STUDY ON THE SENSITIVITY OF THREE OAT VARIETIES TO THE SADDLE GALL MIDGE, *HAPLODIPLOSIS MARGINATA* (VON ROSER) (DIPTERA: CECIDOMYIIDAE)

F. CENSIER[1], S. CHAVALLE[2], G. SAN MARTIN Y GOMEZ[2], M. DE PROFT[2] and B. BODSON[1]

[1] Crops Management Unit, Gembloux Agro-Bio Tech, University of Liege
Passage des Déportés 2, BE-5030 Gembloux, Belgium
[2] Plant Protection and Ecotoxicology Unit, Life Sciences Department
Walloon Agricultural Research Center
Balachowsky building, Chemin de Liroux 2, BE-5030 Gembloux, Belgium
Corresponding author e-mail: florence.censier@gmail.com

ABSTRACT

The saddle gall midge, *Haplodiplosis marginata* (von Roser, 1840) is a univoltine pest of cereals which occurs in Europe. The larvae feed on stems and attractive saddle-shaped depressions, driving to important yield losses when the galls are numerous. After 40 years without any reporting, large populations of *H. marginata* and important damage have been observed since 2010 in wheat crops in Belgium, especially in the Flemish Polders where clay soils and intensive farming of cereals favour heavy infestations. According to some research conducted in the 1960s during the last outbreak, oat (*Avena sativa* L.) is known to be one of the less favourable hosts to the saddle gall midge. Our study was performed in order to assess the host sensitivity of three oat varieties currently grown in Belgium: EVITA, EFFEKTIV and FREDDY. Therefore, oat varieties were sown on infested soil in two separate enclosures in a glasshouse. In the first enclosure, only the three oat varieties were grown; in the second one, these three oat varieties were grown together with two varieties of spring wheat: GRANNY and KWS CHAMSIN. Two parameters were measured: the percentage of leaves with laid eggs, and the number of galls per stem. The percentage of leaves with eggs showed that the infestation was significantly lower on oats when they were in presence of wheat. The egg infestation was also significantly higher on wheat than on oat, which means oat is a much less favourable host plant than spring wheat for egg laying. Oat varieties were significantly different from each other regarding the number of galls per stem, but with very little damage compared to wheat. The FREDDY variety even seemed to be completely resistant to saddle gall midge, as no galls were observed although there was a similar percentage of leaves with eggs for the three oat varieties. Cropping oat could thus contribute to reduce infestations of *H. marginata*.

Key words: Cecidomyiidae, *Haplodiplosis marginata*, oat, host sensitivity, varietal resistance

INTRODUCTION

After 40 years without any reporting in Belgium, a resurgence of the saddle gall midge, *Haplodiplosis marginata* (von Roser, 1840) has been observed since 2010. This Diptera, from the family Cecidomyiidae, is a small univoltine pest which attacks various cereals in Europe (Skuhravá *et al*. 1983). Large populations of *H. marginata* and important damage have especially been observed in wheat crops of Flemish Polders where clay soils and intensive cropping of cereals are particularly favourable for heavy infestations (Censier *et al*, 2012).

In Belgium adult flights generally occur from the end of April until June. Imagos only live a few days and mate just after the emergence. Eggs are laid on cereal leaves and after hatching, young larvae crawl to the stem where they feed hidden under the leaf sheath and induce saddle-shaped galls (De Clercq and D'Herde 1972, Skuhravý *et al*. 1983). From mid-June to

mid-July full grown larvae leave stems after rain, fall to the ground and spend about nine months in the soil. In the next spring, usually in April or May, larvae migrate from deeper layers to the soil surface where they pupate, which takes between two and four weeks before emergence (Skuhravý *et al*. 1993).

If all cultivated cereals can be attacked by *H. marginata*, oats (*Avena sativa* L.) are known to be the poorest hosts and to rarely suffer from economic damage (Hulshoff 1959, Woodville 1973, Golightly 1979). However, only few studies were conducted since the 60s and these lasts concerned old varieties which are no longer grown nowadays (Schutte 1964, De Clercq and D'Herde 1972).

