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CHEMICAL CONTROL OF *HAPLODIPLOSIS MARGINATA* VON ROSER (DIPTERA: CECIDOMYIIDAE)

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SUMMARY

The saddle gall midge, *Haplodiplosis marginata* (von Roser), has been detected in Belgium since 2010, after several decades without any reporting. It had indeed caused serious damages between 1965 and 1970. This insect is a European cereal pest whose larvae feed on stems and engender saddle-shaped depressions, resulting in yield losses. Face with the resurgence of this pest, it was decided to study its spatial distribution and, because serious damages were observed in some regions, to develop effective curative control. To date, chemical protection seems to be the only immediate solution in case of heavy emergences. Experimentation was conducted in a highly infested field (Meetkerke, Belgian Polders), according to a randomized complete blocks arrangement with four replications.

Foremost, a lambdacyhalothrin-based insecticide was used to evaluate efficiency of several protection schemes, ranging between one and four spray(s). The large spread of flights observed during the 2011 spring allowed to highlight the effect of treatment date on the attack intensity and also on the galls distribution along the stem, on the different internodes: the lower internodes were protected by the early sprayings, while last sprayings induced reduction of galls number on the upper internodes. Moreover, several insecticides already registrated in cereals against aphids were compared for their efficacy against saddle gall midge. Studied pyrethroids have shown a very good efficacy, ranging between 75 % and 87 %, when applied twice with a 2 weeks interval. To be efficient, insecticide applications must thus be synchronized with the flights and egg-laying periods. Monitoring the phenology of flights is thus essential as part of integrated pest management against saddle gall midge.

Key words: Diptera, Cecidomyiidae, *Haplodiplosis marginata*, chemical control, insecticides, pyrethroids, integrated pest management

INTRODUCTION

The saddle gall midge, *Haplodiplosis marginata* (von Roser, 1840), is a polyphagous species developing on various cereals (Hordeum, Secale, Triticum) and also on grasses, mainly on *Elymus repens* (L.) Gould (Hulshoff, 1959; Dewar, 2012). This small Diptera, from the family Cecidomyiidae, only develops one generation per year (Skuhravý *et al.*, 1993).

In Belgium, adults usually emerge in May and at the beginning of June, but sometimes the fly of adults may be prolonged up to the end of June (Skuhravý *et al.*, 1993). The life of an imago is very short lasting one up four days. After mating females lay eggs on the youngest leaves of cereals. Eggs hatch a few days later; young larvae crawl to the stem under the leaf sheaths, where larvae develop. As reaction of the presence of midge larvae, stem produces a longitudinal depression of 5-10 mm ended by two ridges looking as a horse saddle (De Clercq and D'Herde, 1972 ; Skuhravý *et al.*, 1993). When galls are numerous, they can cause break of stems and important yield losses. From June to mid-July, full-grown larvae – which are 2,5-4 mm long and rosa-red – leave these saddle-shaped galls and drop to the soil where they spend the majority of their life from July, to April of the next year. In the spring, in April or May, the larvae move up from deeper layers to the surface of soil where they pupate. Pupation lasts 14-26 days and then adults emerge (Skuhravá, 2000).

Saddle gall midge, which is a major pest in Central Europe (mainly on wheat and barley), is not very well known in the Western part of the continent (Skuhravý *et al.*, 1993 ; Skuhravá, 2000). It had already caused huge damage during previous outbreak periods. The last one reported in Belgium and in The Netherlands occurred between 1965 and 1970 (De Clercq and D'Herde, 1972). Later, it was never reported again until 2010, where large populations and severe damage were observed, especially in the Flemish polders, a region with clay soils where wheat is cropped intensively.

Faced with the come back of this pest, we sought to develop efficient curative control methods for the cases of severe infestation, as it was already the case in 2011 for some fields in Belgian polders. To date, crops chemical protection seems to be the only immediate solution in case of heavy emergences.

MATERIALS AND METHODS

Experimentation was conducted in a winter wheat field in Meetkerke (Brugse polders, Belgium), highly infested by *H. marginata*, according to a randomized complete blocks arrangement with four replications. 16 treatments were compared, on plots of 16 m² for a total of 64 plots.

