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BIOLOGICAL CONTROL OF THE DAMSON-HOP APHID, *PHORODON HUMULI* (*HOM.: APHIDIDAE*), USING THE LADYBEETLE *HARMONIA AXYRIDIS* (*COL.: COCCINELLIDAE*)

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The possibility of using *Harmonia axyridis* (Pallas) to control the damson-hop aphid *Phorodon humuli* (Schrank) in a dwarf-hop garden was studied in northern France in 1994 and 1995. Second and third instar larvae of *H. axyridis* were released at different stages of the aphid population increase (early, at the time of insecticide treatment threshold was exceeded and late).

In the control, the number of aphids reached 191.3 ± 30.8 per leaf at the end of June. In the plots where 50 larvae per plant were released, the best control was obtained when larvae were released early and the aphid population was approximately 20 per leaf. In this case, the average number of aphid per leaf did not exceed 54.5 ± 10.3 aphids at the end of June, which is lower than the insecticide treatment threshold of 80 aphids per leaf. Indigenous predators, especially *Adalia bipunctata* L., complemented the effect of *H. axyridis*.

KEY-WORDS: *Humulus lupulus, Phorodon humuli, Harmonia axyridis,* biological control, release, *Adalia bipunctata.*

Phorodon humuli (Schrank) is the most important pest of hop, *Humulus lupulus* L. in northern France. This aphid has an holocyclic life-cycle. The eggs are laid in autumn on *Prunus* species and hatch in March (Blackman *et al.*, 1984). Alates migrate to hop fields in May where they achieve high number in summer. The commercial value of hops can be seriously reduced by the sooty mould that grows on the honeydew produced by the aphids. Moreover, *P. humuli* is also a vector of virus diseases (Cloquemin *et al.*, 1986).

As chemical control has become ineffective against the damson-hop aphid, effectiveness of the polyphagous ladybeetle *Harmonia axyridis* Pallas as biological control agent was tested in the field in northern France in 1994 and 1995.

This paper presents the results obtained in 1994 and 1995 in a dwarf-hop garden at Laventie (Pas-de-Calais).

MATERIAL AND METHODS

The experiment was done in a 0.15 ha garden on dwarf-hops (variety: Target) trained on a 3.0 m high trellis. Plants were spaced 0.40 m apart within rows and 3.0 m between rows. There were 11 rows of hop plants in the garden.

In 1994, the predator *H. axyridis* was added to half the plants in a row. The other 20 plants in the row were not treated (control). Second and third instar larvae of the ladybird were released at the top of each plant: 20 and 40 larvae on June 3 and 23, respectively.

Aphid numbers were estimated weekly by counting the number on two leaves per plant and the number of natural enemies by counting the number present on the upper 0.70 m of each plant.

In 1995, 50 second and third instar larvae *H. axyridis* were released per plant on May 31 (early release), June 15 (when chemical control was required) and June 22 (late release), respectively.

Each plot consisted of a panel of twenty plants separated from neighbouring plots by a 2.0 m plant free-gap treated with Confidor (imidaclopride: 0.150 g/ha). A randomised block design was used, replicated 4 times. Prey and natural enemies were sampled as in the previous year except that the numbers of aphids on one leaf were counted.

RESULTS

In 1994, *H. axyridis* had no effect on aphid population development compared to the control (table 1, fig. 1). At time of the first release, the aphid population had already reached 90.4 ± 20.2 per leaf which is greater than the chemical treatment threshold of 80 aphids per leaf. At the peak in aphid density on June 16, the mean numbers of aphids per leaf were similar on the control (405.5 ± 48.8) and treated plots (432.9 ± 34.6). In both plots, the natural enemies, especially *A. bipunctata* were very effective in regulating the pest. The second release was carried out too late and no noticeable effect was observed. However, figure 1 indicates that larvae, pupae and adults of *H. axyridis* were found from June 3 to July 7.