The present study was performed in order to assess the host sensitivity of three oat varieties currently grown in Belgium. The first objective of this study was to evaluate the egg laying levels on these three oat varieties when *H. marginata* had or not the choice to lay eggs on alternative species (i.e. spring wheat). The second objective was to assess the ability of saddle gall midge larvae to complete their development on these oat varieties.

MATERIALS AND METHODS

The experiment was conducted in glasshouses on three oat varieties: FREDDY, EFFEKTIV and EVITA. They were sown on infested soil in separate lines, with 10 plants of one variety per line. Two treatments were compared: oat growing alone and oat growing together with spring wheat. In a first enclosure only the three oat varieties were grown (= "Oat alone"). In a second one these varieties were sown alternately with lines of two spring wheat varieties: GRANNY and KWS CHAMSIN (="Oat + Wheat") (Figure 1). Each enclosure was delimited with a veil before adult emergence.

A first series of observations was performed to assess the egg laying levels for each variety and for the two treatments. Therefore the percentage of leaves with egg clusters was measured for 20 stems of each variety of oat and spring wheat. Afterwards, at the end of the feeding phase of larvae, the damage levels were measured for oat varieties by counting galls induced on each stem. Damage levels on the two spring wheat varieties could not be assessed due to excessive attacks. However larvae were counted on 20 stems of each spring wheat variety before their migration to the soil.

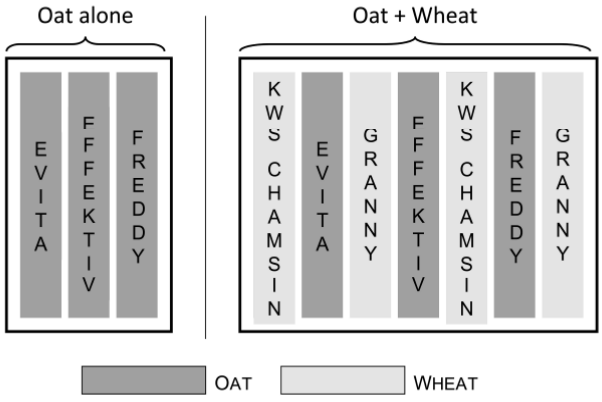

Figure 1. Disposal of oat and spring wheat varieties in the two enclosures, according to the treatment "Oat alone" and the treatment "Oat + Wheat".

Statistical analyses

Statistical analyses were performed with R 2.15 (R Development Core Team 2008).
The proportion of leaves with eggs was analysed using generalised linear models with binomial distribution of residuals and log link. A first model was used to test if the proportion of leaves with eggs was different between treatments (Oat alone or Oat + Wheat) and/or between oat varieties. For this model the dependent variable was the proportion of leaves with eggs and the explanatory variables were the oat variety, the treatment and their interaction. A second model was applied, considering only the data for treatment where oats are grown together with spring wheat. For this model the dependent variable was the percentage of leaves with eggs and the explanatory variable was the species.
The number of galls per stem on oat varieties was analysed by means of a generalised linear model with Poisson distribution of residuals and log link. As the residuals showed a moderate overdispersion (~3), a quasi-likelihood approach was used to incorporate this overdispersion in the model. The number of galls per stem was used as the dependent variable, and the variety, the treatment and the interaction variety x treatment as explanatory variables. As no galls were observed for the FREDDY variety (zero variance) only the two other varieties were included in the model.
For all models significance of explanatory variables was tested using type II likelihood ratio tests (LR) (analysis of deviance) with the Anova function from the "car" package (Fox 1997). The conditions of application of all models have been checked (residuals plots and overdispersion coefficient).

RESULTS AND DISCUSSION

Laying levels

The analysis of the proportion of oat leaves with eggs showed a very highly significant difference between treatments ($\chi^2 = 28.60$; Df = 1; $P < 0.0001$), regardless of the variety (Table 1). On average 36.4% of leaves have egg clusters of *H. marginata* when oat is grown alone against only 14.4% when oat is grown together with spring wheat (Figure 2).

