Analyses of factors influencing the population dynamics of cereal aphids and their relevance to model extensions

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Abstract: Getreideblattläuse (Hemiptera: Aphididae) sind die bedeutendsten Schädlinge von Winterweizen im Frühjahr und Sommer. Sie führen jedoch nur zu signifikanten Ertragsausfällen, wenn biotische und abiotische Faktoren ein optimales Populationswachstum erlauben. Einige dieser Faktoren sind bereits in Simulationsmodellen berücksichtigt. In der vorliegenden Arbeit wurden Sorteneinflüsse, die Nähe von Winter- zu Sommerwirten und meteorologische Parameter bezüglich der Migrations- und Populationsentwicklung als weitere mögliche Faktoren im Hinblick auf Modellerweiterungen untersucht. 8 Winterweizensorten zeigten weder bezüglich der Entwicklung von Nachkommen (in Klippkäfigen, BBCH-Stadium 32 und 69), noch während der Erstbesiedelungsphase von geflügelten Getreideblattläusen (Ende Mai, Anfang Juni) bedeutende Unterschiede. Die Nähe von Winter- zu Sommerwirten beeinflusste in unterschiedlicher Weise den Populationsaufbau der wirtswechselnden Arten im Winterweizen. In Jahren mit hoher Populationsentwicklung auf den Winterwirten konnte nur für *Rhopalosiphum padi* L. signifikant erhöhte Populationsdichten im Winterweizen in nächster Nähe zu *Prunus padus* L. festgestellt werden. Die frühe Migration wurde anhand von Saugfallendaten verschiedener Standorte der letzten Jahre untersucht. Das Erstauftreten von *R. padi* (1. Fänge in Saugfallen) zeigte sich dabei recht konstant am 13. Mai eines Jahres. Die Beziehungen zwischen den weiteren Migrationsereignissen und meteorologischen Parametern waren jedoch eher schwach ausgeprägt (R^2<0,21, p=0,01); wobei hier Globalstrahlung (R^2=0,21), Temperatur (R^2=0,18) und Windgeschwindigkeit (R^2=0,14) die deutlichsten Beziehungen zeigten.

Keywords: population models, migration, resistance, winter wheat, cereal aphids,

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Aphids annually infest winter wheat, *Triticum aestivum* L., in late spring and early summer in Central Europe, but densities leading to strong yield losses are reached only occasionally (Basedow et al., 1994). Three aphid species, *Sitobion avenae* Fabr., *Metopolophium dirhodum* Walk. and *R. padi* L., usually occur in cereal crops with increasing densities from late spring onwards (Basedow et al., 1994). Modelling population levels of cereal aphids is a key tool in integrated pest management for winter wheat. Over the last 30 years, considerable efforts have been made to investigate the population dynamics of aphids (DeWit and Rabbinge, 1979; Entwistle and Dixon, 1987). In Central Europe to date, two models have attained greater importance in late spring: LAUS (Friesland, 1986) and GETLAUS01 (Gosselke et al., 2001). The first one estimates the population level of *S. avenae* in spring in winter wheat fields and has obtained regional significance in practical plant protection. In contrast, the model GETLAUS01 is a scientific model, not designed for practical plant protection. It describes in great detail the population dynamics of *S. avenae*, *R. padi* and *M. dirhodum*. Both models have been improved over time and extended with several factors, e.g. by including the effects of antagonists, fertilisation, crop density, plant protection agents and meteorological parameters on population development. The objective of this study was to analyse the following three factors in terms of their impact on population and migration characteristics: cultivar, proximity between winter and summer hosts and migration (according to meteorological parameters).

Materials and methods

Cultivar experiments

The importance of differences between cultivars for cereal aphid development (antibiosis and settlement behaviour) was investigated in greenhouse and field experiments (in 2005 and 2006). The cultivars used for the study (Tommi, Hybnos I, Strube type 93-11-21, Akratos, Dekan, Batis, Certo, Ritmo) are winter wheat cultivars grown under practical farming conditions. They are covering a broad range of genotypes and qualities (Bundessortenamt, 2006). The cultivar Strube-type 93-11-21, which has no official approval so far, was included in this study, because in preliminary tests, aphids showed a reduced performance on this cultivar. This cultivar also differed from the other cultivars by its numerous small hairs on leaves and ears (Strube, pers. com.). Clip cage experiments were arranged with synchronized adults of *S. avenae* ("green strain") and *M. dirhodum*. At each of three plant development stages, 15 clip-cages per cultivar and aphid species each containing two apterous adults, were caged for 7 to 9 days (tissue-bag cages for *S. avenae* at BBCH 69).

Field experiments (untreated plots, five repetitions) served to determine the settlement behaviour of winged aphids. Aphids were counted (80 to 300 tillers per repetition) and grouped according to different instars and morphs: L1/L2-, L3- and L4-larvae, larvae with visible wing buds as nymphs, adults without wings as apterae and winged adults as alatae. For the analysis of immigration, numbers of winged aphid were estimated on the second, third and fourth evaluation time (i.e., May 25th, June 10th and 16th).