TABLE 1

Average number of aphids per leaf (± sd) in the control plot and in the plot where H. axyridis *larvae were released in 1994*

Dates	Control	*H. axyridis*
June 3	90.4 ± 20.2	—
June 9	110.2 ± 20.2	120.3 ± 10.1
June 16	432.9 ± 34.6	405.5 ± 48.9
June 23	255.9 ± 26.5	235.7 ± 21.2
July 1	177.1 ± 15.9	137.3 ± 17.7
July 7	41.5 ± 10.3	66.0 ± 14.6
July 15	1.9 ± 0.9	1.8 ± ± 1.1
July 21	0.7 ± 0.4	0.5 ± 0.3
July 29	0.1 ± 0.1	0.1 ± 0.1
August 5	0.1 ± 0.1	0.1 ± 0.1
August 12	0.1 ± 0.1	0.0

In 1995, the aphid population in the control plot increased up to an average of 191.3 ± 30.8 per leaf on June 28. On the plants on which *H. axyridis* was released early,

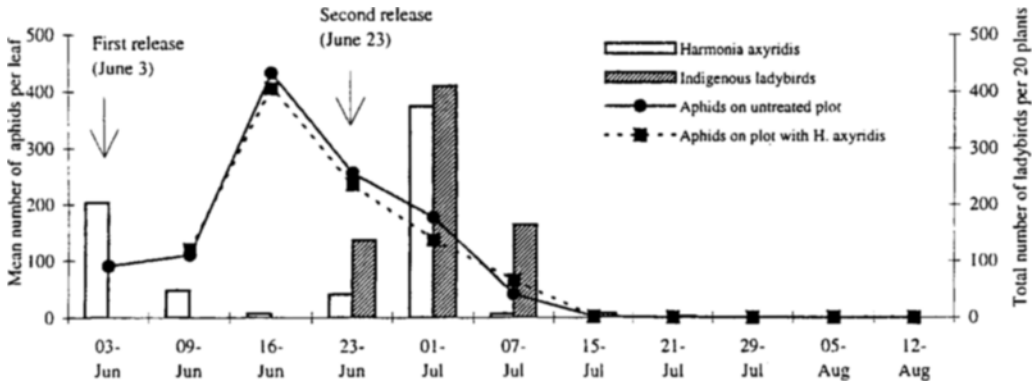

Fig. 1. Aphid population density and coccinellid numbers in 1994.

i.e., on May 3 when there were 21.0 ± 5.7 aphids/leaf, the ladybeetle kept the aphids below the chemical treatment threshold up to late June, when indigenous predators began to reduce the aphid number (table 2, fig. 2a). Coccinellidae were the most numerous predators (table 3). *A. bipunctata* and *Coccinella septempunctata* L. represented 65.9% and 1.4% of the predator complex, respectively.

The treatment in which *H. axyridis* larvae were released on June 15 was done at the time when aphid numbers were close to 80 aphids per leaf. The result also showed that *H. axyridis* reduced the aphid population before the plants were colonized by indigenous predators table 2, fig. 2b). However, damage was observed on these plots: honeydew and sooty mould.

The release on June 22 (table 2, fig. 2c) was done when the plants were heavily infested with 136.0 ± 22.0 aphids/leaf. The treatment resulted in a decrease in the aphid population in the following weeks. However, the aphids reached numbers that resulted in damage to the leaves.

DISCUSSION

The aphid *P. humilis* is the most important pest of hops. Its populations are regulated by a complex of entomophagous insects, especially coccinellids, usually too lately to prevent damage to the plants. The aim of employing biological control against this pest was to introduce an entomophagous insect which would keep the aphid populations below the economic threshold until the hop plants are colonized by indigenous coccinellids. The predator released was the Chinese ladybeetle *H. axyridis*. One release of 50 third instar larvae per plant at the end of May reduced prey abundance and prevented plant damage. This predator may also be used late in the season if greater numbers are released; however, there is then a risk of plant damage.

