EKOLOGIJA. 2009. Vol. 55. No. 3–4. P. 215–219
DOI: 10.2478/v10055-009-0028-2

Sitodiplosis mosellana – a new winter wheat pest in Lithuania

Žilvinas Liatukas[1]*,

Vytautas Ruzgas[2],

Remigijus Šmatas[1]

*[1] Lithuanian Institute of Agriculture,
Instituto av. 1,
LT-58344 Akademija,
Kėdainiai distr., Lithuania*

*[2] Lithuanian University of Agriculture,
Studentų 11,
LT-53361 Akademija,
Kaunas distr., Lithuania*

During the period 2007–2008, observations of a new winter wheat pest – orange wheat blossom midge (OWBM) *Sitodiplosis mosellana* (Géhin) belonging to Diptera: Cecidomyiidae was carried out at the Lithuanian Institute of Agriculture located in central Lithuania. The first pest outbreak was observed in 2007. Screening of 123 breeding lines in 2007 showed that all of the genotypes screened were susceptible to OWBM. A detailed analysis of breeding populations showed that 44.3% of them had grain damage over 5%. Trapping of midge males with a pheromone in 2008 showed that the number of midges per day ranged from 0 to 327, depending on the assessment day and the location of traps. The period of intensive flying of midges matched with the susceptible winter wheat growth stage (BBCH46-59). Very few larvae were found in winter wheat ears later, possibly due to too low temperatures during the egg laying, hatching and development of larvae.

Key words: orange wheat blossom midge, air temperature, *Triticum aestivum*

INTRODUCTION

Orange wheat blossom midge (OWBM), *S. mosellana* (Géhin) belonging to Diptera: Cecidomyiidae is a pest of spring and winter wheat in temperate climate zones in North America, Europe, West Asia and the Far East. At present, financial losses due to grain damage by this pest exceed several hundreds of millions of euros worldwide in the years favourable for this species (Doane, Olfert, 2008; Oakley, 2008). This pest over-winters as diapausing cocooned larvae. The diapause can be prolonged up to 12 years, although the most intensive emergence occurs in the first two years (Barnes, 1952; Mukerji et al., 1988; Wise, Lamb, 2004). The diapause is broken in spring due to rising soil temperatures. Post-diapause development is initiated when larvae exit the cocoons and move to soil surface. Adult emergence and subsequent egg-laying start about 2–3 weeks later. Oviposition occurs in florets of wheat heads just before flowering (Elliot, Mann, 1996). Eggs hatch in about 4–7 days, and the larvae feed on the developing ovary and mature in approximately three weeks. Mature larvae remain in wheat heads until moist conditions occur; then larvae drop to the ground, burrow into the soil, spin a larval cocoon and overwinter. All these phenological events are regulated by temperature (Gagné, Doane, 1999). Attack by this wheat midge decreases grain germination capacity, volume weight, grain and flour yield and the Hagberg falling number (Miller, Halton, 1961; Helenius, Kurppa, 1989).

Control of OWBM includes a broad spectrum of measures. The most effective and desirable is growing resistant cultivars possessing the mono-resistance gene *Sm1* (McKenzie et al., 2002). Some effect can be provided by cultivars possessing partial resistance (Von Basedow, 1977). The main disadvantage of this method is shortage of resistant cultivars across Europe. Results have been achieved only in the United Kingdom where, due to high economic losses (in 2004 estimated over 80 million euros), resistance breeding was successfully accelerated. Resistant varieties have occupied around 20% of cropped area in the last years in most problematic zones (Oakley, 2008). Chemical control is efficient from the viewpoint of adult pest susceptibility to pesticides, but it is complicated due to a long (4–6 weeks) period of adults' emergence. Effective application of insecticides is possible only using monitoring traps for everyday checks of adults and subsequent adjustment of pesticide sprayings. On the other hand, application of insecticides destroys natural control by parasites, especially by *Macroglenes penetrans* (Kirby) (Elliot, Mann, 1997).