Table 1. Estimation of the effect of variety and treatment on the percentage of oat leaves with eggs, by analysis of deviance.

	LR (χ^2)	Df	P
Variety	2.93	2	0.231
Treatment (alone vs with wheat)	28.60	1	8.9e-08 ***
Variety x Treatment	5.50	2	0.064

There was no significant difference of the laying levels between oat varieties after controlling for the treatment ($\chi^2 = 2.93$; Df = 2; $P = 0.231$). Indeed the mean percentage of leaves with eggs ranged between 22.6% and 28.3%, respectively for the EFFEKTIV and EVITA varieties (Figure 2). There was thus no preferential laying on either oat variety.
The interaction variety x treatment was close to the 0.05 significance level ($\chi^2 = 5.50$; Df = 2; $P = 0.064$) (Table 1), which is probably due to the fact that the difference between the treatments is slightly higher for the EFFEKTIV variety than for the two others (Figure 2).

The comparison of laying levels between species when they were grown together showed a very highly significant difference between oat and spring wheat (χ^2 = 138; Df = 1; P < 0.0001) (Table 2). Indeed the mean percentage of leaves with eggs was 14.4% for oat while it reached 73% for spring wheat (Figure 2).

Table 2. Comparison of egg laying levels between species for the treatment "Oat + Wheat" only, by analysis of deviance.

	LR (χ^2)	Df	P
Species	138	1	< 2e-16***

Therefore it appears that egg clusters were significantly less numerous on oats when grown in presence of spring wheat. Moreover, females would preferentially lay eggs on spring wheat when they have the choice between oat and spring wheat. We can confirm that these oat varieties, currently grown nowadays in Belgium, are still less attractive hosts for the saddle gall midge than spring wheat. At the scale of a field, it might however be possible to drain egg laying by cropping oats on infested soil, and thus to restrict the spread of this pest to neighbouring fields.

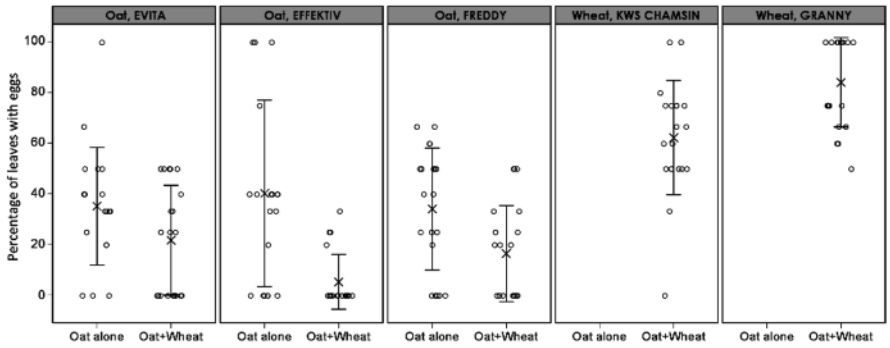

Figure 2. Mean percentage of leaves with eggs of *H. marginata* for the three oat varieties grown alone or together with spring wheat.
X = Mean (± Standard Error) **o** = observed value

Damage levels

Regarding damage levels on oats a mean difference of 0.75 gall per stem was observed between the EVITA and EFFEKTIV varieties (Figure 3). The analysis of deviance table shows that this difference was very highly significant regardless of treatment (χ^2 = 19.69, Df = 2, P <0.0001) (Table 3). The EVITA variety (0.97 gall per stem on average) had a higher sensitivity level to *H. marginata* than the EFFEKTIV variety (0.22 gall per stem on average). The damage level for these two varieties may be considered different from that of FREDDY variety. For this last variety no galls were observed on 107 stems examined, although the egg laying level was similar to the two other varieties (Figure 2). The FREDDY variety therefore seems to be fully resistant to saddle gall midge.