Proximity between winter and summer hosts

Winter wheat fields adjacent to a large hedge (with several *P. padus* and *Rosa ssp.*) were used to investigate the relationship between the distance between winter and summer hosts and early population build-up. Three subplots with different distances to the hedge (D_1: 0-8 m, D_2: 8-24 m, D_3: 24-60 m) were situated in the wheat fields. A minimum of 100 tillers per subplot was visually inspected for the numbers of aphids from May to July in 2004 to 2006 (based on weekly counts, converted into aphids per square meter).

Migration

Data sets, collected from several suction traps (Rothamsted-type) in Central Europe, were available (EURAPHID, project partners; >60 locations/years). Flight activity data were correlated with different meteorological parameters from the next weather station (>20 km) available from the German weather service (DWD). Multiple variables were calculated from the values (e.g. positive and negative sum standards, numbers of hours above certain critical values, etc.). Data sets were analysed with several statistical methods such as correlation and regression analyses (with different model assumptions).

Results and discussion

Cultivar experiments

The caging experiments (antibiosis) at the shooting stage (BBCH 30-32) showed no significant differences between the cultivars for either instars of both cereal aphids, except for L3-larvae of *M. dirhodum* (Fig. 1). Significantly more L3-larvae were found on cultivar Tommi compared to Ritmo. Caged aphids in the field (BBCH 65-69) developed more slowly (mean daytime temperatures: 19.3°C) compared to laboratory conditions (mean temperatures: 22°C). Moreover, mean numbers of offspring varied more broadly and standard errors were more pronounced. A whole population cycle of the offspring was rarely observed within the cages for either species. No significant differences between cultivars and aphid species were obtained (data not shown).

The experiments on settlement behaviour indicate that the most frequent naturally immigrating species is *R. padi*, followed by *S. avenae* and *M. dirhodum*. The aphid population peak on most cultivars was in early July (BBCH 77/83), whereas the subsequent population crash differed among the cultivars according to their ripening stage. The mean numbers of all instars of *R. padi* differed significantly only between cultivars on several evaluation dates. Differences in immigration intensity and early settling behaviour were minor. For *S. avenae* a greater number of alatae was only found on the Strube-type 93-11-21 early on in the observation period, but due to the low numbers involved, this difference was not statistically significant ($p>0.05$). On June 10th, significantly higher numbers of winged *S. avenae* settled on Hybnos I compared to cultivars Tommi and Akratos. No alatae of *M. dirhodum* were observed on the first evaluation date, and later no significant differences were found between the cultivars. On May 25th, significantly more *R. padi* were found on cultivar Batis than on cultivar Tommi. Concerning the other instars of any aphid species or evaluation times, no significant differences were found between the cultivars. In conclusion, the results demonstrate that there is no difference in attractiveness or host suitability for any of the winter wheat cultivars tested. It would therefore appear that these factors are of minor importance as variables for population and migration models.

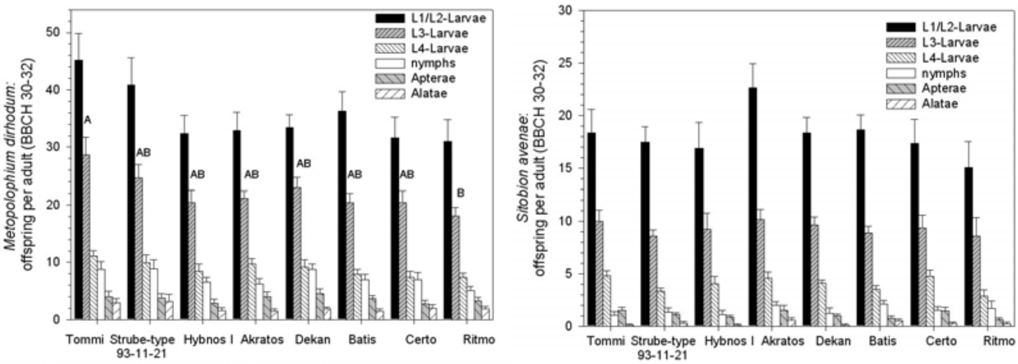

Fig. 1: Mean numbers (±SE) of offspring (grouped in developing instars) originating from single apterous adults of *M. dirhodum* (left) and *S. avenae* (right) caged on eight winter wheat cultivars at BBCH-stage 30-32. Cultivars followed by the same letter do not differ significantly (significant differences only in *M. dirhodum* L3-larvae: Tukey-Kramer Test, p=0.05, n=15).