Sitodiplosis mosellana larvae in winter wheat fields of the Lithuanian Institute of Agriculture have been noticed since 2000 but at a frequency less than 1 larva per 100 winter wheat

* Corresponding author. E-mail: liatukas@lzi.lt

ears. The first serious outbreak of this pest occurred in 2007. No information about this pest in recent papers from Lithuania and Latvia was found. Only *Contarinia tritici* (Kirby), which damages winter wheat grains together with *S. mosselana*, was mentioned (Spungis, 2003; Pakalniškis et al., 2006; LR VAAT, 2009). Therefore, in 2008 it was decided to start detailed observations of *S. mosellana* at the Lithuanian Institute of Agriculture.

MATERIALS AND METHODS

During the period 2007–2008, investigations of orange wheat blossom midge (OWBM) (*S. mosellana*) were carried out at the Lithuanian Institute of Agriculture (LIA) located in central Lithuania (55°23'50"N and 23°51'40"E) in winter wheat breeding nurseries with different crop rotations and different distances to previous winter wheat fields. The field with wheat breeding nurseries in 2007, the year of OWBM outbreak, was located near the field with winter wheat in 2006. Winter wheat breeding nurseries were checked for OWBM in 2007 at wheat grain milk development stages BBCH 73–75. OWBM larvae were monitored in 123 advanced breeding lines and in three cultivars by hand-threshing ears. Three check-resistant cultivars possessing the resistance gene *Sm1* ('Gatsby', 'Magister', 'Skalmeje') (HGCA 2008) were checked in the same nursery. Presence of larvae was checked in 10 ears per genotype. Grain damage was checked in breeding lines of populations in F3–F5 generations. Every ear was threshed individually for preparation of breeder seeds. All lines of a population were evaluated for damage as one unit during preparation of breeder seeds; 150 were checked in F3 generation, 80 ears in F4 generation and 40 ears in F5 generation. In total, 192 crossing combinations were checked. According to the number of damaged grains the lines were divided into four groups – up to 1%, 1–5%, 5–10% and over 10%.

Pheromone traps and synthetic sex pheromone lures for catching males were obtained from the UK company 'AgriSence'. The traps were set in three fields at the end of May 2008 when some wheat genotypes started heading (BBCH 45–52). Observations were done until the end of the midge flight when the wheat reached anthesis (BBCH 61–63).

Field 1 was a take-all nursery with continuous wheat cultivation since 2005; one trap was set up in the middle of this place. Field size was 0.25 ha (40 × 62 m).

Field 2 was the main winter wheat breeding nursery field in the crop rotation with winter wheat cultivation every ninth year. Winter wheat was cultivated in an adjacent field in 2007. Two traps were arranged at the opposite sides of this field at a distance of about 20 m from the adjacent field. The size of both fields was 3.7 ha (90 × 410 m) each.

Winter wheat was cultivated in Field 3 after black fallow; the adjacent fields were without winter wheat cultivation at a distance of about 500 m in 2007. Two traps were arranged at the opposite sides of this field. Field size was 3.2 ha (120 × 265 m).

Trapped midges were counted daily. Winter wheat nurseries for OWBM larvae were monitored at wheat growth stages BBCH 73–79 in hand-threshed ears. As larvae were detected in extremely low frequencies (less than 1 larva per 100 ears), further grain damage was not investigated.

Meteorological data from the weather station situated near the experimental fields were used. The mean June temperature was 17.6 °C and 16.1 °C in 2007 and 2008, respectively. The long-term mean temperature of June during 1924–2008 was 15.7 °C, whereas the mean temperature of June 1–15 was 19.0 °C and 16.5 °C in 2007 and 2008, respectively. The sum of active air temperatures (≥10.1 °C) in June 1–15 2007 was 134.9 °C and in 2008 at the same period was 97.1 °C. The difference between the years was 37.8 °C of active temperatures.

RESULTS

Survey of OWBM larvae in 2007 in the advanced breeding lines nursery showed that all of the 123 genotypes were susceptible, since the majority of checked ears were infested. The number of larvae in infested ears ranged within 1–6. No OWBM larvae were found in the resistant cultivars 'Gatsby', 'Magister', 'Skalmeje'.