The choice of tested products and doses was guided by the fragmentary information of previous experiments on *H. marginata* in different countries (Popov *et al.*, 1998; OEPP, 2000; Mölck, 2007; Dewar, 2012). Besides, most of these insecticides were pyrethroid-based products, already registrated in cereals against aphids. It was therefore easy to get to their extension registration against the saddle gall midge, since experiments have proven their efficacy against this pest.

Experimentation included two parts: in the first one, the same insecticide (KARATE ZEON, CS 100 g lambda-cyhalothrin/L) was applied, according to eight different schemes, ranging from one to four weekly spray(s) with the recommended dose (0,05 L/ha) (Table 1). In the second one, different insecticides applied twice were compared (on May 12 and May 25, 2011) (Table 1). Of the seven evaluated insecticides, four were pyrethroids (DECIS 2.5 EC ; FASTAC ; CYMTOP and MAVRIK 2F). PIRIMOR is a pirimicarb-based-insecticide, of the carbamates' family. As for Experimental Product 2 (EXP 2), it consists of both a pyrethroid (cypermethrin) and a organo-phosphorus (chlorpyrifos-ethyl).

At the end of each repetition, two untreated plots were left as border to prevent spray drift, as the rest of the field had to be treated by the farmer.

Table 1. Treatments

Product	a.s. and concentration	Dosis/ha	Spray A: May-3	Spray B: May-12	Spray C: May-19	Spray D: May-25
1 Control	–	–				
2 Kar. (A - - -)	lambda-cyhalothrin 100 g/l	0.05 l	X			
3 Kar. (A B - -)	lambda-cyhalothrin 100 g/l	0.05 l	X	X		
4 Kar. (A B C -)	lambda-cyhalothrin 100 g/l	0.05 l	X	X	X	
5 Kar. (A B C D)	lambda-cyhalothrin 100 g/l	0.05 l	X	X	X	X
6 Kar. (- B - D)	lambda-cyhalothrin 100 g/l	0.05 l	X		X	
7 Kar. (- B C D)	lambda-cyhalothrin 100 g/l	0.05 l		X	X	X
8 Kar. (- - C D)	lambda-cyhalothrin 100 g/l	0.05 l			X	X
9 Kar. (- - - D)	lambda-cyhalothrin 100 g/l	0.05 l				X
10 Pirimor	pirimicarb 50 % WG	0.25 kg		X		X
11 Exp 1	uncommunicable	–		X		X
12 Decis 2.5 EC	deltamethrin 25 g/l EC	0.20 l		X		X
13 Fastac	alpha-cypermethrin 50 g/l	0.20 l		X		X
14 Cymtop	cypermethrin 100 g/l	0.25 l		X		X
15 Mavrik 2F	tau-fluvalinate 240 g/l EW	0.15 l		X		X
16 Exp 2	chlorpyrifos-ethyl 500 g + cypermethrin 50 g/l	0.50 l		X		X

Kar. = Karate zeon, CS containing lambda-cyhalothrin 100 g/l.

Spraying were made using a backpack sprayer fitted with a ramp of 2.5 m, and at a litrage equal to 360 liters of mixture per hectare. The date of first treatment was determined from the flight monitoring and corresponded with the detection of the first eggs laid on the leaves. Then, treatments have approximately succeeded at a weekly rate (Figure 1). First spraying took place on May 3, 2011, that is to say four days after the first flight peak, and the last one was made five days after the end of the last flight peak.

