Suction trap catches partially predict infestations of the grain aphid *Sitobion avenae* in winter wheat fields

Short title: Suction trap catches predict aphid infestations

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Abstract

Effective pest monitoring programs are needed for providing reliable advice on when pest populations require active management. We studied whether suction trap catches of the grain aphid *Sitobion avenae* during the period 1989-2009 can be used to predict field infestations of this aphid in Swedish winter wheat fields. We found that suction trap catches of *S. avenae* until the time of crop heading (GS51) were significantly related to both number of aphids per tiller (R^2 = 0.69 at GS 59 and R^2 = 0.27 at GS 69) and proportion of fields with infestations above economic threshold (R^2 = 0.49 at GS 59 and R^2 = 0.40 at GS 69). This effect was consistent across Swedish regions and years. This information could be used by advisory services and farmers to decide whether field inspection to estimate the profitability of insecticide treatment at heading is needed. To improve the predictive ability further, suction trap catches could be combined with weather data and information about biological control potential in different landscapes.

Keywords: economic threshold; pest monitoring; pest management; spring migration

Introduction

Suction traps have long been used for monitoring phenology of flying aphids (Harrington et al. 2007), and suction trap catches have been found to correlate positively with field infestation levels of bird cherry oat aphids (Fabre et al. 2010; Teulon et al. 2004), soy bean aphids (Rhainds et al. 2010) and black bean aphids (Way et al. 1981). Optimising the use of pesticides will require better knowledge of insect population dynamics, as well as economic threshold values. Suction trap catches can also be used to estimate the need for chemical treatments against pests (Sigvald 2012).

Cereal aphids cause direct damage to wheat by feeding, through honeydew production that increases fungal infection (Larsson 2005), and by transmitting Barley Yellow Dwarf Virus (BYDV) (Foster et al. 2004). In Scandinavia, *Sitobion avenae* (F.) is the most important aphid on wheat (Hansen 1995; Larsson 2005), but the infestation levels vary a lot among regions and years (Larsson 2005). Therefore, it is particularly important to develop effective pest monitoring schemes and to adopt economic spray and action thresholds. Larsson (2005) found economic thresholds between 1 and 12 *S. avenae* per tiller in southern Sweden depending on crop growth stage and expected yield level.

In Scandinavia, *S. avenae* populations overwinter primarily in grasslands (Larsson 1993), and winter wheat crops are colonised primarily during May and June, whereas damage to the wheat crops occurs primarily in late June and July during flowering and milk ripening. Therefore suction trap catches of migrating aphids in late spring and early summer should have good potential to predict damaging *S. avenae* infestation levels in winter wheat crops. In Scandinavia, *S. avenae* populations are low in number most years and do not require insecticide application. In years with high *S. avenae* infestations, insecticides are usually applied after crop heading in combination with fungicides. In this study we test whether spring and early summer catches of *S. avenae* in suction traps are related to aphid tiller counts in farmers' winter wheat fields in Sweden. We test whether aphid abundances in the field and the likelihood of exceeding economic spray thresholds can be predicted by the suction-trap catches. If this holds true, suction trap catches could be used to advise farmers whether monitoring of aphid abundances in their fields are worthwhile during a specific year.

Materials and methods

Data collection

Catches of *S. avenae* 1989 – 2009 were collected from five suction traps located in the regions of Uppsala, Östergötland, Västra Götaland, Kalmar and Skåne, in southern Sweden (Fig. 1; Appendix S1). The suction traps are of Rothamsted model, located 12.2 m above ground level, and with airflow of about 2800-3000 m^3 per hour. The suction trap catches were related to average tiller counts of *S. avenae* in farmers' winter wheat fields located in the same region as the respective suction trap (Fig. 1). The counts were from monitoring in unsprayed plots by the Plant Protection Centres at the Swedish Board of Agriculture (Appendix S1). We analysed the relationship between the cumulative number of *S. avenae* caught in suction traps from early April (but no *S. avenae* were ever caught before beginning of May) until crop heading (growth stage (GS) 51; Zadoks et al. 1974) which usually occurred in June and the average number of aphids per tiller found in the field one and two weeks after heading. This corresponded to the average week when the fields in each region had reached GS59 and GS69, respectively (from here on called GS59 and GS69). We considered only year/region combinations with tiller count data available from at least 9 fields. The average infestation level across fields for each region and year was considered as a replicate in the analyses. For more details about suction the trap catches and tiller counts, see Appendix S1. ***[FIGURE 1 HERE]***

Data analysis

The cumulative number of *S. avenae* in suction traps from early April until heading at GS51 was related to 1) number of aphids per tiller at GS59 and GS69, and 2) the proportion of fields above economic thresholds of 2 aphids per tiller at GS59 and 6 aphids per tiller at GS69 (thresholds for Swedish winter wheat fields with expected crop yield <8.0 t/ha (Larsson 2005)). To analyse the data we performed generalized linear models (GLM's) or generalized linear mixed effects models (GLMM's), in R 2.14.0 (R Development Core Team 2011). We conducted separate analyzes for suction trap catches crossed with region, and suction trap catches crossed with year as fixed factors. When analyzing the effects on number of aphids per tiller we used GLM's with Gaussian distribution, since data was averaged across fields. To account for non-normality of the model residuals we log transformed number of aphids per tiller and the number caught in suction traps prior to analysis. When analyzing effects of suction trap catches on proportions of fields above economic thresholds we carried out GLMM's with binomial error structure using the glmer function in the lme4 package. Since over-dispersion was detected in these models an observation level vector was added as a random factor. With this approach each data point receives a unique level of a random effect that can absorb the over-dispersion in the data (Bolker et al. 2009). Model simplification was conducted by comparing all possible models with the Akaike Information Criterion adjusted for small sample size (AICc). Linear regression was conducted to estimate the explanatory power (R^2) of the suction trap catches.