Grain damage of the breeding lines in F3–F5 generations of half of the populations was 1.1–5.0% (Table 1). Populations with grain damage 5.1–10.0% were less frequent (26%). Heavily damaged grains (≥10.1%) were characteristic of 18.3% of populations.

Table 1. **Amount of winter wheat grains damaged by OWBM larvae, 2007**

Grain damage level, %	Number of populations per level	Percentage of populations
≤1.0	14	7.4
1.1–5.0	93	48.3
5.1–10.0	50	26.0
≥10.1	35	18.3
Total	192	100.0

The number of OWBM in pheromone traps revealed that adult midges were abundant at the beginning of winter wheat heading BBCH45-52 in 2008 (Table 2). The period of intensive flight lasted till wheat anthesis BBCH 63–65.

The number of midges per day ranged from 0 to 327 depending on the trapping date and the location of traps. Fields 1 and 2 were characterized by a very intensive OWBM infestation, whereas traps in field 3 showed only very few midges from time to time.

The intensive flight of midges in field 1 lasted for 12 days during the entire observation period. The number of trapped midges ranged from 0 to 86; the total number during the first 12 days of observation was 375, and 20 midges were caught during the remaining 13 days.

The second field was characterized by a shorter but more intensive 11-day flight period of OWBM. The number

Table 2. **The number of OWBM in pheromone traps, 2008**

Counting date	Winter wheat growth stages	Field number		
		Field 1	Field 2	Field 3
		Mean number of OWBM per trap per day		
31 May	45–50–52*	17	8.5	0
01 June	46–51–53	16	19	0
02 June	47–52–54	31	13	0
03 June	48–53–55	86	327	1
04 June	40–53–57	4	11	1.5
05 June	53–57–58	21	13.5	0
06 June	55–57–59	21	20.5	1
07 June	56–58–60	28	7.5	0.5
08 June	57–60–61	62	16.5	0
09 June	58–61–62	34	1.5	0.5
10 June	60–62–63	31	0.5	0
11 June	61–63–65	24	0	0
Total: May 31–June 11		375	438.5	4.5
Total: May 31–June 24		395	438.5	4.5

* BBCH growth stages: the first number – late, the second – medium, the third – early ripening cultivars.

of midges trapped in field 2 ranged from 0 to 327. Field 2 differed markedly from field 1 in the peak of flight activity of midges: 86 midges in field 1 and 327 in field 2. The total number of midges in field 2 depended greatly on the number of midges caught on one day, June 3, when 74.6% of the total was caught.

In the third field without winter wheat nearby in the previous year, only a very few midges were caught over the 25-day period.

DISCUSSION

Differences in the infestation by OWBM could depend on the different rates of development of the breeding lines. Some lines differed in heading time by up to 10 days. The OWBM flight period lasts several weeks, but, due to the influence of the environment, the intensive flight of midges only partially coincides with the beginning of wheat heading. Another possible explanation for differences among breeding lines is that some wheat genotypes express oviposition deterrence which can cause a lower infestation of some genotypes (Lamb et al., 2002; Lamb et al., 2003; Olfert et al., 2009). The number of damaged grains in 44.3% of the populations in the F3–F5 generations was over 5%. As winter wheat is grown in Lithuania for high quality grain, this damage level is sufficient to be of economic importance in commercial wheat (Lamb et al., 2000). Based on this relatively high level of damage, we conclude that OWBM should be considered as a new pest of winter wheat in Lithuania. This statement is confirmed by observations of Oakley et al. (1998) and Oakley (2008) who determined the economic threshold as 10 or more midges caught in a pheromone trap per day.

Although wheat was heavily infested in 2007, the weather conditions were relatively unsuitable for OWBM due to dry soil, whereas soil surface was wet in 2008. If conditions are dry during May and June, larvae remain dormant until the following year (Elliot, Mann, 1996). As expected, given the moist soil conditions, midges flew actively in 2008. Their flight began before the first trapping day on May 31 because on the first day from 6 to 17 midges were caught per trap. The number of midges in traps during the period of active flight in June often exceeded the economic threshold which is 10 midges per day per trap (Oakley, 2008). Usually, OWBM larvae drop out of wheat ears and burrow in the soil to a depth of 0–6 cm (Doane, Olfert, 2008). Soil in both fields with abundant WOBM flying was ploughed after harvesting to a depth of about 25 cm. Given the level of infestation in 2007 and the level of flight activity in 2008, larvae must be able to move through 10–20 cm of soil to reach the surface. This biological trait complicates control of this pest by agrotechnical measures.

