Conventional and organic cropping systems at Suitia VI: Insect populations in barley

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Abstract. In 1988, insects were sampled from tillers and by pitfall trapping in a long-term field experiment consisting of plots of organic and conventional barley. The organic crops suffered from lack of nitrogen and from draught stress, and growth and development were retarded. The stand characteristics were suggested to be the major determinants of the four-fold higher densities of *Rhopalosiphum padi* (L.) (Hom., Aphididae) and the 50 % lower densities of *Frankliniella tenuicornis* Uzel (Thys., Thripidae) in the conventional than in the organic barley. The 75 % lower catch rate of *Bembidion* spp. (Col., Carabidae) in the conventional barley was attributed to lower activity resulting from the more closed canopy and more dense crop. However, the effect of an aphicide applied to the conventional crop was confounded with the true habitat effects. The densities of *Coccinella septempunctata* L. (Col., Coccinellidae) were almost three times higher in the conventional than in the organic barley, which in turn was attributed to the higher prey (aphid) densities.

Index words: *Hordeum vulgare, Rhopalosiphum padi,* Coccinellidae, Carabidae, Staphylinidae, Araneae, *Frankliniella tenuicornis*

Introduction

One of the major problems encountered in developing organic agriculture is how to avoid excessive pest damage to the crop plants, as pesticides are not allowed. The effects of cropping systems on insect populations have been dealt with in several experimental studies (e.g. DRITSCHILO & WANNER 1980, WICHTRUP et al. 1985, HOKKANEN & HOLOPAINEN 1986, LETSCHERT 1986, BURN 1987, EL-TITI & LANDES 1988; see also POTTS & VICKERMAN 1974), many of which have concentrated on epigeal faunas, especially Carabidae (Col.). In this study, the focus was on populations of the main cereal pest, *Rhopalosiphum padi* (L.) (e.g. RAUTAPÄÄ 1976) and its predators in barley (*Hordeum vulgare* (L.)) in conventional and organic experimental systems. The object was to describe rather than explain the possible differences in aphid infestation and numbers of their epigeal polyphagous predators

(e.g. HELENIUS 1990) between the systems. Sampling was confined to just one year, 1988, of the experiment, started already in 1981 (see HANNUKKALA et al. 1990, in this issue).

Material and methods

Details of the experimental design are given by HANNUKKALA et al. (1990), in this issue. The entomological sampling was done in the rotation *a* in 1988, in which barley was grown in all the plots. The cultivar was *Pokko* Hja. The sampling was confined to a 2 m×6 m area in the centre of each of the experimental plots. The treatments (cropping systems) nested with the cropping pattern (organic or conventional) are given in Table 1. Spraying with dimethoate, at a rate of 268 g/ha, was made in the conventionally grown plots on 3rd June, when the crop was at the two-leaf stage. There were no controls for the effects of spraying, which thus became confounded by other effects of the cropping pattern.

The populations of *R. padi* were monitored, from colonization to collapse, by sampling tillers of barley between 1st June and 29th June. Incidence counts (e.g. EKBOM 1987) were made on 1st June and 7th or 8th June, and score estimation (see LOWE 1984) was used on 15th June, 22nd June and 29th June. The sample size was 20 tillers per plot, except on 29 June, when the collapse of the populations could be confirmed visually. The total number of aphids was counted in situ. At the peak density, on 22nd June, the sampled tillers were pulled up gently, and the aphids located on the stem base (c.f. WIKTELIUS 1987) below the soil surface were included.

In order to monitor the activity abundance (c.f. HALSALL & WRATTEN 1988) of epigeal predators, three pitfall traps, with a diameter of 120 mm, were placed in a row, at 2 m intervals in each plot. The medium was water with detergent added. The traps were emptied once a week from 25th May to 29th June. The numbers of carabids (Col., Carabidae), staphylinids (Col., Staphylinidae), spiders (Araneae), adults of *Coccinella septempunctata* L. and coccinellid larvae (Col., Coccinellidae), and the total numbers of aphids in the catch were counted.