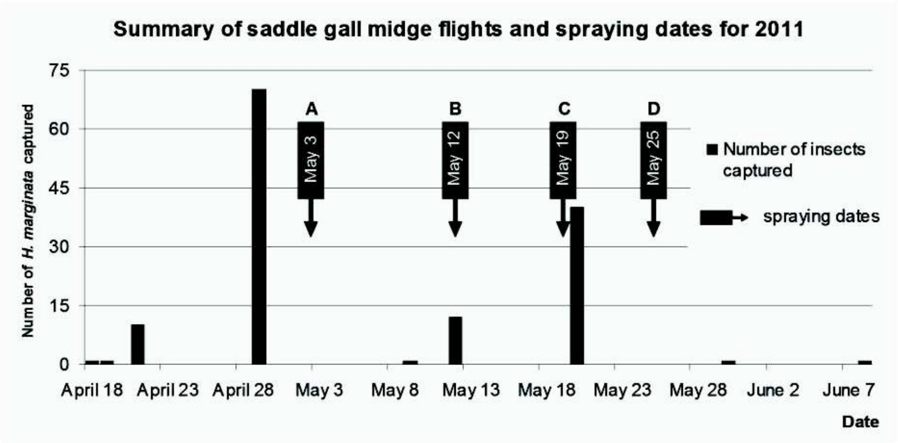

Figure 1. Saddle gall midge flights and spraying dates for 2011

On June 30, 2011, 30 stems were randomly picked in each plot. After defoliation, the number of galls on each internode was noted. From these observations, the following parameters were evaluated: percentage of affected stems, mean number of galls per stem, distribution of galls on the internodes (IN) and percentage of efficacy, defined according Abbott's formula (Dutcher, 2007):

$$\text{Percentage of efficacy} = 100 \times \frac{1 - \text{Number of galls in treated schema}}{\text{Number of galls in control}}$$

Statistical analyses were performed using Minitab software (Minitab Inc., State College, PA, USA), Version 15.0. Angular transformation was used for parameters relating to the percentage of affected stems and the percentage of efficacy (Dagnelie, 1998). One-way analyses of variance (AV1) were then applied (α = 0.05), after verification of application conditions (normality test of Ryan-Joiner and test for equal variances). Additional tests of Dunnett (comparisons with the control) and Tukey (pairwise comparisons, without the control) were also carried out (α = 0.05).

For mean number of galls per stem, square root transformation was applied. Although conditions of normality and of equal variances were not always fulfilled, two-way analyses of variance (AV2) were performed (α = 0.05). Indeed, the analysis of variance is "quite insensitive to non-normality of parental populations and, for sample of same size, to inequality of variances" (Dagnelie, 1998), which is true in this case, as these analyses are based on a total of 120 stems. Dunnett and Tukey tests were also realized (α = 0.05), since the normality condition is very few restrictive given the rapid convergence of the sampling distributions of the mean to normal distributions (Dagnelie, 1998).

RESULTS

Efficacy of a pyrethroId (lambda-cyhalothrin-based insecticide) according to different insecticides schemes

The results obtained for the parameters measured on stems from plots treated with KARATE ZEON – according to several application modalities – are listed in Table 2.

Regarding the percentage of affected stems, there are some significant differences between modalities. So, control stems are the most frequently affected (92 %). This degree of attack is significantly different from every others modalities (p-value < 0.05 for Dunnett test). In contrast, the greatest reduction of affected stems is observed in the case of quadruple treatments, with only 6 %. According to Tukey test, this attack level is significantly different from the modalities with one spraying date, with 58 % of affected stem for date D (p-value = 0.0032**) and 63 % for date A (p-value = 0.0007***). Between these extremes, it can be considered that schemes with two or three treatments constitute a homogenous group, with a percentage of affected stems ranging from 24 % to 39 %.

Table 2. Effect of a lambda-cyhalothrin-based insecticide (Karate zeon) – applied according to different schemes – on damage parameters

	CONTROL	KAR. A - - -	KAR. A B - -	KAR. A B C -	KAR. A B C D	KAR. A - C -	KAR. - B C D	KAR. - - C D	KAR. - - - D
Percentage of affected stems	92% ^{a}	63% ^{b}	35% $^{b-d}$	24% $^{c-d}$	6% ^{d}	39% $^{b-d}$	35% $^{b-d}$	28% $^{c-d}$	58% $^{b-c}$
Mean number of galls per stem*	9.2 ^{a} ± *11.13*	5.5 ^{b} ± *7.50*	1.9 $^{c-d}$ ± *5.27*	0.9 $^{c-d}$ ± *2.61*	0.3 ^{d} ± *1.56*	1.6 $^{c-d}$ ±*3.31*	1.0 $^{c-d}$ ± *2.48*	1.1 $^{c-d}$ ± *2.49*	2.5 $^{b-c}$ ± *4.03*
Percentage of efficacy	-	40.4% ^{a}	80.2% $^{b-c}$	90.2% $^{b-c}$	96.7% ^{c}	83%$^{b-c}$	89.4% $^{b-c}$	87.8% $^{b-c}$	73.1%$^{a-b}$