OWBM distribution in pheromone traps across fields showed the impact of previous crop on a possible damage of winter wheat. The field with continuous wheat cultivation was heavily infested by midges, whereas pheromone traps in a field without nearby wheat in the previous year caught few midges. These data are consistent with results of other studies (Smith et al., 2004; Oakley, 2008; Olfert et al., 2009). However, pheromone traps in another winter wheat field, which had been sown to oats in the previous year, caught almost as many midges as when wheat had been sown to wheat. The traps in this field were located about 20 m from the adjacent field which had been under wheat in the previous year. Such a distance is greater than the usual distance males are supposed to disperse (Smith et al., 2004), but males seem to have been attracted to the pheromone traps over that distance. Another possible explanation of the high trap catches are that OWBM had infested the oats grown in this field in 2005 and 2006, although high levels of infestation in oats are unlikely (Wise et al., 2002). Or, it is possible that females, which typically cover greater distances, were caught passively in the traps, although they should not have been attracted by the pheromone (Smith et al., 2004); this possibility, however, does not seem to be high because of the high catches of OWBM on the traps. Females are attracted by volatiles of wheat heads. However, traps that could attract females and show the likely infestation level are only in the development stage (Birkett et al., 2004; Smith et al. 2004; Bruce et al., 2007).

Weather conditions in the first part of June 2007 and 2008 were probably particularly conducive to OWBM and the appearance of this insect as a winter wheat pest. The mean temperature was 19.0 °C in 2007 and 16.1 °C in 2008. The long-term mean temperature in June during 1924–2008 was 15.7 °C, i. e. by 3.3 °C and 0.4 °C higher than during the study. Rising temperatures in the last decade could be a cause of OWBM outbreak in the recent years. The sum of active air soil temperatures (≥10.1 °C) in 2007 during June 1–15 was by 37.8 °C higher than in 2008. The minimal air temperature showed similar relations. The higher temperatures in 2007 could have been more favourable for female egg laying than the lower temperatures in 2008, based on temperature effects observed in Canada (Wise, Lamb, 2004). However, prediction of intensive OWBM flight by summing active temperatures was not effective in Europe (Oakley et al., 1998). Other weather conditions, such as precipitation, did not provide a clear explanation for the differences in grain damage between 2007 and 2008.

OWBM can cause a damage to winter wheat that reaches economic levels in Lithuania. None of the winter wheat advanced breeding lines were known to be resistant to OWBM. Cultivation does not prevent OWBM from overwintering successfully in the soil. The flight of midges occurs through June in Lithuania, which overlaps the growth stages of winter wheat susceptible to infestation. OWBM can be detected with commercially available pheromone traps, although these traps work most effectively if wheat was present near the trapping location in the previous year.

ACKNOWLEDGEMENTS

We are thankful to the Ministry of Agriculture for support of the programme "Plant Breeding and Introduction" and to the Lithuanian State Science and Studies Foundation (project No. 07004 KVIETPOLIMER).

