OILB/SROP

GROUPE DE TRAVAIL "LUTTE INTEGREE EN CEREALES"

Réunion de WAGENINGEN (Pays-Bas) 1-2 mars 1984.

IOBC/WPRS

Working group "INTEGRATED CONTROL OF CEREAL PESTS"

Meeting at WAGENINGEN (Netherlands) 1-2 march 1984.

SOMMAIRE

INTRODUCTION

The meeting of the 1st and 2nd march 1984, at Wageningen corresponded with the 10th anniversary of our IOBC working group "Integrated control in cereals". Therefore it has been a summary of the last ten years of research on animal pests of cereals and specially aphids as well as the start of new works.

. The good quality of the research done by the different subgroups : "economic strategies" (formerly "crop losses"), "host plant interaction" (formerly "resistance"), "crop manipulation" (formerly "soil pests") and "ecology", allowed us to make considerable progress in the knowledge of the cereal aphids and their associated fauna and flora. The main topics are :

- aphid depredation on small grains : the mechanisms and consequences are now better known. The influence of aphids on yield does no only differ with the level of infestation at a given time but also with the phenological stage of the infested plant, the expected yield and the component of yield which is taken into consideration. Consequently more than one economic threshold have to be recommended depending on the above conditions.

- role of the main natural enemies of cereal aphids : parasitoïds, entomophthorales, specific predators and polyphagous predators. For some enemies it is now possible to study really population dynamics and establish aphids/ennemy models allowing to quantify the contributions of these ennemies to the aphid mortality. The effect of insecticides on predatory soil fauna was also largely studied.

- finally the relationships of cereal aphids with their host plants, so far partially known, are intensively studied besides the varietal resistance.

. According to these results it has been decided to concentrate the efforts on the following points :

- better knowledge of the role of M. dirhodum and R. padi on the cereal yield (former studies were mainly done on S. avenae), and more generally quantification of the early incidence of aphids (before heading);

- further studies on the biology of the natural enemies of cereal aphids : growth models in order to quantify their role on aphid populations;

- solving the difficult problem of predator sampling;

- effect of agricultural techniques on aphid population dynamics;

- continuing to study aphid-host plant relationships.

The practical use of these studies will allow to establish a complete system of integrated protection of cereals, limiting the insecticide spray to its minimum requirement for the benefit of agriculture.

I would like to end up this brief introduction in pointing out the fact that the good progress of our group during ten years has only been possible thanks to the dedication of convenors of the group and different subgroups : F. SCHUTTE, H. SUTER, G. LATTEUR, K. GEORGE, R. BARDNER and Th. BASEDOW. Many thanks to them and more generally to all members of the group whose work is partly summarised in this volume. Finally a special thank for G.W. ANKERSMIT for the good organisation of the meeting at Wageningen.

The convenor

C.A. DEDRYVER

Liste des Participants

ANKERSMIT, G.W. - Laboratorium voor Entomologie,
Binnenhaven 7,
6709 PD Wageningen,
Nederland.

BARDNER, R. - Rothamsted experimental Station,
Harpenden,
Herts,
U.K.

BASEDOW, Th. - BBA,
Schlosskoppelweg 8,
D-2305 Heikendorf-Kitzeberg,
B.R.D.

BODE, E. - Biologische Bundesanstalt,
Abt. für Pflantzenschutzmittel und Anwendungstechnik,
Messeweg 11/12,
3300 Braunschweig,
B.R.D.

BURN, A.J. - Department of applied biology,
University of Cambridge,
Pembrokestr.,
Cambridge CB2 3DX,
U.K.

CASTAÑERA, P. - Depto. Proteccion vegetal,
I.N.I.A. - C.R.I.D.A. -06,
Carretera,
La Coruna Km 7,
Appartado 8. III,
Madrid,
Espana.

DE CLERCQ, R. - Burg. van Gansberghelaan 96,
9220 Merelbeke,
België.

CHANSIGAUD - Station de Zoologie,
I.N.R.A.,
Route St.-Cyr,
78000 Versailles,
France.

DEDRYVER C.A. - I.N.R.A.,
Laboratoire de Zoologie,
Domaine de la Motte-Au-Vicomte
35650 Le Rheu,
France.

DEWAR, A.M. - Brooms Barn Experimental Station,
Highham,
Bury St. Edmunds,
Suffolk,
U.K.

GARDNER, S. - Laboratorium voor Entomologie,
Binnenhaven 7,
6709 PD Wageningen,
Nederland.

GEORGE, K.S. - Harpenden laboratory Maff,
Hatching green,
Harpenden,
Herts,
U.K.

GUERIN, A. - Protection des Végétaux,
13, route de la Forêt,
Biard,
86000 Poitiers,
France.

HÖLLER, C. - Institut für Phytopathologie,
Lehrstuhl Schafdtiere,
Universität Kiel,
Olshausenstr. 40-60 ,
2300 Kiel,
B.R.D.

JEPSON, P.C. - Chemical Entomology Unit.,
Building 3,
The University,
Southampton S09 5NH,
U.K.

KELLER, S. - Federal Research Station for Agronomy,
Reckenholzstr. 191,
CH-8046 Zürich,
Switzerland.

LATTEUR, G. - Station de Zoologie appliquée,
8, Chemin de Liroux,
5800 Gembloux,
Belgique.

MANTEL, W.P. - Research Institute for Plant Protection,
P.O.B. 9060,
6700 GW Wageningen,
Nederland.

OGER, R. - Centre de recherches agronomiques de l'Etat,
Avenue de la Faculté 22,
5800 Gembloux,
Belgique.

PIERRE - I.N.R.A. - E.N.S.A.R.,
Laboratoire de Zoologie,
65 Route de St-Brieuc,
35042 Rennes CEDEX,
France.