Tab. 1: Relative frequency (%) of significantly greater aphid counts found at 3 groups of distances from the hedge. Aphid species followed by the same letter do not differ significantly (Tukey-Kramer Test, p=0.05).

year and no. of evaluation days	aphid species	relative frequency (%) D_1 vs. $D_{2/3}$	D_2 vs. $D_{1/3}$	D_3 vs. $D_{1/2}$
2004-West	*R. padi*	5	0	0
7	*S .avenae*	14	0	14
	M. dirhodum	14	0	5
2004-East	*R. padi*	19	0	5
7	*S. avenae*	14	5	19
	M. dirhodum	10	5	5
2005-East	*R. padi*	44	6	0
6	*S. avenae*	6	6	6
	M. dirhodum	0	0	6
2006-East	*R. padi*	67	0	0
4	*S. avenae*	25	8	8
	M. dirhodum	17	0	0
mean	*R. padi*	33.7 ±13.7^a	1.4 ±1.4^b	1.2 ±1.2^b
relative	*S. avenae*	14.8 ±4.0^a	4.7 ±1.7^a	11.8 ±3.0^a
frequency	*M. dirhodum*	10.1 ±3.7^a	1.2 ±1.2^a	3.8 ±1.3^a

Proximity between winter and summer hosts

On both sides of the hedge, significant differences in numbers of *R. padi* between subplots were only observed on a few evaluation dates in 2004. The opposite was observed for 2005 and 2006, where higher population densities of *R. padi* occurred on the winter hosts: significantly more aphids settled in wheat subplots nearest to the winter hosts (Tab. 1). Interestingly, *M. dirhodum* respond differently to *R. padi*, occurring on its winter hosts in the hedge in larger numbers in both years. Hence, it was only on a few evaluation dates that significantly higher numbers of *M. dirhodum* were recorded in subplots close to the hedge. The hedge did not influence the distribution of non-host alternating species *S. avenae*. In contrast to *M. dirhodum* (and *S. avenae*), it seems that *R. padi* benefits from a close proximity between its winter and summer hosts especially in those years, when high population development on *P. padus* occurs. Density gradients levelled off at about 12 m distances to winter hosts (decreased abundances), and the population densities of *R. padi* were equal to the mean field densities. Landscape elements like hedges may cause turbulence forcing small flying insects such as aphids to land with greater frequency on the leeward side of the hedge. In 2004 however, when the population level of *R. padi* on *P. padus* was generally low, no significant differences between the population build-up were detected, either on the lee- or on the windward side. Furthermore, it seems unlikely, that the major source for the observed high numbers of *R. padi* settling close to the field edge was from long distance migration. According to our results, the landscape type (e.g. numbers of hedges with winter hosts in small structured landscapes) seems to be an important factor determining the size of local sources of *R. padi* with short distance spread, and may be included in extensions of models for predicting detailed population dynamics.

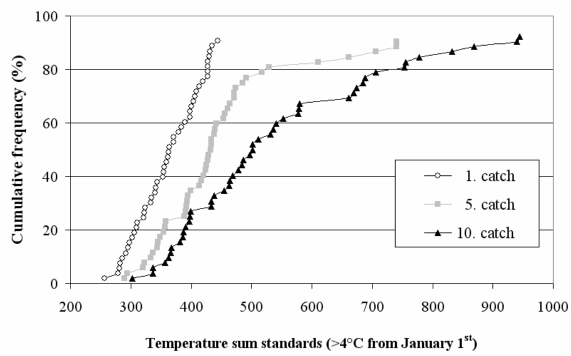

Fig. 2: Accumulative frequency of 1st, 5th, and 10th catch of *R. padi* in suction traps (n=52) according to temperature sum standards (above 4°C from 1st of January).

Migration

The analyses of the first occurrence of cereal aphids in suction traps showed varying results for the different species. *R. padi* was caught most consistently on May 13th (±1.2 days), whereas the date of first catch of *S. avenae* (June 2nd ±2.5) and of *M. dirhodum* (May 29th ±2.7) differed more. Consequently, a small range of temperature sum standards (>4°C from January 1st) between 290 to 410 degree days described the first occurrences of *R. padi* (e.g. 1st catch) best (Fig. 2). Following the full course of the migration intensity, several significant relations ($p>0.01$; $n=61$) were found with migration intensity. With increasing global radiation and temperature, higher numbers of cereal aphids occurred in suction traps, whereas lower numbers were found when precipitation, relative humidity, and wind speed increased. The results obtained correspond with threshold values for migrating aphids from laboratory experiments (NOTTINGHAM et al., 1991; MALLOCH et al., 2006). Unfortunately, the minor coefficients for determination ($R^2<0.21$) are insufficient for prediction and modelling migratory events. Nevertheless, the temperature sum standards and thresholds may help to identify days with migratory potential. So far, the migration results do not allow reliable predictions of migratory intensities, except for the first catches of *R. padi*. Further multivariate statistical analyses are needed to better relate migration behaviour in early spring and subsequent population build-up.

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