On 29th June two quadrates of 0.092 m² per plot were sampled for absolute densities of coccinellid adults, larvae and pupae. On 11th July, 20 panicles per plot were sampled to determine the infestation level of *Frankliniella tenuicornis* (Uzel) (Thysanoptera, Thripidae). The adults and larvae of the thrips were flotated from the panicles by submerging the samples in water (ca. 20°C) containing detergent for one day, after which the dead animals were decanted and counted. The dry matter weight of the panicles was determined.

Standard analysis of variance procedures were used for testing statistical significance of treatment effects. The model was described by HANNUKKALA et al. (1990). The notation S.E.

Table 1. Treatments representing the different systems in the conventional and organic cropping. The treatments were nested within the cropping patterns. There were three blocks. For details, see HANNUKKALA et al. (1990).

	Crop in 1988	Preceding crop in 1987
Conventional:		
1. Monoculture	barley	barley
2. Cereal rotation	»	»
3. Diverse field crop rotation	»	turnip rape
4. Ley rotation	»	oats
Organic:		
5. Composted green manure	barley + clover undersown	oats + faba bean mixed crop
6. Green manure	»	»
7. Composted slurry	barley	»
8. Slurry	»	»

is used for standard errors of means, and these are given as mean ±S.E.

Results and discussion

R. padi *in barley*

The conventional barley was colonized quicker by *R. padi,* i.e. the proportion of infested tillers grew faster, and the populations reached peak densities four times higher in this as compared to the organic barley (Table 2). The reasons for the obvious failure of the aphicide in controlling the aphids are not known. There were no significant differences in aphid densities between the systems in conventional cropping, or between the systems in organic cropping.

The mild infestation in organic cropping is evidently related to the fact that the growth of barley was very poor. The above-ground biomass of barley at about the time (4th July) of peak aphid density was only 18.9 % of that in the conventional farming (KORVA & VARIS 1990, in this issue). The canopies were not closed, and the growth stage was 31 (1st node visible; TOTTMAN et al. 1979), while the canopies of the conventionally grown barley crops were closed, and the growth stage was 53 (one-fourth of the ear emerged).

Nitrogen deficiency, which was especially pronounced early in the season during the aphid period and led to draught stress due to insufficient root growth, was obviously one of the major reasons for the poor performance of the organic barley (KORVA & VARIS 1990). The nitrogen content and metabolism in host plants plays an important role in the growth and development of herbivorous insects and their populations (MATTSON 1980), and it is realistic to assume that this nitrogen/host plant/herbivore relationship also contributed to the results presented here.

By the end of June, practically all aphids had disappeared from the crops; small colonies were encountered occasionally, most of which were in the organic barley. The rapid development and degeneration of the aphid populations was caused by exceptionally hot weather conditions combined with exceptionally high rates of colonization by alate migrants.

The numbers of aphids in pitfall traps were high (Table 3), confirming the finding of SOPP et al. (1987) and WIKTELIUS (1989) that cereal aphids are active on the soil surface. The 27-fold greater catch in the conventional as opposed to the organic farming during the collapse period is best explained by the larger peak populations on stems combined with the

Table 2. Incidence (proportion of infested tillers) and mean density (numbers/tiller) of *Rhopalosiphum padi* and mean density of *Frankliniella tenuicornis* (numbers/panicle) in organic and conventional barley. (±S.E.)

		Date	Organic	Conventional	p
R. padi	incidence	1/6	0.1 ±0.03	0.4 ± 0.03	0.04
		7—8/6	0.2 ±0.05	0.4 ± 0.05	0.2
		22/6	1	1	
	mean	22/6	19.6 ±2.38	88.42 ±15.98	0.03
F. tenuicornis	mean	11/7	28.7 ±2.23	16.45 ± 1.26	0.02

Table 3. Mean catch of *Rhopalosiphum padi* in pitfall traps (numbers/trap/day) in organic and conventional barley. (±S.E.)

