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POPULATION DYNAMICS AND LIFE-CYCLE OF CORN BORERS IN SOUTH ATLANTIC EUROPEAN COAST

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ABSTRACT - *Sesamia nonagrioides* Lef. and *Ostrinia nubilalis* Hbn. are the main pests of maize in the mediterranean countries. Population fluctuations of both species were studied in NW Spain through 1990-1996. The abundance of both species varied greatly between and within locations. Their attacks were very intense in 1995 and 1996, reaching 100% of damaged plants in two plots, 30-50% in a third one and 7% in a fourth plot. In several plots and years we found more than one larvae per plant at harvest. The captures of adult moths made with pheromone traps indicate the existence of two generations, the first one flying in May and the second one in July-August. The larvae of first generation of both species rarely attack maize, but by September, most plants have been colonized by *S. nonagrioides* and, in a lesser degree, by *O. nubilalis* larvae. Larvae of both species overwinter inside the dead plants of maize, that are usually left in the fields after harvesting by most farmers. Given the mild winter temperatures of the South Atlantic coast, most of them survive until the next spring and produce the adults of first generation. Cultural methods (e.g. destruction of plant stems) and the use of resistant maize genotypes could improve the management of maize borers, diminishing their economic damages.

KEY WORDS: *Sesamia nonagrioides*; Pink stem borer; *Ostrinia nubilalis*; European corn borer; Seasonal abundance; Population density; Maize; *Zea mays*.

INTRODUCTION

The introduction of maize in different continents was followed by the attack of native insect species, that became pests on maize fields. The pyralid *Ostrinia nubilalis* (Hbn.) is the main pest of corn in Central Europe and also in North America, where it has been introduced accidentally (DICKE and GUTHRIE, 1988). In some zones, several species of noctuids of the *Sesamia* genus have been reported as the main problems for the cultivation of maize. *Sesamia calamistis* Hampson is the main pest of corn in a large part of Africa (ONUKOGU, 1984; SHANOWER *et al.*, 1993a), *Sesamia botanephaga* Tams and Bowden causes such extensive losses in second season maize (August-November) in the rain forest zone of Ghana that farmers are reluctant to plant maize during that season (SHANOWER *et al.*, 1993b), and *Sesamia nonagrioides* Lef. causes important losses in Morocco (LESPÈS and JOURDAN, 1940) and Southern Europe (ALFARO, 1955; ANGLADE, 1961a; PROTA, 1965; TSITSIPIS *et al.*, 1984). In Greece, late corn is heavily infested, and losses of 80-100% are not unusual (TSITSIPIS *et al.*, 1987). In Israel, *S. nonagrioides* increased its populations in the period 1969-1979, to become the main pest (MELAMED-MADJAR and TAM, 1980). Other *Sesamia* species cause heavy damages in sorghum (*Sesamia cretica* Led.; ANGLADE, 1972), and sugar cane (18% of yield losses in Papua New Guinea are due to *Sesamia grisescens* Walker; KUNIATA and SWEET, 1994).

Designing effective means of control needs a detailed knowledge of the population dynamics of these pests. The seasonal ecology of *Sesamia nonagrioides* has been studied in Sardinia (PROTA, 1965), Greece (TSITSIPIS *et al.*, 1984; TSITSIPIS and ALEXANDRI, 1989), Southern France (GILLYBOEUF *et al.*, 1994) and Portugal (FIGUEIREDO and ARAUJO, 1990). In Spain *S. nonagrioides* and specially *O. nubilalis* cause important losses in Aragón and Catalonia (NE Spain), where maize is an extensive crop (ALFARO, 1955; GIMENO and PERDIGUER, 1993a). In Galicia (NW Spain) maize is cultivated mainly in small plots as a source of animal food, without any kind of pest control (MALVAR *et al.*, 1993). In these plots larvae of *O. nubilalis* are common, but *Sesamia nonagrioides* is now the main pest. The only information on these species in NW Spain was reported by DELGADO DE TORRES (1929) and URQUIJO (1939). The last author found in 1934

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that *S. nonagrioides* was present in 24.9±3.1% of plants (±SE, range: 0-70%, n=40 plots) whereas *O. nubilalis* in 18.0±25.1 % (range: 0-90%, n=40 plots). Unfortunately there is no information on date of sampling and the number of plants examined.