Results

For all tests, the most parsimonious model based on AICc included a positive main effect of the cumulative number of aphids caught in suction traps, but never the interaction between this variable and region or year (Fig. 2). Thus the positive effect of suction trap catches on tiller counts and proportion of fields exceeding economic thresholds was consistent across regions and years. For GS59, but not GS69 the most parsimonious models furthermore included a main effect of region, suggesting that the number of aphids varied across regions. This model was competing with the one lacking the main effect of region (ΔAICc <2.0 than the best). No other competing models were present. ***[FIGURE 2 HERE]***

The positive relationship between number of aphids caught in suction traps until GS51 and number of aphids per tiller in the field was highly significant at both GS59 and GS69 (GS59 model with region and suction trap: $t = 4.698$, $P < 0.001$, GS59 model with suction trap only: $t = 5.398$, $P < 0.001$; GS69 model with suction trap only: $t = 3.992$, $P < 0.001$). However, the explanatory power of the suction trap catches at GS51 was reduced over time, from $R^2 = 0.69$ at GS59 to $R^2 = 0.27$ at GS69. The positive relationship between suction trap catches until GS51 and the proportion of fields above economic thresholds were also significant (GS59 model with region and suction trap: $z = 4.045$, $P < 0.001$; GS59 model with suction trap only: $z = 4.451$, $P <$

0.001; GS69 model with suction trap only: $t = 3.883$, $P < 0.001$), and the explanatory power decreased over time from $R^2 = 0.49$ at GS59 to $R^2 = 0.40$ at GS69.

Discussion

Suction trap catches of *S. avenae* until the time of crop heading in Swedish winter wheat fields were correlated not only with the average number of aphids in the crop, but also with the proportion of fields in a region exceeding economic thresholds. This effect was significant both one and two weeks after heading and was consistent across regions and years. This suggests that suction trap catches in spring and early summer can be used to monitor aphid pest pressure, and can help to predict when active pest management is needed. However, the relationship between suction trap catches and field infestations are not strong enough to determine if insecticide treatment is profitable in individual fields. Instead, we suggest that suction trap catches can be used to determine if it is worthwhile for individual farmers to go out and monitor aphid abundances.

A lot of variability in aphid infestation rates remain unexplained ($R^2 = 0.27 – 0.69$). There are several ways in which the predictive ability of a monitoring system based on suction trap catches might be improved. First, weather patterns may have a strong impact on cereal aphid migration and survival (Davis et al. 2014; Harrington et al. 2007). For example, Harrington et al. (2007) found that spring migration by *S. avenae* occurred earlier with increasing temperatures but was delayed by rainfall in spring. Therefore, taking spring weather patterns into account may increase the predictability of the suction trap data. Secondly, natural enemies such as parasitoids, predators and pathogens may have strong effects on *S. avenae* population growth rates in the field (Plantegenest et al. 2001; Thies et al. 2011), and their impact often vary depending on surrounding landscape structure (Winqvist et al. 2011). To improve predictability, the suction trap data could be combined with models that take the landscape-dependent variability in natural enemy impact into account (Jonsson et al. 2014). Thereby the regional predictions of aphid infestation levels could be adjusted according to the landscape composition in different sub-regions. For example heterogenous landscapes where fields are mixed with non-crop habitat often have more effective biological control than homogenous landscapes dominated by agricultural fields (Rusch et al. 2013), and fields in heterogenous landscapes may thus tolerate higher aphid colonization levels without reaching economic spray thresholds. Third, we correlated the suction trap catches with infestation levels within whole regions, which implied that a field could be located up to 200 km or more away from the suction trap. It is possible that a higher explanatory power may be achieved if only fields within a smaller radius would be considered. However, studies that correlated suction trap catches of aphids with field infestations at smaller spatial scales (1-10 km radius) did not necessarily find stronger correlations than we did (Vialatte et al. 2007; Rhainds et al. 2010). Finally, aphids are also strongly affected by local field conditions and management (Geiger et al. 2010), including sowing dates, fertilization regimes and crop nitrogen levels (Aqueel and Leather 2011). If the intention is to predict aphid infestation rates in individual fields such conditions will need to be considered as well.

To conclude, our work shows that suction trap catches of aphids in spring and early summer can be used to predict aphid infestation rates in the field in southern Sweden. Importantly we related suction trap catches with economic spray thresholds and still found a significant relationship. This information can be used by advisory services and farmers to decide the need for field inspection to estimate the profitability of insecticide treatment. To improve the predictability of the suction trap catches a first step could be to combine it with regional weather data. As a next step the model predictions could be adjusted according to known differences in biological control efficacy in different landscapes.

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Figure legends

Figure 1. Map of the five Swedish regions where suction traps were located and field counts made: Uppsala län, Västra Götalands län, Östergötlands län, Kalmar län, and Skåne län. Suction trap locations are indicated with dots.

Figure 2. Relationship between cumulative number of *S. avenae* caught in suction traps until GS51, and the average number of *S. avenae* per tiller in fields within the same region at (a) GS59, and (b) GS69, and with the proportion of fields in the same region with aphid abundances above the economic threshold at (c) GS59, and (d) GS69. Each dot represents one year-region combination.