Table 3. Estimation of the effect of variety and treatment on the number of galls per stem by deviance analysis, for the EVITA and EFFEKTIV varieties

	LR (χ^2)	Df	P
Variety	19.69	2	5.3e-05 ***
Treatment (alone vs with wheat)	4.34	1	0.037 *
Variety x Treatment	1.71	1	0.191

In addition there was a significant difference in the number of galls per stem between treatments regardless of the variety (χ^2 = 4.34, Df = 1, P = 0.037), with an average of 0.76 gall per stem for oats grown alone and 0.43 gall per stem when oats were grown in presence of spring wheat (Figure 3). This difference in damage levels could be explained by more numerous egg clusters on oats when they were cultivated alone. Finally the effect of variety did not depend on the treatment and vice versa (no significant interaction variety x treatment, P = 0.191) (Table 3).

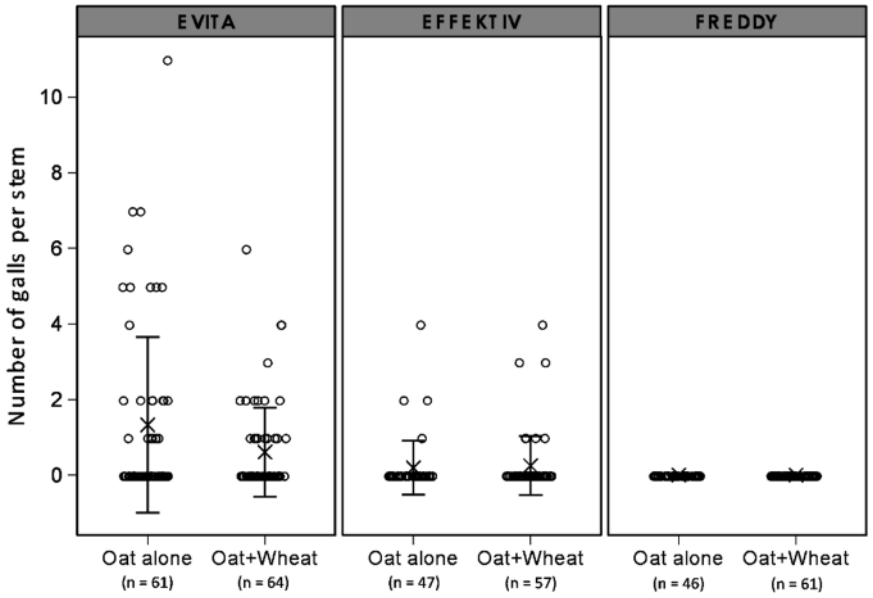

Figure 3. Mean number of galls per stem for the three oat varieties grown alone or with spring wheat. X = Mean (± Standard Error) **o** = observed value

Overall a gradient of sensitivity was observed for the three oat varieties. This kind of cereal however remains a very unfavourable host for the saddle gall midge, compared for example with spring wheat which is known to be one of the most favourable cereals to *H. marginata* (De Clercq and D'Herde 1972, Woodville 1973, Skuhravý *et al*. 1993). For spring wheat varieties included in this experiment, infestation levels reached on average 136 larvae per stem and 85 larvae per stem respectively for GRANNY and KWS CHAMSIN varieties. Such huge differences in damage levels between oat and spring wheat had already been observed on field trials by De Clercq and D'Herde (1972).

These very low damage levels for oats can be explained by an important -or even total- failure of larval development. This phenomenon had already been underscored by Skuhravý *et al*. (1993) who related that 95% to 98% of the larvae hatched from eggs on oat leaves died within two to five days after their migration under the leaf sheaths.
In conclusion, because of its low sensitivity to the saddle gall midge, cropping oat in a heavily infested field may permit not only to drain the egg laying but also to drastically reduce infestations of *H. marginata*. Nijveldt and Hulshoff (1960, 1961) had noted substantial decreases of larval populations in the soil after oat crops, whereas cropping much favourable cereals like spring wheat significantly raised the larval infestation in the soil after harvesting.
Just as the old oat varieties previously grown, EVITA, EFFEKTIV and FREDDY varieties could constitute an additional tool as part of the Integrated Pest Management against *H. marginata*.

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