Here we present a seven-year monitoring of the incidence of corn borers in harvested plants at one locality. In addition, we show the seasonal changes of the larval population at 3-4 localities during three years. These data allow us to determine the number of generations and the time of the year when damage is most intense. Results can be used to design control methods against these pests, based fundamentally on cultural control (such as the alteration of sowing dates; CARTEA *et al.*, 1994) and the selection of varieties of maize resistant to the borers.

MATERIALS AND METHODS

To monitor the incidence of corn borers, we counted the number of larvae in maize stems, at different times before, during and after harvest. This monitoring was carried out by dissecting the stems collected from several sample sites located at Pontevedra and A Coruña provinces (NW Spain, Fig. 1).

The abundance at harvest of both species was evaluated from 1990 until 1996 at the plots of the Misión Biológica de Galicia (MBG), located at Salcedo (Pontevedra). In 1993 we also evaluated the abundance of both species in plots located at Mabegondo, Canicouva, Valga, and three plots at Pontecaldelas: Espiñeira, Parada and Cuñas (see Fig. 1).

In 1994 we started a seasonal analysis of the abundance of corn borer larvae at four locations (Arbo, Barrantes, Cuñas (Pontecaldelas) and Pontevedra), which continued on three plots in 1995 (the same locations excepting Arbo), and four plots in 1996 (the same as in 1995 and Valongo). From preliminary samples made in 1993 (N=1572 plants) we calculated that a sample size of 38-60 plants was enough to estimate the abundance of *S. nonagrioides* with an error of 15% of the mean. For this reason we proceeded to the weekly collection of 50 stems at random (100 in the first samplings), that were directly dissected in the field. We recorded the number of caterpillars, groups of very young larvae and pupae of both species. This seasonal analysis was made on plots planted with the same hybrid of maize (DMB 15-70), a cultivar chosen because it is the most used of its cycle of maturation in NW Spain, and it has a susceptible line in its formula (furthermore it has been codeveloped at MBG, and therefore might be produced by ourselves even if it disappears as a commercial variety). Any difference between locations in borer attack could not be attributed to genetic variability in the host plants.

The period of flight was studied by placing light and pheromone traps at MBG plots. In 1991 we tested pheromone traps obtained from Traptest® by Agrimont Enichem (2 traps for *S. nonagrioides*, 2 for *S. cretica* and 6 for *O. nubilalis*). These traps did not provide good results and were no longer used. In 1992 two light traps were used, but they captured very few adult moths. In 1993-96 pheromones were obtained from the Escola Técnica Superior d'Enginyeria Agraria de Lleida (NE Spain) (see RIBA *et al.*, 1994). In

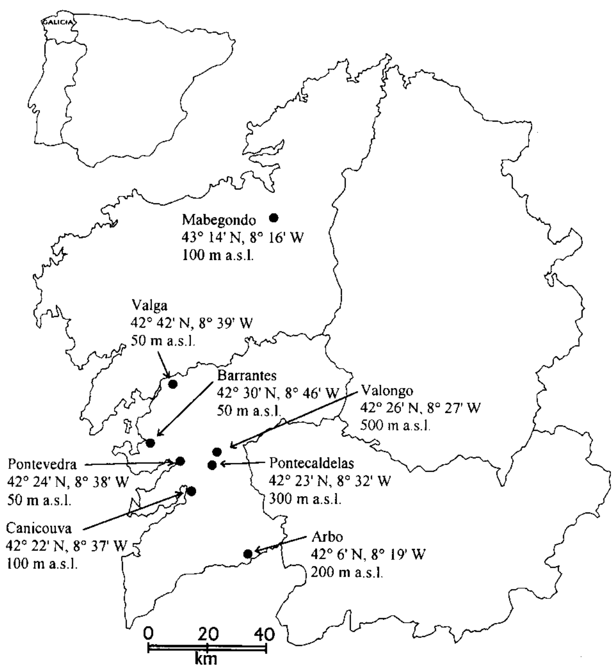

FIGURE 1 - Map of Galicia (NW Spain), showing the aproximate situation of sampled locations.