Trapping period	Organic	Conventional	p
15—22 June	15.0 ±1.89	269.3 ± 19.06	<0.001
22—29 June	38.1 ±6.05	1 025.6 ±129.32	0.05

higher density of stems (Korva & Varis 1990) in the conventional farming, which resulted in a difference in densities per unit area that was relatively larger than the difference in densites per stem (tiller).

Epigeal predators

The pitfall catches did not reveal many statistically significant differences in the activity abundances of epigeal predators between organic and conventional cropping (Table 4). The catch rate of *Bembidion* spp. was four times higher in the organic than in the conventional barley. As with most of the other taxa, the exception being spiders, the catch rates were highest during the first week of trapping. However, in the case of *Bembidion* spp. the first week's catch was 1.5 times higher in the organic than in the conventional barley, but thereafter the ratio increased to 16.3 ($p < 0.001$, chi-square test). This was not observed with the other taxa. One explanation for the sharp reduction in catch rate after the first week in the conventional barley would be an increased mortality or decreased activity because of the spraying with dimethoate.

An alternative explanation is that the reduction in the catch rate in the conventional barley was caused by some changes in the crop habitat; the two types of habitat, conventional and organic, became increasingly different over the course of time. The habitat charac-

teristics affecting activity and diffuse movement patterns, rather than the population density of the *Bembidion* spp., such as lower prey density, lower tiller density and more sun-exposed soil surface in the organic farming, may have contributed most to the difference between conventional and organic barley in the catch rates of the beetles. In the plot experiments, the plot boundaries apparently were not the population boundaries.

It has been suggested that *Bembidion* are important predators of *R. padi* early in the season, and that they may even prevent outbreaks if the immigration rate of aphid colonists is moderate (Ekbom & Wiktelius 1985, Chiverton 1987, Helenius 1990). In the study year, however, the initial infestation was high, and it is doubtful that the *Bembidion* spp. could have had anything but a minor contribution to the lower peak densities of aphids in the organic as compared to the conventional barley.

Within organic cropping, the catch rate of *Bembidion* spp. in the system given uncomposted green manure (treatment 6) was significantly lower than in the other systems ($p = 0.005$) (Fig. 1). The reasons for this can only be speculated; it seems as if catches were influenced by both the type and the management of the organic fertiliser.

There was an indication of a higher catch rate of *Pterostichus* spp. in the conventional than in the organic barley. The difference per-

Table 4. Mean catch of carabids, staphylinids, spiders, *Coccinella septempunctata* and coccinellid larvae in pitfall traps (numbers/trap/day) during 25th May−29th June in organic and conventional barley. (±S.E.)

	Organic	Conventional	p
Carabidae			
Bembidion spp.	0.17 ± 0.018	0.04 ± 0.012	0.005
Trechus spp.	0.05 ± 0.011	0.09 ± 0.010	0.3
Clivina fossor (L.)	0.01 ± 0.004	0.03 ± 0.011	0.6
Harpalus spp.	0.02 ± 0.003	0.02 ± 0.003	0.8
Pterostichus spp.	0.07 ± 0.012	0.16 ± 0.030	0.06
Others	0.01 ± 0.003	0.02 ± 0.003	0.1
Staphylinidae	0.26 ± 0.019	0.28 ± 0.038	0.4
Araneae	0.47 ± 0.048	0.55 ± 0.159	0.7
C. septempunctata adults	0.05 ± 0.008	0.12 ± 0.024	0.2
Coccinellid larvae	0.06 ± 0.009	0.24 ± 0.045	0.09

sisted after the application of dimethoate. The result may be explained by habitat preferences, as in the case of *Bembidion* spp., but aggregation to the plots of high prey density is also possible (c.f. BRYAN & WRATTEN 1984). The *Pterostichus* are large, very mobile carabids whose peak activity period overlaps with the peak and collapse phases of *R. padi* (e.g. HELENIUS 1990).

In the conventional cropping, the catch rate of staphylinids was significantly higher (0.44 ± 0.042 specimens/trap/day) in the ley rotation (treatment 4) than in the monoculture (0.20 ± 0.053, treatment 1). The lowest mean catch was in the organic cropping in the plots manured with uncomposted slurry (0.20 ± 0.014, treatment 8). Many species of staphylinids are saprophages; thus, the numbers should be related to amount of decomposing material in soil.

