Comparison of Field Population Growths of Three Cereal Aphid Species on Winter Wheat

Vojtěch JAROŠÍK[1], *Alois HONĚK*[2] *and Aleš TICHOPÁD*[1]

[1]*Department of Zoology, Charles University, Prague, Czech Republic;* [2]*Research Institute of Crop Production, Prague-Ruzyně, Czech Republic*

Abstract

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Population growths of three aphid species colonising winter wheat stands, *Metopolophium dirhodum*, *Rhopalosiphum padi* and *Sitobion avenae*, were analysed by regression method. The calculations were based on counts in 268 winter wheat plots at 3 or 7 day intervals over 10 (leaves) or 6 (ears) years. The population dynamics of a particular species differed widely between years. Density independent exponential growth of the population was most common, but its rate differed significantly between species, and for *S. avenae* also between populations on leaves and ears, on which the populations grew fastest. Field estimates of the intrinsic rate of increase derived from the exponential growths ranged between 0.010–0.026 in *M. dirhodum*, 0.0071–0.011 in *R. padi*, and between 0.00078–0.0061 and 0.0015–0.13 in *S. avenae* on leaves and ears, respectively. In the populations with the most vigorous population growth, *S. avenae* on ears and *M. dirhodum* on leaves, the rate of population increase significantly decreased with increasing aphid density.

Keywords: *Metopolophium dirhodum*; *Rhopalosiphum padi*; *Sitobion avenae*; population dynamic; pest monitoring; winter wheat

Cereal aphids are a serious problem in wheat growing (e.g. Dixon 1987). In Central Europe, three species are serious pests of winter wheat: *Metopolophium dirhodum* (Walker), *Sitobion avenae* (F.) and *Rhopalosiphum padi* (L.). The aphids migrate to wheat stands around mid-May from their winter hosts *Rosa* spp. (*M. dirhodum*), different *Poaceae* (*S. avenae*) and *Prunus padus* L. (*R. padi*). Aphid populations stay on wheat for a short, distinct period during which they grow monotonically. Their numbers sharply decline as host quality decreases during plant maturation in summer.

The analysis of population dynamics of the cereal aphids is complicated because the numbers of immigrant aphids, the length of time available for population growth and its rate are influenced by host-plant cultivar and vigour, microclimate and natural enemies (Dixon 1987). A forecast of aphid abundances is difficult due to overlapping generations and variation in age structure of the populations which is rarely stable (Barlow & Dixon 1980).

We describe seasonal trends of population increases of the aphids using a 10 year series of counts on winter wheat shoots, and a 6 year series of counts on ears. These long-term population data enabled to assess the magnitude and range of population increase in the field.

MATERIAL AND METHODS

Aphid densities were recorded at two localities: (a) At Prague-Ruzyně (50°06′N, 14°15′E) aphids were counted 1987–1996 in winter wheat stands grown under standard agricultural practices, without insecticides. The cultivars were Hana, Regina, Viginta and Zdar. Each year, 5–15 experimental plots of ca. 25 m^2 were established within the wheat

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stands. A total of 107 plots were investigated. The quality of host-plants in these plots differed due to variation in soil quality, mineral nutrition, water availability, crop density, cultivar and weather variation. (b) At Sedlec (50°10′N, 14°30′E) aphids were monitored in 1989–1994, in small experimental plots established for the routine testing of new cultivars. Aphids were counted in 161 plots of 54 established and new cultivars of which only 11 were grown throughout the whole experimental period. The wheat was sown in a series of 1.4 × 7 m (10 m^2) plots, in the 4^{th} year of a 10-year crop rotation system, and grown under optimum conditions. Mineral fertilisers were applied at standard doses 120 kg/ha N, 120 kg/ha P and 160 kg/ha K. Agricultural practices recommended for wheat growing in the Czech Republic (Špaldon 1982) were followed, except for the applications of insecticide.

Aphids were counted weekly or at 3–4 d (1990) intervals, from before aphid immigration until their disappearance from the crop. Each time, 30–300 tillers were examined, depending on aphid abundance. At Prague-Ruzyně, the aphids on leaves (including leaf sheaths) and on ears were recorded separately, except in 1991 when only the numbers on ears were recorded. The tillers were selected at random at 2–5 places within each experimental plot. At Sedlec, aphid numbers were recorded at two fixed places within each plot and on a total of 40 or 60 ears.