1993, we used 10 water traps (a plastic bottle with water and two lateral holes) with *S. nonagrioides* pheromone. In 1994 we used 16 water traps and four funnel traps (a cylinder with one small entrance at its top) with *S. nonagrioides* pheromone. In 1995 we tested three trap types: 9 water traps (4 for *S. nonagrioides* and 5 for *O. nubilalis*), 4 funnel traps (2 per species) and 6 conic traps (3 per species; described by ZANDIGIACOMO *et al.*, 1993). Conic traps turned out to be the most effective, and were the only kind used in 1996: three conic traps for *S. nonagrioides* and two for *O. nubilalis* were situated at MBG plots, and one trap per species at Valongo, Cuñas and Barrantes. Phenologic events in the flight curves were related to the degree-days accumulated from first January, using 10 °C as the minimum threshold temperature (GIMENO and PERDIGUER, 1993b). Mean daily temperatures were obtained from the station located at MBG plots and the station of Ribadumia, at 1 km of distance from our Barrantes plot.

RESULTS

Abundance of S. nonagrioides *and* O. nubilalis *larvae at harvest in several locations*

There was a marked variability in the infestation rate of different plots in the period 1993-1996 (Table 1), although the maximum density of both species was usually found in the same plot. The incidence of corn borers was specially high in the coastal localities (Fig. 1). The correlation between the density of both species is positive (r= 0.59, d.f.= 17, p= 0.009),

TABLE 1 - *Abundance of larvae of S. nonagrioides and O. nubilalis in maize fields at harvest (November). Cultivars used were EVA in 1993 and DMB 15-70 in 1994-96. N indicates the number of plants dissected.*

		Larvae per plant	
Locality	N	*S. nonagrioides*	*O. nubilalis*
1993			
Canicouva	250	1.48	0.48
Valga	300	1.34	0.05
Pontevedra	500	0.51	0.04
Cuñas	300	0.41	0.07
Espiñeira	400	0.26	0.05
Mabegondo	270	0.08	0.09
Parada	410	0.05	0.11
1994			
Barrantes	1000	1.53	0.68
Pontevedra	1000	0.47	0.17
Arbo	1000	0.26	0.24
Cuñas	1000	0.14	0.13
1995			
Barrantes	100	1.93	0.60
Pontevedra	100	1.75	0.21
Cuñas	100	0.17	0.03
1996			
Barrantes	100	3.70	0.27
Pontevedra	100	2.07	0.44
Cuñas	100	0.33	0.08
Valongo	100	0.07	0.00

which suggests that their abundance could be regulated by similar factors.

At the MBG plots, the main pest was *S. nonagrioides* from 1990 to 1996 (Table 2), and it caused considerable damage to stems and in a lesser degree to ears, while *O. nubilalis* larvae where found more frequently on ears. Natural infestation reached the level of one larva of *S. nonagrioides* per plant at harvest only in three years (1991, 1995 and 1996). In 1992 one plot reached also this level, but it was close to another plot that was artificially infested with 40 eggs of *S. nonagrioides* per plant. The increase in abundance of larvae of *S. nonagrioides* was probably due to the artificial infestation, because the abundance of *O. nubilalis* was very similar in this plot and the control plot (Table 2). The abundance of both species at MBG is highly variable between years, but there is a tendency for a positive correlation between them (r= 0.73, d.f.= 6, p= 0.062) (the second plot of 1992 has been excluded).

TABLE 2 - *Abundance of larvae of S. nonagrioides and O. nubilalis in maize plots at the Misión Biológica de Galicia, Pontevedra, NW Spain. In 1990-92, results refer to a mixture of maize varieties, in 1993 EVA variety was used and in 1994-1996 DMB 15-70 variety was sown. N indicates the number of plants dissected.*

		Larvae per plant	
Year	N	*S. nonagrioides*	*O. nubilalis*
1990	576	0.83	0.05
1991	372	1.58	0.08
1992	623	0.58	0.02
1992*	320	1.72	0.02
1993	500	0.51	0.04
1994	1000	0.47	0.17
1995	100	1.75	0.21
1996	100	2.07	0.44

* This plot was adjacent to a plot where an artificial infestation with 40 eggs of *S. nonagrioides* per plant was made.