Coccinellids

The sampling for coccinellid densities was done just after the collapse of the aphid populations. According to assessment based on visual observations, the coccinellid densities at that time were at their maximum. In the conventional cropping, the mean density of adult *C. septempunctata* was 48.9 per m², but in the organic cropping, only 18.1 per m² ($p < 0.05$, t-test). The mean densities of coccinellid larvae were 21.7 and 3.6 per m², respectively. Altogether only nine pupae were sampled, all in the conventionally grown barley. The most obvious explanation for the pattern was aggregation of the predators to the patches of high prey density, i.e. plots of conventional barley.

Thrips

The results concerning *F. tenuicornis* were from just one sampling, and do not allow definite conclusions. However, at the time of sampling, the population densities of *F. tenuicornis* were almost twice as high in the ears of barley in the organic cropping than in the
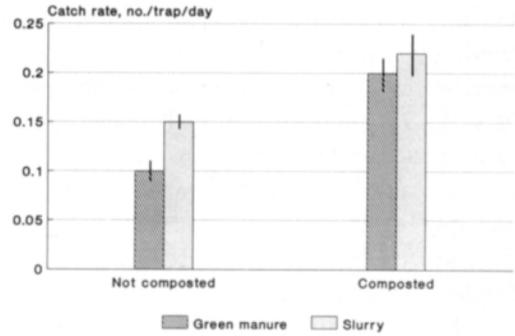

Fig. 1. Catch rates (number of specimens/trap/day) of *Bembidion* spp. in pitfall trapping in the organic barley. (Vertical bars: ± S.E.)

conventional cropping (Table 2). Relative to the biomass of panicles, the infestation was even more severe in the organic barley, as the ears weighed only 33.3 % of those in the conventional barley ($p = 0.002$) (Fig. 2). At sampling, the ear emergence was only 70 % in the organic barley, whereas in the conventional barley it was 100 %. Host plant and habitat characteristics may explain the difference between the cropping alternatives. *F. tenuicornis* causes total and partial white heads in cereals (REUTER 1901, KANERVO 1950), but the damage was not assessed in this study.

The findings of this study cannot be generalized to make a comparison of organic vs. conventional cropping. They are useful in
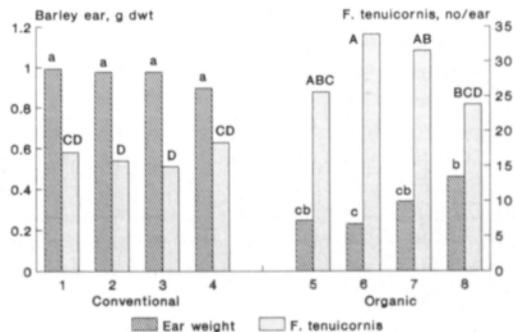

Fig. 2. The means of ear weight of barley and mean densities of the thrips *F. tenuicornis* (adults and larvae) on the ears on 29th June. The numbers 1—8 on the x-axis denote the treatments as explained in Table 1. Statistically significant differences are indicated by letters above the bars (HSD-tests).

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showing how the host plant and stand characteristics, varying along with the input levels, may be key factors in determining the numbers of pests and their natural enemies. Concerning the most mobile arthropods, plot experiments allow for choice between the habitat patches. For example, in order to determine the effects of agronomical practices on carabids, comparisons between entire fields or, preferably, farms should be made in the long term.