Received 6 June 2009
Accepted 19 August 2009

References

1. Abdel-Aal E.-S. M., Hucl P., Sosulski F. W., Graf R., Gillott C., Pietrzak L. 2001. Screening spring wheat for midge resistance in relation to ferulic acid content. *Journal of Agricultural and Food Chemistry.* Vol. 49. P. 3559–3566.
2. Barnes H. F. 1952. Studies of fluctuations in insect populations XII. Further evidence of prolonged larval life in the wheat-blossom midges. *Annals of Applied Biology.* Vol. 39. P. 370–373.
3. Birkett M. A., Bruce T. J. A., Martin J., Smart L. E., Oakley J., Wadhams L. J. 2004. Responses of female orange wheat blossom midge, *Sitodiplosis mosellana* to wheat panicle volatiles. *Journal of Chemical Ecology.* Vol. 30. P. 1319–1328.
4. Bruce T. J., Hooper A. M., Ireland L., Jones O. T., Martin J. L., Smart L. E., Oakley J., Wadhams L. J. 2007. Development of a pheromone trap monitoring system for orange wheat blossom midge, Sitodiplosis mosellana, in the UK. *Pest Management Science.* Vol. 63. P. 49–56.
5. Ding H., Lamb R. J. 1999. Oviposition and larvae establishment of *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) on wheat (*Gramineae*) at different growth stages. *The Canadian Entomologist.* Vol. 131. P. 475–481.
6. Doane J. F., Olfert O. 2008. Seasonal development of wheat midge, *Sitodiplosis mosellana* (Géhin) (Diptera: Cecidomyiidae), in Saskatchewan, Canada. *Crop Protection.* Vol. 27. P. 951–958.
7. Elliot R. H., Mann L. M. 1996. Susceptibility of red spring wheat, *Triticum aestivum* L. cv. Katepwa, during anthesis to damage by wheat midge, *Sitodiplosis mosellana* (Géhin) (Diptera: Cecidomyiidae). *The Canadian Entomologist.* Vol. 128. P. 367–375.
8. Elliot R. H., Mann L. M. 1997. Control of wheat midge, *Sitodiplosis mosellana* (Géhin), at lower chemical rates with small-capacity sprayer nozzles. *Crop Protection.* Vol. 16. P. 235–242.
9. Helenius J., Kurppa S. 1989. Quality losses in wheat caused by the orange wheat blossom midge *Sitodiplosis mosellana*. *Annals of Applied Biology.* Vol. 114. P. 409–417.
10. *HGCA. Winter wheat recommended list 2005–2009*. http://www.hgca.com [accessed 04 11 2008].
11. Gagne R. J., Doane J. F. 1999. The larval instars of the wheat midge, *Sitodiplosis mosellana* (Géhin) (Diptera: Cecidomyiidae). *Proceedings of Entomologist Society of Washington.* Vol. 101. P. 57–63.
12. Lamb R. J., Sridhar P., Smith M. A. H., Wise I. L. 2003. Oviposition preference and offspring performance of a wheat midge *Sitodiplosis mosellana* (Géhin) (Diptera: Cecidomyiidae) on defended and less defended wheat plants. *Environmental Entomology.* Vol. 32. P. 414–420.
13. Lamb R. J., Tucker J. R., Wise I. L., Smith M. A. H. 2000. Trophic interaction between *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) and spring wheat: implications for yield and seed quality. *The Canadian Entomologist.* Vol. 132. P. 607–625.
14. Lamb R. J., Wise I. L., Smith M. A. H., McKenzie R. I. H., Thomas J., Olfert O. O. 2002. Oviposition deterrence against *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) in spring wheats (Gramineae). *The Canadian Entomologist.* Vol. 134. P. 85–96.
15. *Lietuvos Respublikos valstybinė augalų apsaugos tarnyba.* http://www.vaat.lt [accessed 25 02 2009].
16. McKenzie R. I. H., Lamb R. J., Aung T., Wise I. L., Barker P., Olfert O. O. 2002. Inheritance of resistance to wheats midge, *Sitodiplosis mosellana*, in spring wheat. *Plant Breeding.* Vol. 121. P. 383–388.
17. Miller B. S., Halton P. 1961. The damage to wheat kernels caused by wheat blossom midge (*Sitodiplosis mosellana*). *Journal of the Science of Food and Agriculture.* Vol. 12. P. 391–398.
18. Mukerji M. K., Olfert O., Doane J. F. 1988. Development of sampling designs for egg and larval populations of the wheat midge, *Sitodiplosis mosellana* (Géhin) (Diptera: Cecidomyiidae), in spring wheat in Saskatchewan. *The Canadian Entomologist.* Vol. 120. P. 497–505.
19. Oakley J. N., Cumbleton P. C., Corbett S. J., Saunders P., Green D. I., Young J. E. B., Rodgers R. 1998. Prediction of orange wheat blossom midge activity and risk of damage. *Crop Protection.* Vol. 17. P. 145–149.
20. Oakley J. N. 2008. Control needs for changing pest distribution. *Arable cropping in a changing climate: Proceedings of the HGCA Conference.* United Kingdom: HGCA. P. 87–92.