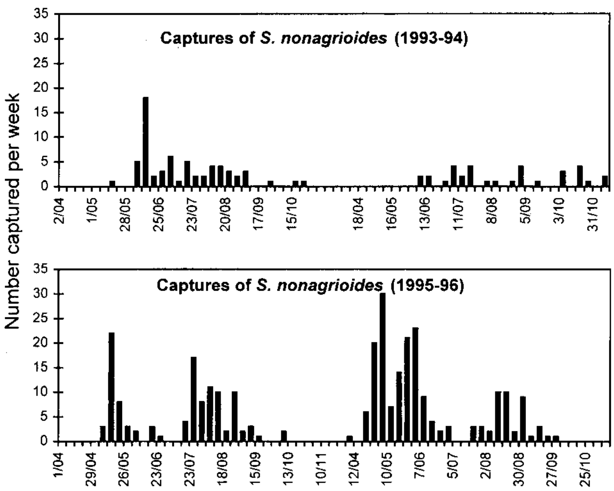

FIGURE 2 - Captures of adult *S. nonagrioides* during 1993-96 at Pontevedra (MBG plot) in pheromone traps. See Methods for the number of traps per year.

Abundance of adults

The number of adults of *S. nonagrioides* captured by means of pheromone traps in 1993-1994 was very small (Fig. 2). In 1995 and 1996 there were two clear periods of flight, suggesting the existence of two generations. Data for 1993-94 are unclear, probably because traps had low effectivity and/or because population density of this species was specially low in both years (see Table 2). Figure 3 presents the flight curves for *O. nubilalis* at MBG in 1995-96, showing a small peak in May and a clear maximum in August,

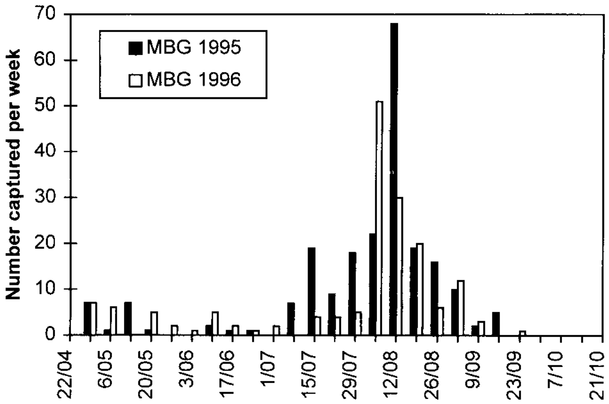

FIGURE 3 - Captures of adult *O. nubilalis* at Pontevedra (MBG plot) in 1995-96 by means of 10 (1995) and 2 (1996) pheromone traps.

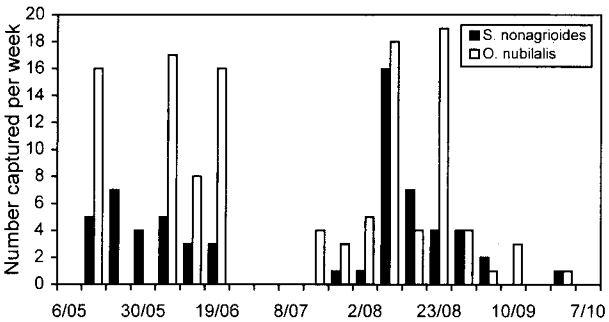

FIGURE 4 - Captures of adult *S. nonagrioides* and *O. nubilalis* in 1996 at Barrantes plot by means of one pheromone trap per species.

and suggesting also the existence of two generations per year. The same occurred at Barrantes (Fig. 4). The first flight of *S. nonagrioides* had a peak after 199-395 degree-days and the second after 1023-1220 (Table 3). These values are very similar to the values found by M. Eizaguirre (GIMENO and PERDIGUER, 1993b) for NE Spain: 312 and 1062 degree-days.