For each season and each species, the data from individual plots were fitted by linear regression model in which population growth was linearised by log transformation of population size *N* on leaves or ears and by expressing time in day-degrees (*DD*) above the lower development threshold of 5°C. The model corresponding to a density independent exponential population growth was

$$ln(N(DD)) = ln(N(0)) + rDD$$

where: *ln(N(DD))* – response variable

ln (N(0)) – intercept

r – slope of the regression line and the population growth rate

DD – explanatory variable

The explanatory variable was the sampling date expressed in *DD*, which was calculated from the beginning of immigration until the maximum log aphid abundance. The population growth rate *r* can be considered a field estimate of the intrinsic rate of increase (Jarošík *et al*. 1996, 1997).

To test for deviations from the density independent exponential growth square of the explanatory variable was calculated and subtracted from the model:

$$ln(N_1(DD)) = ln(N_1(0)) + rDD - rDD^2$$

$$ln(N_2(DD)) = ln(N_2(0)) + rDD - rDD^2$$

If the subtraction caused a significant reduction in deviance, there was evidence of decreasing population growth with increasing aphid density. Calculations were made by use of general linear modelling in GLIM (Francis *et al*. 1994).

RESULTS

The population growth of individual species significantly differed between species and years (ANOVA interaction between species and years: $F = 7.16$; df = 12, 1253; $P < 0.0001$). The population growths of *Sitobion avenae* significantly differed on leaves and ears (interaction: $F = 10.41$, df = 7, 562; $P < 0.0001$). The growth rates of individual species also significantly differed among years (*Metopolophium dirhodum*: $F = 42.87$; df = 7, 463; $P < 0.0001$, $R^2 = 57\%$; *Rhopalosiphum padi*: $F = 9.88$; df = 5, 226; $P < 0.0001$, $R^2 = 50\%$; *S. avenae*, leaves: $F = 88.71$, df = 7, 251, $P < 0.0001$, $R^2 = 24\%$; *S. avenae*, ears: $F = 8.67$, df = 9, 320, $P < 0.0001$, $R^2 = 25\%$).

R. padi colonised the whole plant. Its rate of increase was the lowest and the least variable of the three species. The populations grew monotonically in an exponential way. The regression estimates of its field intrinsic rate of increase ranged between 0.00078–0.0061.

M. dirhodum was the dominant species on leaves and avoided ears. It was the species with the fastest growth on leaves. Its field estimate of the intrinsic rate of increase was between 0.010–0.026. Its population growth significantly ($F = 2.98$; df = 8, 456; $P = 0.003$) decreased with increasing aphid density in seasons with the highest exponential growth.

S. avenae was dominant on ears but also occurred on leaves. On leaves, the field estimates of intrinsic rate of increase ranged from an extremely high 0.15 (1995) to negative values (1988 and 1996). These extreme values appeared at low aphid abundances and were biased by the migration pattern between leaves and ears. In 1995, the aphids had migrated to winter wheat stands very late, and shortly afterwards moved from leaves to ears. The high value of population increase thus reflected the massive migration to stands in late spring rather than population growth. The negative values in 1988 and 1996 are explicable by adverse conditions for aphid development after immigration to wheat stands (cf. Honěk & Martinková 1999). The negative growth was a consequence of a time lag between immigration to stands and population growth that started not earlier than after the aphids migrated from leaves to ears. The unbiased field estimates of the intrinsic rate of increase attributable to population growth on leaves were rather low and ranged between 0.00078–0.0061. The estimates did not decrease with increasing density. On the other hand, on ears *S. avenae* grew fastest of all species. The field estimates of the intrinsic rate of increase ranged between 0.0015–0.13. Similarly to *M. dirhodum* on leaves in seasons with the highest increase its population growth significantly ($F = 7.47$; df = 10, 311; $P < 0.0001$) decreased with increasing aphid density.

DISCUSSION

Rhopalosiphum padi with the lowest, least variable and monotonically increasing population growth is a generalist, adapted to a cool and humid microclimate (Leather *et al*. 1989) that does well in dense wheat stands (Honěk 1991a,b). Its unconstrained exponential growth is probably a consequence of its rapid adaptation to changes in environmental quality by an increasing tendency to migrate on and between host plants. By contrast, the decreasing rate of population growth with increasing density in *Metopolophium dirhodum* (a species that has the fastest growth on leaves) can be a consequence of its restricted distribution. The species is confined to leaves and an emigration as the leaf space becomes limiting is prevented.