For each parameter, means or percentages with at least one common index do not differ significantly, according to ANOVA tests (α = 0.05). * Mean±Standard Deviation

Overall, observations show that the mean number of galls per stem is even lower than the spraying number is high (Figure 2). Thus, the minimum is reached in the case of a quadruple treatment, with only 0.3 galls per stem. Schemes with two or three treatments form a homogeneous group (according to Tukey test, α = 0.05), with an infestation level between 0.9 and 1.9 galls per stem on average. The two modalities with a single treatment have higher mean numbers of galls per stem ; and plots with the earliest treatment (5.5 galls per stem) are significantly more attacked than those with multiple treatments. Moreover, all plots with treatment(s) have also a different level attack from control plot, for which there were 9.2 galls per stem.

Eventually, similarly observations can be made for the percentage of efficacy. Thus, it appears that most efficient treatments are observed for modalities with two to four treatments. These modalities have homogeneous efficacy, ranging between 80.2 % and 96.7 %. Efficacy is case of quadruple treatment (96.7 %) is also significantly different from these with single spraying (73.1 % for spraying on date D and 40.4 % for spraying on date A). Furthermore, modality with the earliest treatment (single spraying on date A) shows a significantly lower percentage of efficacy (with 40.4 %) than those with several treatments.

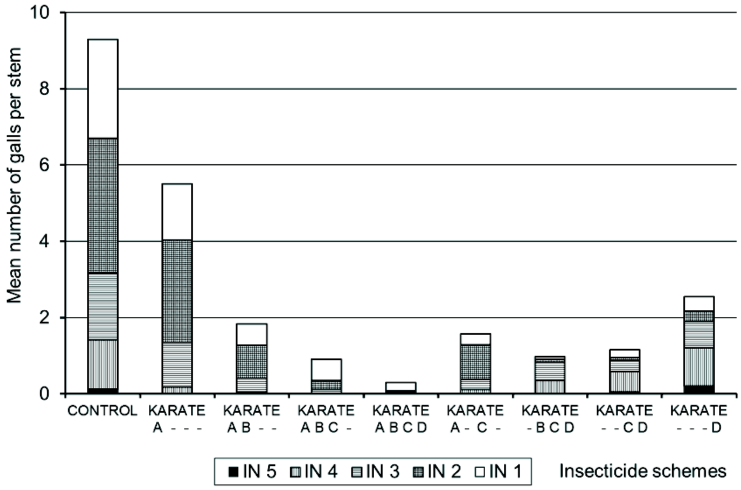

Figure 2. Mean number of galls per stem for the different applications with Karate zeon, with distribution on each internode.

The impact of spraying number and their application date on the galls location can also be analyzed by decomposing the attacks by level: firstly, the number of galls on the two lower internodes (IN 4 and IN 5) and, secondly, the number of galls on the two upper internodes (IN 1 and IN 2) (Figure 3). The galls correspond respectively to larvae generated by insects from the first and the second flights peak.