At Cuñas (Pontecealdelas) plot, pheromone traps captured very few lepidopterans (only one individual of *S. nonagrioides* and 15 of *O. nubilalis*), whereas at Valongo no adults of corn borers were captured. Pheromone traps of *S. nonagrioides* captured many *Mythimna unipuncta* adults (e.g. in 1995 at MBG only 112 individuals of *S. nonagrioides* were captured versus 322 individuals of *M. unipuncta*). Traps were therefore not selective.

Seasonal abundance of larvae of S. nonagrioides *and* O. nubilalis *in 1994-1996*

In all years, the plot at Barrantes had the highest levels of damage by corn borers. Nevertheless, borer density changed conspicuously between years and locations (Fig. 5 and 7). In 1994 larvae of *S. nonagrioides* were relatively rare in all plots excepting Barrantes, where they reached one larva per plant only by September (Fig. 5). Damages produced by both species in 1995 were considerable. All sampled plants were damaged at harvest at Pontevedra and Barrantes, while damage remained at 30% at Cuñas.

In 1995 larvae of *S. nonagrioides* were extremely abundant at Barrantes and Pontevedra, but at Cuñas (Pontecaldelas) showed similar low densities as in 1994 (Fig. 5). At Pontevedra maize was present in the field at the moment of flight of the first generation of *S. nonagrioides*, and probably for this reason small larvae were abundant in young plants during June. However, the levels of infestation in July were low (Figure 5). The greatest density of larvae was found on September 8, with 2.3 larvae/plant, and the maximum of pupae was observed in July-August. At Barrantes plot, the number of larvae of *S. nonagrioides* per plant reached a maximum of 5.3 on September 22 (Figure 5), and slowly diminished toward values of 2 larvae/plant at harvest (November). Figure 6 shows that the damage to the plants at Barrantes increased in infestation from 20% to 100% in only 2 weeks. At this plot the highest density of pupae of *S. nonagrioides* was found in August-September, while groups of very young larvae were rarely observed, probably due to the late sowing. At Cuñas results were clearly different (Figure 5). Groups of very young larvae were never observed and the number

TABLE 3 - *Number of degree days accumulated from first January and phenological events in* S. nonagrioides *and* O. nubilalis *flight curves.*

	Sesamia nonagrioides		*Ostrinia nubilalis*	
Locality	first generation peak	second generation peak	first generation peak	second generation peak
MBG 1995	375 (15 May)	1023 (28 July)	–	1132 (8 August)
MBG 1996	199 (8 May)	1094 (16 August)	–	1010 (8 August)
Barrantes 1996	395 (26 May)	1220 (12 August)	518 (9 June)	1351 (26 August)

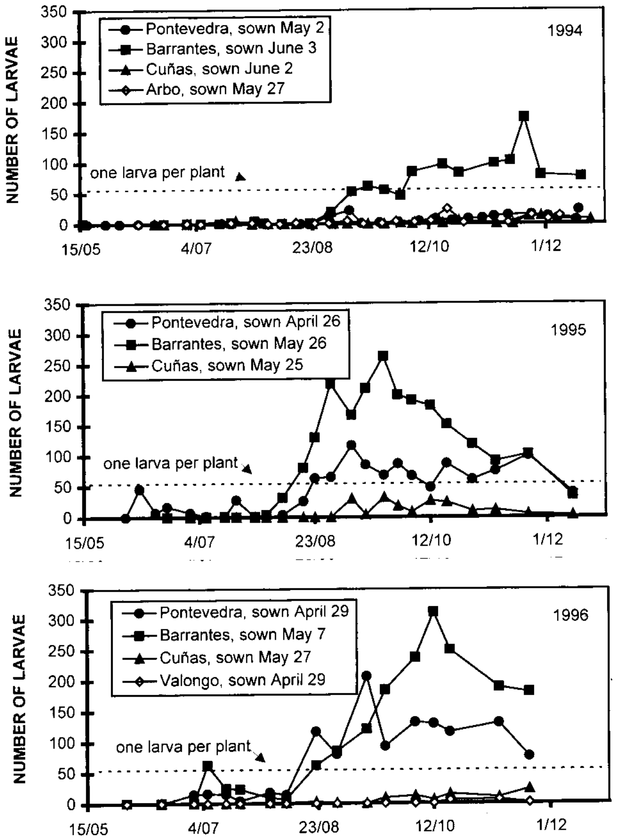

FIGURE 5 - Weekly abundance of larvae *S. nonagrioides* in 1994-1996.