This ladybeetle is voracious, fecund, and has a large prey range. It has been mass reared by a French company on the eggs of *Ephestia kuhniella* Zeller (Lep., Pyralidae) for more than hundred and fifty generations (Schanderl *et al.*, 1988). Moreover, it has been shown to be effective against the rose aphid (Ferran *et al.*, 1996) and now against the hop aphid.

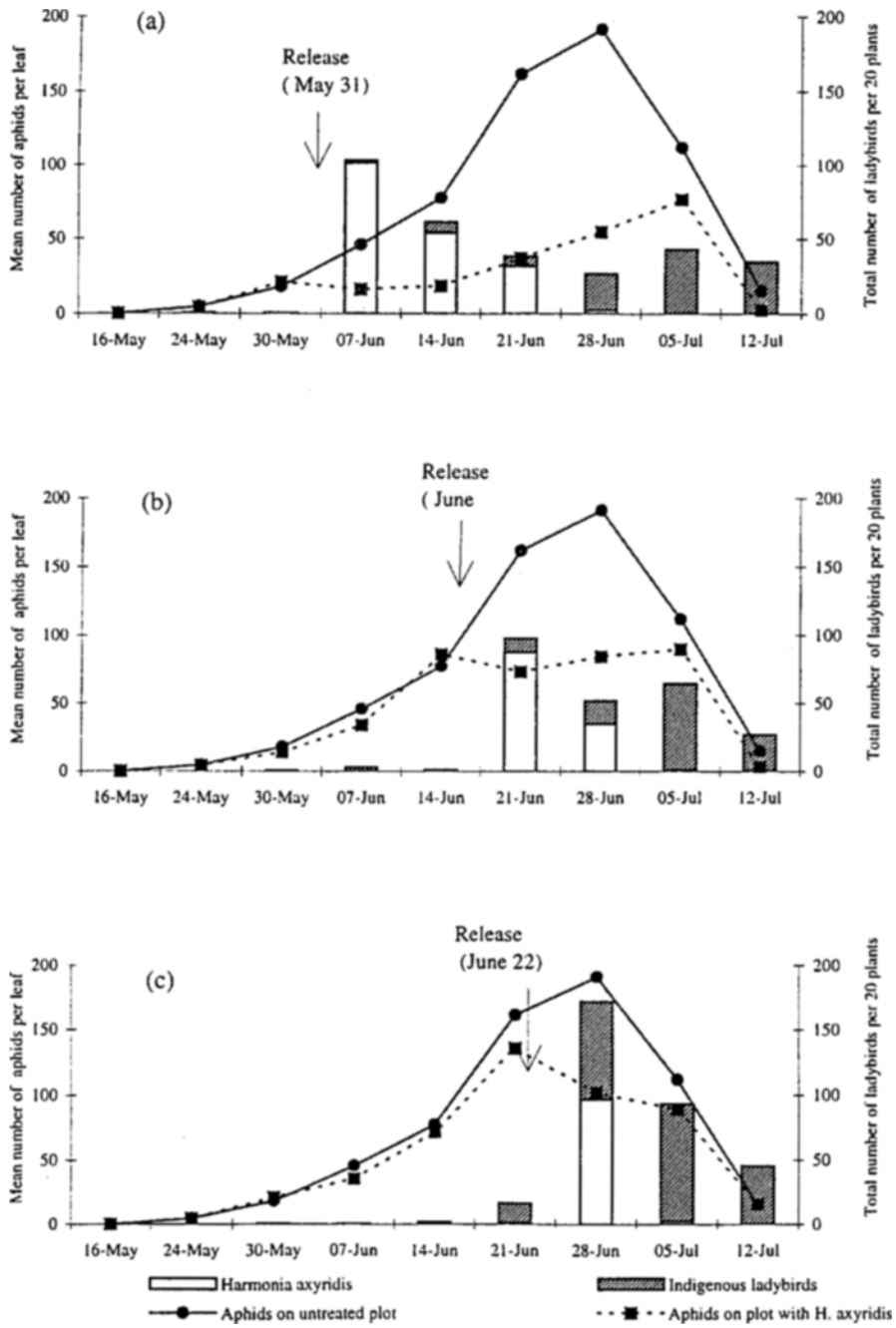

Fig. 2. Aphid population density and coccinellid numbers in 1995. (a): early release, (b): at time of chemical treatment threshold and (c): late release.

