a case of multicollinearity and can be ignored.

The number of dead mummies was correlated with Zadoks plant development and RWA density. However, this does not explain the cause of death of the parasitoid or hyperparasite harbored in the mummy, but reflects, rather, the progression of RWA infestation and parasitism over time.

The number of *D. rapae* mummies recovered

Table 4. Simple correlation coefficients between variables pooled for wheat and barley (df=58).

	Zdk	Rtg	Infth	Tillh	RWA	Pred	Drap	Hypar	Syrp	Cham	Cocc
Zdk	1.000										
Rtg	0.001	1.000									
Infth	0.099	0.065	1.000								
Tillh	0.372**	-0.010	0.427**	1.000							
RWA	0.128	0.299*	0.325*	0.221	1.000						
Pred	0.142	-0.040	-0.217	0.095	0.046	1.000					
Drap	0.010	0.195	0.548**	0.109	0.300*	-0.257*	1.000				
Hypar	0.443**	0.100	0.161	0.408*	0.265*	0.083	0.109	1.000			
Syrp	0.018	0.090	-0.147	-0.167	-0.071	0.539**	0.003	-0.106	1.000		
Cham	0.178	-0.054	-0.168	0.118	-0.027	0.306*	-0.217	0.230	0.283*	1.000	
Cocc	-0.010	-0.056	-0.161	0.173	0.146	0.542**	-0.212	-0.060	-0.073	0.075	1.000
Ddmum	0.393**	-0.086	0.141	0.345*	0.391*	0.089	0.047	0.158	-0.078	0.130	0.004

* = P≤0.05; ** = P≤0.01; Zdk=Zadoks Plant development; Rtg=RWA plant rating; Infth=total infested tillers/hill; Tillh=tillers/hill; RWA=RWA/10 tillers; Pred=predators/10 tillers; Drap=*D. rapae*/10 tillers; Hypar=hyperparasites/10 tillers; Syrp=*Syrphus*/10 tillers; Cham=*Leucopis*/10 tillers; Cocc=Coccinella/10 tillers; Ddmum=dead mummies/10 tillers

from caged pots differed according to aphid densities within the cages (Fig 1). When emerged *D. rapae* were removed once daily, the number of RWA parasitized was significantly greater than that when mummies were removed twice a day. The shape of the curves generated in both experiments resembles a type II functional response (6), generally characteristic of invertebrate predators and parasitoids (5). That both curves level off at prey densities of 50 to 200 aphids/cage, and then sharply increase at 250 aphids/cage may suggest that *D. rapae* searched randomly at the lower prey densities, but switched to a system whereby their efficiency was maximized at the highest prey density. While data in this experiment are insufficient to draw conclusions, predation models

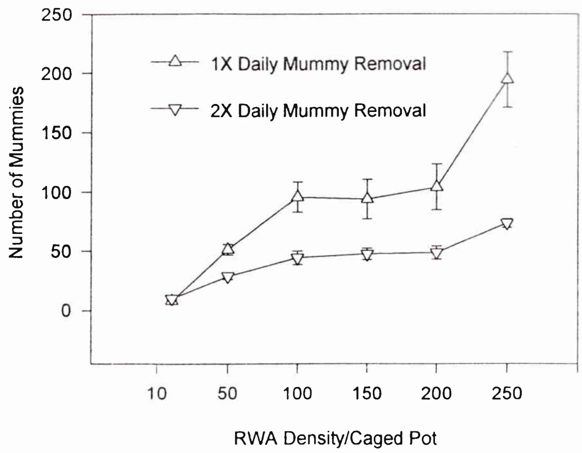

Figure 1. Functional response of *D. Rapae* at different RWA densities (mean ± SE).

for parasites show a linear relationship between prey density and parasitism rate in situations where the parasites avoid revisiting previously parasitized prey by means of marking pheromones or some other mechanism (13,14).