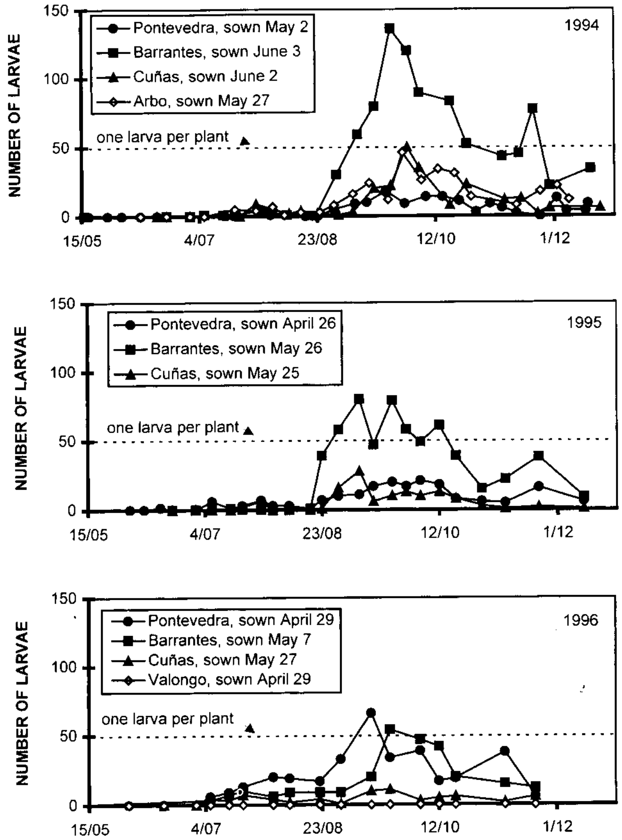

FIGURE 7 - Weekly abundance of larvae *O. nubilalis* in 1994-1996.

of larvae remained very low during the season, with a maximum of 0.6 larvae/plant on September 22.

In 1996 the degree of attack by *S. nonagrioides* was similar to 1995. Maximum density was achieved on October 9, with 6.2 larvae/plant at Barrantes. All

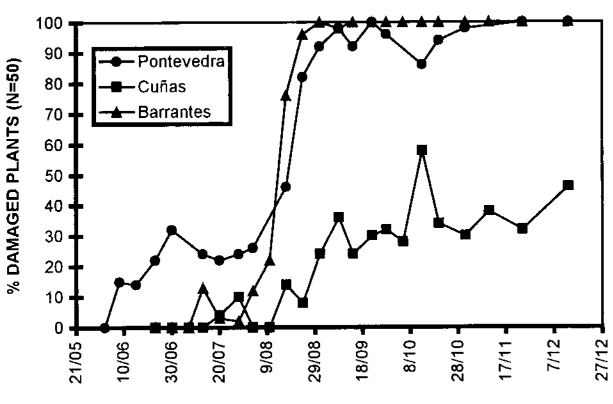

FIGURE 6 - The seasonal changes in the percentage of maize plants damaged by corn borers in 1995. Note the extremely fast grow of damage at Barrantes.

plants were damaged at harvest at Barrantes and Pontevedra, 50% at Cuñas and 7% at Valongo.

With regard to *O. nubilalis*, results are summarized in Figure 7. This species was more common in 1994 than in 1995 and 1996. Again, the highest incidence was observed on the plot of Barrantes, largely exceeding the value of one larva per plant from late August to November. In 1996 its density increased at Pontevedra.

DISCUSSION

The natural control of corn borers

There are two major properties of populations that need to be explained: differences in mean abundance between environments and variation in the number of individuals about the mean in any one environment. Density-dependent mechanisms are supposed to maintain insect populations more or less stable, but some theories support the view that climatic factors can also regulate populations if they can act in a density-dependent way (KIMMINS, 1987).