21. Olfert O., Elliott R. H., Hartley S. 2009. Non-native insects of agriculture: strategies to manage the economic and environmental impact of wheat midge, *Sitodiplosis mosellana*, in Saskatchewan. *Biological Invasions.* Vol. 11. P. 127–133.
22. Pakalniškis S., Bernotienė R., Lutovinovas E., Petrašiūnas A., Podėnas S., Rimšaitė J., Sæther O. A., Spungis V. 2006. Checklist of Lithuanian Diptera. In: Bernotienė S. et al. (eds.). *New and Rare for Lithuania Insect Species. Records and Descriptions.* Vol. 18. Vilnius: Society of Lithuanian Entomologists. P. 52.
23. Smith M. A. H., Lamb R. J. 2001. Factors influencing oviposition by *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) on wheat spikes (Gramineae). *The Canadian Entomologist.* Vol. 133. P. 533–548.
24. Smith M. A., Wise I. L., Lamb R. J. 2004. Sex ratios of *Sitodiplosis mosellana* (Diptera: Cecidomyiidae): implications for pest management in wheat (Poaceae). *Bulletin of Entomological Research.* Vol. 94. P. 569–575.
25. Spungis V. 2003. A checklist of Latvian Cecidomyiidae (Diptera, Cecidomyiidae) with notes on new records. *Latvijas Entomologs.* Vol. 40. P. 5–11.
26. Von Basedow T. 1977. The susceptibility of some spring wheat varieties to the attack by two wheat blossom midge species (Dipt., Cecidomyiidae). *Anzeiger für Schädlingskunde Pflanzenschutz Umweltschutz.* Bd. 50. S. 129–131.
27. Wise I. L., Lamb R. J. 2004. Diapause and emergence of *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) and its parasitoid *Macroglenes penetrans* (Hymenoptera: Pteromalidae). *The Canadian Entomologist.* Vol. 136. P. 77–90.
28. Wise I. L., Lamb R. J., Smith M. A. H. 2002. Susceptibility of hulled and hulless barley (Gramineae) to *Sitodiplosis mosellana* (Diptera: Cecidomyiidae). *The Canadian Entomologist.* Vol. 134. P. 193–203.

Žilvinas Liatukas, Vytautas Ruzgas, Remigijus Šmatas

SITODIPLOSIS MOSELLANA – NAUJAS ŽIEMINIŲ KVIEČIŲ KENKĖJAS LIETUVOJE

S a n t r a u k a

Oranžinis kvietinis gumbauodis *Sitodiplosis mosellana* (Diptera: Cecidomyiidae), naujas žieminių kviečių kenkėjas Lietuvoje, tirtas 2007–2008 m. Lietuvos žemdirbystės institute, esančiame centrinėje šalies dalyje. Pirmas kenkėjo gausus pasireiškimas nustatytas 2007 m. 123 selekcinių linijų tyrimas 2007 m. parodė, kad visi genotipai buvo jautrūs šiam kenkėjui. Detali grūdų pažeidimo analizė parodė, kad 44,3 % tirtų selekcinių populiacijų pažeistų grūdų buvo daugiau nei 5 %. Naudojant feromonines gaudykles uodų patinams pritraukti 2008 metais, pastarųjų pagauta nuo 0 iki 327, atsižvelgus į gaudymo dieną bei gaudyklių vietą. Intensyvus uodų skraidymo laikotarpis sutapo su jautriu kviečių vystymosi tarpsniu (BBCH 46–59). Tačiau vėliau kviečių varpose lervų rasta itin mažai, galbūt dėl per žemų temperatūrų lervų ritimosi ir vystymosi metu.

Raktažodžiai: oranžinis kvietinis gumbauodis, oro temperatūra, *Triticum aestivum*