Nevertheless, the adults that develop from the released larvae leave the plants quickly as do other coccinellids, so biological control is limited to the use of larvae.

TABLE 2

Mean number of aphids per leaf (± sd) in the control plot and plots where H. axyridis *were released early (May 31), when aphid abundance reached the chemical treatment threshold (June 15) and late (June 22)*

Dates	Control	May 31	June 15	June 22
May 16	0.0	0.0	0.0	0.0
May 24	4.7 ± 1.3	4.1 ± 1.2	4.2 ± 1.2	4.4 ± 1.5
May 30	18.0 ± 6.1	21.0 ± 5.7	14.0 ± 2.9	20.9 ± 4.3
June 7	46.0 ± 11.4	16.1 ± 4.2	34.6 ± 10.6	35.7 ± 8.9
June 14	77.4 ± 15.8	18.4 ± 5.6	86.2 ± 17.8	72.0 ± 11.7
June 21	161.6 ± 30.7	36.9 ± 9.6	73.3 ± 15.6	136.0 ± 22.0
June 28	191.3 ± 30.8	54.5 ± 10.3	84.5 ± 16.6	102.1 ± 19.6
July 5	111.9 ± 23.2	76.6 ± 14.0	89.8 ± 21.6	89.3 ± 17.9
July 12	15.2 ± 5.4	2.7 ± 1.4	3.4 ± 2.2	15.6 ± 7.9

TABLE 3

Indigenous predators on control plants (%) in 1995

Adalia bipunctata L.	65.9
Coccinella septempunctata L.	16.4
Propylea quatuordecimpunctata L.	0.4
Coccinella decempunctata L.	0.4
Scymnus sp.	1.2
Cantharidae	1.3
Heteroptera larvae	1.3
Anthocoris nemoralis F.	7.5
Orius sp.	0.7
Deraeocoris ruber L.	0.4
Cecidomyiidae	2.0
Syrphidae	2.7
Chrysopidae	0.1

These preliminary results have to be confirmed and extended by further studies. The optimal time of release relative to aphid abundance and the number of larvae to be released need to be specified. In addition, the effect of fungicides on beneficial organisms have to be quantified if they are to be used in the Integrated Pest Management of hop crops.

RÉSUMÉ

La lutte biologique contre le puceron du houblon *Phorodon humuli,* (Hom., Aphididae) à l'aide de la coccinelle *Harmonia axyridis* (Col., Coccinellidae)

La possibilité de lutte biologique contre le puceron du houblon *Phorodon humuli* (Schank) avec la coccinelle *Harmonia axyridis* (Pallas), a été étudiée en 1994 et 1995 dans une houblonnière du nord

de la France. Des lâchers de larves d'*H. axyridis* de 2^{e} et 3^{e} stades larvaires ont été réalisés en fonction de la population aphidienne à 3 dates : lâcher précoce, lâcher au seuil d'intervention chimique et lâcher tardif.

Dans les parcelles témoins, où aucun lâcher de coccinelle n'a été réalisé, les pucerons aptères se sont installés à la mi-mai et se sont développés jusqu'à la fin juin (191.3 ± 30.8 pucerons par feuille). Dans les autres modalités avec lâcher de 50 larves par liane, la meilleure efficacité prédatrice a été obtenue lors du lâcher précoce réalisé sur une population d'environ 20 pucerons par feuille. Dans ce cas, la moyenne de puceron par feuille n'a pas dépassé 54.5 ± 10.3 pucerons à la fin juin, densité inférieure au seuil d'intervention chimique (80 pucerons par feuille). Les espèces auxiliaires indigènes comme la coccinelle *Adalia bipunctata* ont ensuite parachevé l'effet d'*H. axyridis*.

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