Our results indicate that *S. nonagrioides* is the main pest of maize in NW Spain, but its density is highly variable between and within locations. Biotic factors (including predation, parasitism, competition and disease) seem unable to explain this variability. First, corn borers are efectively protected from predators due to their endophytic life style. Second, parasites are very rare. We found less than 1% of parasitism in field collected larvae (only Tachinids). DELGADO DE TORRES (1929) found no parasites of *S. nonagrioides* in the same area, but URQUIJO (1939) found the Tachinid *Ceromasia senilis* as the main parasite of corn borers in Galicia, reaching 6-43% of parasitism on *O. nubilalis* and 25% (only one plot) on *S. nonagrioides* larvae. ALFARO (1972) indicated that *Lydella thompsoni* was the main Tachinid parasite in NE Spain, reaching 20% of parasitism. An egg parasitoid, *Platytelenomus busseolae*, was responsible for 13-43% of parasitism of eggs of *S. nonagrioides* in Greece (ALEXANDRI and TSITSIPIS, 1990) but an attempt to introduce it in Italy as an agent of biological control failed (LAUDONIA *et al.*, 1991), and it seems absent from NW Spain. Third, there is a positive correlation between the abundance of *O. nubilalis* and *S. nonagrioides*, which suggests that competition between larvae of both species is probably negligible (in fact in 1993-1995 we found the highest density of both species in the same plots). The reduction in interspecific competition could be due to the fact that most *O. nubilalis* larvae are found in the ears, whereas *S. nonagrioides* larvae concentrate on the stem. Finally, the incidence of disease factors was also low, although some larvae were found attacked by entomopathogenic fungi (probably *Beauveria*). The incidence of other diseases has not been studied.

Therefore, climatic factors are probably the only natural control method of pink stem borers, because temperatures below -6°C are lethal to larvae (GALICHET, 1982). Larvae of *S. nonagrioides* overwinter inside the dead plants of maize, that are usually left in the field after harvesting by most farmers. In colder areas, like SW France, this species is able to survive low winter temperatures inside the root, where temperature can be 6-7°C warmer than the air temperature (GILLYBOEUF *et al.*, 1994). In the South Atlantic coast of Europe, air temperature rarely goes below 0°C, and therefore *S. nonagrioides* larvae are able to survive in the root but also in the stem. For instance, minimum absolute temperature at MBG in the period 1990-1996 was only -4°C, and this was achieved only in a very few nights. In January-February, larvae are active, and in sunny days they are able to feed (pers. obs.). GILLYBOEUF *et al.* (1994) proposed that uprooting and exposing the stubble on the soil surface should increase mortality of larvae during winter. Unfortunately, this simple method is not useful in the mild winters of our coastal region. The abundance of *S. nonagrioides* at Pontecaldelas, Arbo and Valongo plots was very low compared to Pontevedra and Barrantes, probably due to their lower winter temperature. Therefore, at least in some areas, cold winters protect maize from attacks by the pink stem borer. In the remaining areas, systematic destruction of stems after harvest (for instance by burning them, as traditionally some farmers used to do) could contribute to the control of the populations of *S. nonagrioides* (ALFARO, 1955; 1972). Nevertheless, this method could also contribute to eliminate insect parasitoids that remain inside larvae during winter.

In most coastal locations the percentage of plants that are damaged is about 100% at harvest. Similarly, in NE Spain damages are maximum at plots near water bodies, where humidity is high and winter temperature is mild (GIMENO and PERDIGUER, 1993a). In 1934, larvae of *S. nonagrioides* were found in 33 out of 40 plots sampled in NW Spain (URQUIJO, 1939), but damage never achieved 100%. The maximum rate of damage was 70% at Cambados, a locality very near to our Barrantes plot, where the incidence of *S. nonagrioides* is maximum, reaching 100% damage in three consecutive years. This suggests that the incidence of corn borers increased in recent years, which has been related to the introduction of maize hybrids (ALFARO, 1955; TSITSIPIS *et al.*, 1984) and the increase in cultivated area, or to a greater susceptibility of first american hybrids to european borers (ORDÁS *et al.*, 1988).