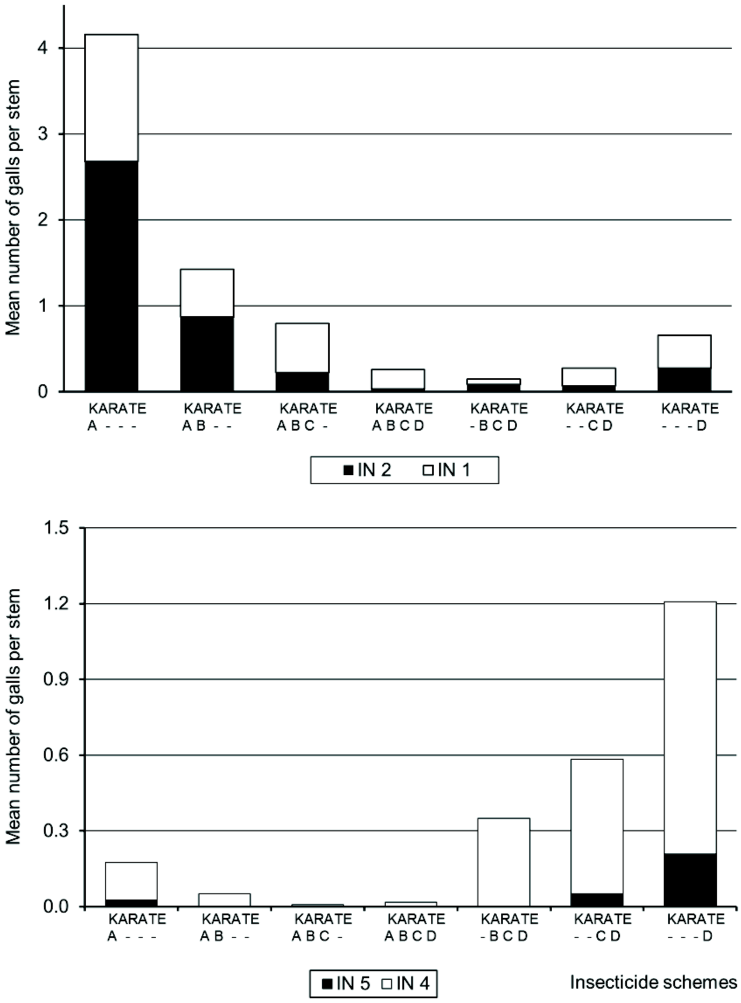

Figure 3. Mean number of galls present on the lower internodes (IN 4 and IN 5) and the upper internodes (IN 1 and IN 2) for each modality.

The third internode was not considered here because, due to its intermediate position, it was not possible to distinguish whether galls were induced by individuals coming from eggs laid during the first or the second flight peak. On the lower internodes, the galls number was significantly reduced for modalities integrating the earliest treatments, while modalities incorporating the latest treatment dates had a much lower impact. The phenomenon is reversed for the upper internodes IN 1 and IN 2. Indeed, it can be observed an overall decrease in the number of galls as the treatment dates are belated.

Efficacy of different insecticides

Experiment conducted on different insecticides gave widely contrasting results, and two groups can be clearly distinguished. On the one hand we find Pirimor and Exp 1 and, on the other hand, the five other tested insecticides (Table 3).

Indeed Pirimor and Exp 1 did not at all proved their efficacy against saddle gall midge. No significant difference could be highlighted compared to control, neither for the percentage of affected stems, nor for the mean number of galls per stem, according to Dunnett test (α = 0.05).

Table 3. Damage assessment parameters for the different insecticides tested.

	Control	**Pirimor**	**Exp 1**	**Decis 2.5 EC**	**Fastac**	**Cymtop**	**Mavrik 2F**	**Exp 2**
Percentage of affected stems	92% ^{a}	85% ^{a}	84% ^{a}	58% ^{b}	42% ^{b}	38% ^{b}	47% ^{b}	48% ^{b}
Mean number of galls per stem*	9.2 ^{a} ± *11.13*	11.3 ^{a} ± *12.62*	7.9 ^{a} ± *9.01*	2.4 ^{b} ± *3.75*	2.3 ^{b} ± *4.18*	1.3 ^{b} ± *2.42*	1.6 ^{b} ± *2.89*	1.8 ^{b} ± *3.34*
Percentage of efficacy	-	0% ^{a}	14.4% ^{b}	74.4% ^{c}	75.6% ^{c}	86.3% ^{c}	82.8% ^{c}	80.6% ^{c}

For each parameter, means or percentages with at least one common index are not significantly different according to ANOVA tests (α = 0.05).

* Mean±*Standard Deviation*

As for the other five insecticides tested (Decis 2.5 EC, Fastac, Cymtop, Mavrik 2F and Exp 2), they cause a very large reduction in damage. In this homogeneous group involving systematically pyrethroid insecticides, the mean number of galls per stem is not significantly different, and ranges from 1.3 to 2.4 (AV2: $F_{4,580}$ = 0.42 ; p-value = 0.788). Figure 4 illustrates these results, representing also the galls distribution on the different internodes. All these insecticides also showed a similar percentage of efficacy, ranging between 74% and 87% (AV1: $F_{4,15}$ = 0.49 ; p-value = 0.740). In this group, the percentage of affected stems changes from 38 % to 58 %. Although these levels of damage are slightly variable, no significant difference could be demonstrated (AV1: $F_{4,15}$ = 0.96 ; p-value = 0.456).