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SELOSTUS

Suitian viljelyjärjestelmät
VI: Hyönteispopulaatiot ohrakasvustoissa

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Suitian koetilalla Uudellamaalla järjestetyssä kenttä-
kokeessa vertailtiin vuosina 1982—1988 kahdeksaa luon-
nonmukaista ja tavanomaista viljelyjärjestelmää. Viimei-
senä koevuonna 1988 tehtiin hyönteishavainnot kaikissa
kierroissa mukana olleesta Pokko Hja -ohrasta. Tuomi-
kirvojen *Rhopalosiphum padi* runsaus arvioitiin viikoit-
taisin verso-otannoin. Epigeeisen petoniveljalkaislajiston
aktiivisuusrunsautta selvitettiin kuoppa-ansapyynnillä.
Leppäpirkkojen *Coccinella septempunctata* runsaudesta
tehtiin kesäkuun lopulla näytealaotanta, ja heinäkuun
puolivälissä otettiin tähkänäytteet kauraripsiäisen *Frank-
liniella tenuicornis* runsauden arvioimiseksi.

Vuosi oli poikkeuksellinen ns. kirvavuosi, ja kasvus-
tojen alkusaastunta oli sekä kotimaisten että kaukolevin-
tänä maahan saapuneiden kolonistien runsauden vuoksi
voimakas. Dimetoaatilla suoritetusta torjuntaruiskutuk-
sesta huolimatta tuomikirvan populaatioiden runsaushuip-
pu tavanomaisessa viljelyssä oli keskimäärin 88 yksi-
löä/verso, mutta luonnonmukaisessa viljelyssä, jossa tor-
juntaa ei tehty, huippu oli vain neljännes tästä, keskimää-
rin 20 yksilöä/verso. Ero selittyi ensisijaisesti sillä, että
luonnonmukaisten järjestelmien ohrakasvustot kärsivät
typen ja veden puutteesta juuri kirvapopulaatioiden eks-
ponentiaalisen kasvuvaiheen aikana: tuomikirvat eivät
kyenneet tehokkaasti lisääntymään heikosti kasvavissa
luonnonmukaisissa ruuduissa. Tavanomaisessa viljelys-
sä tehdyn torjuntaruiskutuksen huono teho johtui ilmei-
simmin siitä, että tehoaine ei tavoittanut ruiskutusajan-
kohtana pääosin juurenniskaan asettuneita kirvoja.

Kauraripsiäiset olivat noin kaksi kertaa runsaampia
luonnonmukaisesti kuin tavanomaisesti viljellyn ohran
tähkissä. Fytomassayksikköä kohden ero oli vielä suu-
rempi, sillä luonnonmukaisesti viljellyn ohran tähkäpai-
no otanta-ajankohtana oli vain 33 % tavanomaisesti vil-
jellyn ohran tähkäpainosta.

Kuoppa-ansapyynnit eivät osoittaneet suuria ruutujen
välisiä eroja maakiitäjäisten (Coleoptera, Carabidae), ly-
hytsiipisten (Col., Staphylinidae) tai hämähäkkien (Ara-
neae) esiintymisessä. Hyrräkiitäjäisten *Bembidion* spp. ak-
tiivisuusrunsaus oli 25 % alempi tavanomaisesti kuin
luonnonmukaisesti viljellyissä kasvustoissa. Mahdollisia
selittäviä tekijöitä olivat habitaattieroavuudet (tavanomai-
nen ohrakasvusto oli ns. normaali, mutta luonnonmukai-
nen oli harva, matalakasvuinen ja sulkeutumaton) sekä
eroavuudet pääasiallisen saaliseläimen, tuomikirvan mää-
rissä. Voimakas kirvasaastunta keräsi tavanomaiseen oh-
raan leppäpirkkoja lähes kolme kertaa suuremman mää-
rän kuin mitä tavattiin luonnonmukaisesti viljellystä oh-
rasta.

Tutkimusvuonna olivat hyönteisten kannalta merkit-
tävimmät erot tavanomaisesti ja luonnonmukaisesti vil-
jeltyjen kasvustojen välillä ensisijaisesti habitaatin raken-
teeseen sekä isäntäkasvin, ohran vesi- ja typpitaloudesta
riippuneeseen laatuun liittyviä. Tuloksia ei voida yleis-
tää toisenlaisiin kasvuoloihin tai kokonaisten tilojen mit-
takaavaan LUOMU- ja tavanomaisen viljelyn vertailussa.