The slow and monotonical increase of *S. avenae* on leaves can be a direct response to the cool and humid microclimate that prevails on the leaves within a wheat stand. *S. avenae* prefers a warm dry microclimate (Honěk 1985), and its rate of population growth is lower on leaves than ears (Sengonca *et al*. 1994). The rate of population growth on leaves did not decrease with increasing density probably because of emigration to ears (Chongrattanameteekul *et al*. 1991). By contrast, the decrease of the rate of population growth on ears as density increases is attributable to the limited surface area of ears (Honěk *et al*. in prep.).

The time lag between immigration to stands and population growth on leaves that caused the negative values of population growth in seasons with low aphid abundance conforms to the results of Carter and Dixon (1981). They interpreted a population decrease caused by this time lag as an alternative explanation to the 'natural enemy ravine' suggested by Southwood and Comins (1976).

The decelerating population growth of *M. dirhodum* on leaves and *S. avenae* on ears as density increases is a consequence of intraspecific competition, which increases in severity as abundance increases and the carrying capacity of the environment is approached. This typically can mean that either the population becomes crowded within the limited space provided by the plant part available for the aphid colony or the quality of the food resource deteriorates in time as a consequence of aphid feeding and plant senescence. Intraspecific interactions were frequently revealed by numerous studies of crowding effects (Dixon 1985). Increasing population density decreases adult body size and fecundity and triggers alata production. These processes decelerate population growth as density increases and thus decrease maximum abundances attained by the population.

On the other hand, predators and parasitoids have little impact on aphid population dynamics (Kindlmann *et al.* in prep.). They are not the cause of the decelerating population growth (Jarošík *et al.* 2003). Similarly, weather variables oscillating with 'normal' limits affect the population dynamics very little (Jarošík & Dixon 1999). A possible reason is that most meteorological factors, to density dependent factors, manifest themselves through their effect on plant quality rather than directly (Jarošík & Dixon 1999).

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Souhrn

Jarošík V., Honěk A., Tichopád A. (2003): **Srovnání populačního růstu tří druhů obilních mšic na ozimé pšenici v polních podmínkách**. Plant Protect. Sci., **39**: 61–64.

Populační růst tří druhů mšic migrujících na pšeničná pole, *Metopolophium dirhodum*, *Rhopalosiphum padi* a *Sitobion avenae*, byl analyzován regresními metodami. Výpočty byly prováděny na základě odpočtů mšic celkem na 268 plochách ozimé pšenice, které byly prováděny v třídenních nebo sedmidenních intervalech po deset let na listech a po šest let v klasech. Populační dynamiky jednotlivých druhů se v jednotlivých letech značně lišily. Nejběžnější byl hustotně nezávislý exponenciální růst. Rychlost tohoto růstu se průkazně lišila mezi druhy mšic a v případě *S. avenae* i mezi populacemi rostoucími na listech a v klasech. V klasech rostly populace *S. avenae* vůbec nejrychleji. Odhady vnitřních rychlostí růstu z jednotlivých ploch kolísaly mezi hodnotami 0.010–0.026 pro *M. dirhodum*, 0.0071–0.011 pro *R. padi* a pro *S. avenae* mezi 0.00078–0.0061 na listech a 0.0015–0.13 v klasech. U populací, u nichž byl růst nejrychlejší, tj. *S. avenae* v klasech a *M. dirhodum* na listech, rychlost růstu průkazně klesala s rostoucí populační hustotou mšic.

Klíčová slova: *Metopolophium dirhodum*; *Rhopalosiphum padi*; *Sitobion avenae*; populační dynamika; monitorování škůdců; ozimá pšenice

Corresponding author:

Doc. RNDr. Vojtěch Jarošík, CSc., Přírodovědecká fakulta Univerzity Karlovy, katedra zoologie, Viničná 7, 128 43 Praha 2, Česká republika
tel.: + 420 221 951 854, fax: + 420 221 951 853, e-mail: jarosik@mbox.cesnet.cz