DISCUSSION

Note that the impact of insecticide protection on winter wheat yield could not be measured in Meetkerke experimentation, due to serious sowing irregularities (spring sowing, without plowing, in an extremely heavy soil and followed by several months of severe drought). It is therefore impossible to quantify the damage caused by the saddle gall midge and to appreciate the agronomical interest of a more or less intensive protection. Only the efficacy of products or treatment schemes could be determined.

We should first underline the efficacy of Karate zeon. Indeed, a single treatment with this insecticide, regardless of the spraying date, has significantly reduced damage, as well as to the percentage of affected stems (with a decrease of approximately 30 % compared to control) as to the mean number of galls per stem (with a minimum efficacy of 40 %).

In 2011, given the spread of flights, several applications were necessary to maintain control on the saddle gall midge. Indeed, on the one hand the attack level is significantly higher when only one application is made and, on the other hand, the highest efficacy is obtained for the schemes with three or four sprays.

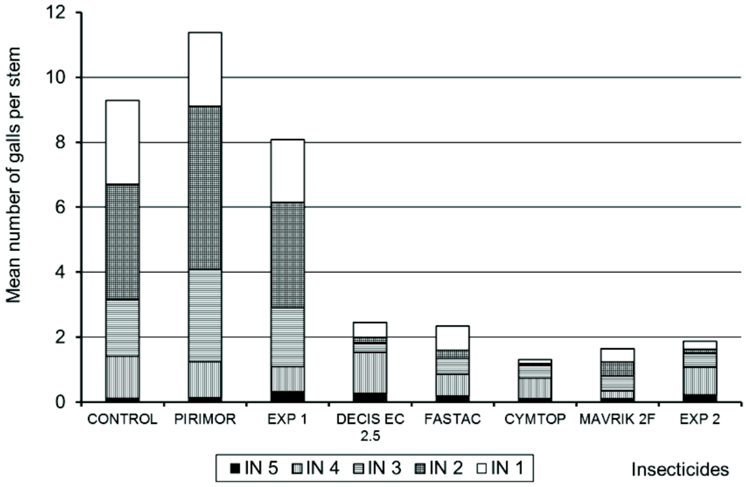

Figure 4. Mean number of galls per stem for the different tested insecticides, with distribution on each internode.

This season was therefore particularly suited to highlight the influence of treatment date on the damage level and on the galls location, since the flights were spread: galls have thus been induced on all internodes. So, scheme with the earliest treatment shows a sharp decrease in the galls number on the lower internodes. Conversely, when insecticide is applied to the latest date (date D), there is a large reduction in the galls number on the upper internodes: larvae present on the internodes below at the moment of these late sprayings were not affected, because they were protected under leaf sheaths.

In other scenarios, where most flights occur together, multiple treatments do not always proved to be necessary, as shown by the results of a similar experimentation conducted by Mölk (2007) with Fastac SC (an alpha-cypermethrin-based insecticide). In this experiment, a treatment performed about 10 days after the single flight peak had shown an efficacy of over 80%, while the same treatment, applied respectively three of four weeks after this peak, was much less efficient with only 20 % and 5 % of efficacy.

The results of this trial, as well as those of similar works done abroad, show that it is essential to synchronize insecticide treatments with the observed scenario: to be fully efficient, an insecticide spray should target eggs hatch, and larvae migration on the leaves. It would be thus useful to establish a flights monitoring and a warning system in areas exposed to attack by *H. marginata*.

Other conclusions could be drawn for products that can reach larvae being already under the leaf sheath: in this case, later applications may be efficient. Conversely, products with a longer persistence of action could be applied earlier, even before egg-laying.

Experimentation comparing various insecticides clearly demonstrates that some products are not adapted for controlling *H. marginata*, as product Exp 1 and Pirimor.

In contrast, products containing a pyrethroid confirm their efficacy, already mentioned by several authors (Popov *et al.*, 1998). Indeed, all have resulted in a significant reduction of damage parameters. Pyrethroid-based insecticides can thus be a tool for saving crops in case of heavy emergence of this pest.

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