The number of generations

Our results indicate that *S. nonagrioides* has two generations per year in NW Spain (see Fig. 2 and 4). This contrast with URQUIJO (1939) who indicates that this species has only one generation in most localities of NW Spain. *S. nonagrioides* has a variable number of generations in different regions. Two generations is the commonest life-cycle (DELGADO DE TORRES, 1929; ALFARO, 1972; ANGLADE, 1972; GÓMEZ DE AIZPÚRUA, 1987), but it seems to have only one generation per year at the Azores (SILVA *et al.*, 1994), three generations in NE Spain (GIMENO and PERDIGUER, 1993b), South of Portugal (FIGUEIREDO and ARAUJO, 1990), Sardinia (PROTA, 1965) and Greece (TSITSIPIS *et al.*, 1984) and four in Morocco (LESPÈS and JOURDAN, 1940). This species clearly shows a latitudinal cline in its voltinism. The existence of two generations has one important implication: the first generation does not breed on maize, because maize is sown in May-June. This determines that overwintering larvae that pupate in spring inside old maize stems give rise to adults that oviposit on other plant species. In fact, a long list of food plants is known for *S. nonagrioides* (PROTA, 1965; LAUDONIA *et al.*, 1991). After a few weeks, larvae start to attack maize even if very few adults seem to be there to lay eggs. We suspect that just a few ovipositions in the maize crop is enough to produce high levels of infestation, because larvae probably migrate from one plant to another, making them highly dispersive (URQUIJO, 1939). This fact is suggested by the finding of some *S. nonagrioides* larvae in pit-fall traps that we placed in maize fields, indicating that they could migrate along the ground. Furthermore, in 1992 the density of larvae at harvest in a plot adjacent to an "insected"plot (40 eggs of *S. nonagrioides* added per plant) was 1.7 larvae/plant, when it was only 0.6 larvae/plant in a control plot (Table 2). Female *S. nonagrioides* can lay up to 400 eggs (AL SALTI and GALICHET, 1986), or even up to 800 eggs (LESPÈS and JOURDAN, 1940). Therefore, just a small number of adults are able to colonize maize fields in a few days. The second generation has high quality food provided by maize plants, where its development is very fast, and by October, most larvae have reached the last instar. These individuals remain there until the following spring.

The adults of *S. nonagrioides* are weak fliers, which makes them very rarely captured in light traps, even in places where the species is abundant (ANGLADE, 1972; GÓMEZ DE AIZPÚRUA, 1987). In our experiments, we captured many more adults of *M. unipuncta* than *S. nonagrioides*, especially with conic traps. Given that we used pheromone of *S. nonagrioides* in these traps, both species should have similar chemicals in their sexual pheromone, which is confirmed by RIBA *et al.* (1994). The high number of *M. unipuncta* captured was probably due to the fact that this species is rather common on sweet corn fields, that were also sown at MBG plots. In this case, even a small number of larvae can reduce the economic value of sweet corn, because it is destined to human consumption.

CONCLUSIONS

The main goal of this research was to understand population dynamics of corn borers in NW Spain. We have found that *S. nonagrioides* has two periods of flight whose peaks can be predicted by degree-days models (GIMENO and PERDIGUER, 1993b). This information will be useful in a management strategy of the borers, that is addressed to the selection of resistant varieties. Resistance to *O. nubilalis* is a quantitative character that has been studied by several authors (JENNINGS *et al.*, 1974; GUTHRIE, 1989), and the economic importance of this species has prompted researches to use biological control with Trichogrammatid wasps, with some succesful results (GREATTI *et al.*, 1993; ZANDIGIACOMO and GREATTI, 1994). Nevertheless, techniques to control the pink stem borer are unsatisfactory (GIACOMETTI, 1995). Mass trapping has been done in Greece, with some promising results (MAZOMENOS and BARDAS, 1988), while ANGLADE (1961a, 1961b), MALVAR *et al.* (1993) and CARTEA *et al.* (1994) studied the existence of resistance in different maize cultivars to the second generation of *S. nonagrioides*, a first step to develop resistant varieties.

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