When the number of RWA parasitized is plotted over time, the effects of parasitism by the emerged *D. rapae* becomes apparent. The number of mummies collected once daily (Fig. 2A) was cyclic with a period of about 4 days. The number of mummies collected increased with increasing prey items in the cage and gradually decreased over time, even though the cyclic behavior persisted. When mummies were collected twice a day (Fig. 2B) there was no pronounced cyclic occurrence in mummy numbers collected. Rather the number of mummies collected peaked at about 6 days when the initial prey density was 100 aphids/cage or greater. When initial prey densities were lower than this the number of mummies collected fluctuated from zero to four without sharp increases. This suggests that the development time of most *D. rapae*, under the conditions of this experiment ranges from five to seven days, and indicates that natural parasitism can be important in limiting aphid populations in the field. A parasitism rate of 23%, observed in this study, may allow a higher economic threshold to be set if combined with plant tolerance to aphid toxins. *D. rapae* has also been observed attacking *Schizaphis graminum* (Rondani), *Rhopalosiphum padi* (L.), and *Rhopalosiphum maidis* Fitch on wheat and barley in Syria. Its abundance is likely due to the nearly complete absence of chemical insecticide usage on wheat and barley in Syria (19) where crop inputs are limited by the low income of the farmers. A viable and cost effective strategy for RWA control in Syria, and that of other aphids in the rainfed areas of western

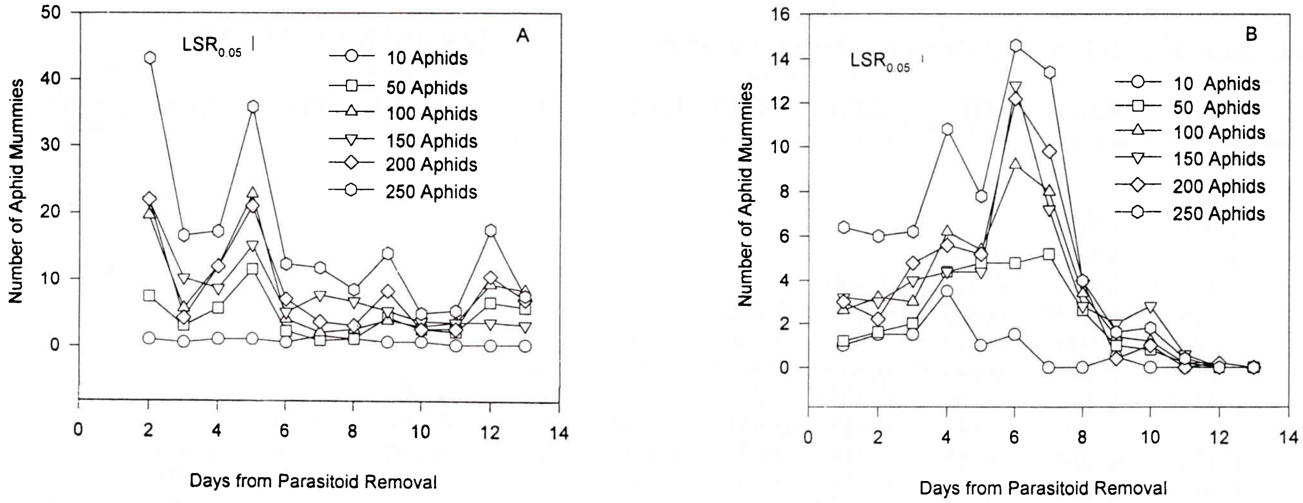

Figure 2. Number of *D. rapae* mummies observed following removal of *D. rapae* from cages containing different RWA densities. In Fig. 2A parastoids were removed from the cages once daily, and in Fig. 2B parasitoids were removed in the morning and afternoon.

Asia, may be to avoid disruption of the natural enemy populations that are already present in the field and to enhance plant tolerance to RWA toxins through plant breeding.

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الملخص

رشماني، ن، ر. ميللر، أ. ف. طرابلسي و ل. كفوري. منّ القمح الروسي *Diuraphis noxia* Kurdjumov (Homoptera: Aphididae) وأعداؤه الطبيعية في شمال سورية. 1993. مجلة وقاية النبات العربية. (11) 2: 99-92

يعتبر منّ القمح الروسي *Diuraphis noxia* آفة خطيرة لعديد من محاصيل الحبوب في دول عديدة. وقد تم القيام بحصر لهذه الآفة وأعداءها الطبيعية في محطة بحوث إيكاردا الرئيسية قرب تل حديا بسورية. وتمّ ملاحظة مدى واسع من الحشرات والطفيليات المفترسة، تنتمي إلى فصائل Coccinellidae، Syrphidae، Chamaemyiidae و Braconidae. كما تمت أيضاً ملاحظة فوق متطفل *Diaeretiella rapae* . ويمكن للأعداء الحيوية أن تسهم بدور تنظيمي هام لمجتمعات من القمح الروسي على القمح والشعير.

كلمات مفتاحية: حبوب، حشرات، مفترسات، طفيليات، فوق تطفل.

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