DI PIETRO J.P. - E.N.S.A.,
Laboratoire de Zoologie,
65 Route de St.-Brieuc,
35042 Rennes Cedex
France.

POWELL, W. - Rothamsted experimental Station,
Harpenden,
Herts,
U.K.

RABBINGE, R. - Theoretische Teeltkunde,
Bornsesteeg 65,
Wageningen,
Nederland.

SHIRES, S.W. - Shell Research Sittingbourne Research Centre,
Sittingbourne,
Kent ME9 8AG
U.K.

WEIBULL, J. - Dept. of Plant and Forest protection,
Swedish Univ. of Agricultural Sciences,
P.O. Box 7044,
S-75007 Uppsala,
Sweden.

WRATTEN, S.D. - Biology department,
The University,
Southampton SO9 5NH,
U.K.

SUBGROUP " ECONOMIC STRATEGIES "

SOUS GROUPE " STRATEGIES DE LUTTE "

EFFECTS OF CEREAL APHIDS ON YIELD AND QUALITY OF WHEAT AND BARLEY

S.D. WRATTEN and K.S. GEORGE*
Department of Biology, Building 44, The University, Southampton SO9 5NH, UK.
*The Harpenden Laboratory, Ministry of Agriculture, Fisheries and Food, Hatching Green, Harpenden, Herts. AL5 2BD, UK.

Summary

The development of a research programme in the United Kingdom concerning aphid damage to wheat is described. It was developed at Southampton University and by the Agricultural Development and Advisory Service (M.A.F.F) with I.O.B.C. collaboration. The report deals first with the chronology of the Southampton work, starting with comparisons of the relative effects of the aphids Sitobion avenae and Metopolophium dirhodum on yield loss in winter wheat. The role of the aphids' feeding position in relation to the physiology of the wheat plant is demonstrated. This is followed by investigations of the role of aphid population level and plant growth stage in the extent of yield loss; field cages were used for this and their advantages are discussed. The development of a simulation model from these experimental data is described, followed by the modification of the model to produce a farmer advisory package on computer. The link between this Southampton work and the collaborative I.O.B.C. field trial, conducted by A.D.A.S. is pointed out and the general conclusion made that the importance of correct spray timing is crucial to rational cereal aphid control.

1. INTRODUCTION

The main work on the above topic in the United Kingdom has been carried out at Southampton and at Harpenden and has been a collaborative venture within the I.O.B.C. sub-groups 'Ecology of cereal aphids' and 'Crop losses'. The work has concerned the direct (non-virus-transmission) effects of the aphids Sitobion avenae (F.) and Metopolophium dirhodum Wlk. The Southampton work has taken an experimental and manipulative approach, including some laboratory work, and has followed the sequence below

A. SOUTHAMPTON WORK

1. Extent of damage: relative effects of the two species (12,14)
2. Nature of damage: grain number/weight changes; grains' competitive ability; leaf senescence (12)
3. Effects of feeding position on extent of yield loss (13)
4. Influence of plant growth stage on yield and quality loss - with unequal aphid burdens (8, 15) with equal aphid burdens (5,7,11)
5. Preliminary studies on yield reductions in barley (7)
6. A damage model for S. avenae (10), and analysis of farmers' profits and losses in the most recent outbreaks.
7. Interactions of damage statistics with pest forecasts of different types and accuracies (4,9,10).
8. Development of a computer-based farmer advisory system through the U.K. 'Prestel' Farmlink viewdata service. Data up to 1979 have been reviewed (8, 16).

The Southampton work will be described below, followed by the M.A.F.F.

investigations which were all field-based and non-manipulative. References to the work described are included but supporting references may be found in the papers described.

2. METHODOLOGICAL APPROACH IN SOUTHAMPTON WORK

Cereal aphids in summer in Europe are of sporadic occurence which means that experiments designed to investigate the yield losses they cause are difficult to conduct efficiently; several years may pass with populations at too low a level for useful field experimentation. For this and the other reasons listed below, the Southampton approach has been to manipulate populations using field cages. These have usually been 2m x 2m x 2m and covered in 1mm 'Tygan' mesh. The advantages of this method are:

1) Guaranteed populations brought about by the improved microclimate within the cages.

2) Single-species populations (crop usually sprayed with an insecticide of low persistence before aphid innoculation)

3) Periods of population growth and decline can be manipulated by varying date of introduction and by spraying out the populations with insecticides.

4) The populations are clonal/derived from clonal laboratory cultures.

5) The aphids (though not always the experimental crop) can be guaranteed free of plant-pathogenic viruses.

The use of cages has been combined with growth-room work in which aphids have been confined to particular plant organs and with open-field plot work in outbreak years.

Because of the large number of variables involved, work on crop losses caused by insects is complex. Although the familiar relationship between yield and pest number (Fig. 1) can provide a useful synthesis, it is too simple a framework and a range of factors will modify it. These factors include:

1) The pest's feeding position on the plant; different plant organs contribute differently to grain yield and quality.

2) The timing of the pest infestation. Usually early populations cause more damage than late ones.

3) The pest species. Some species will be inherently less harmful than others, partly because of factors 1) and 2) above, or the individuals may be larger, the way they damage the plant may differ, etc.

4) The yield metric used. Grain number per ear, 1000-grain weight, mean weight per grain etc. may all vary differently with respect to aphid number.

5) Grain quality. It does not follow that the relationship between grain quality and pest number will parallel that for yield, or that a quality change can occur only in association with a yield loss. Also, the aspect of quality measured (total nitrogen, α-amylase activity, flour colour) will affect the relationship.

6) The pest metric used. The options include: cumulative aphid numbers, log numbers, peak numbers, numbers above a threshold etc. The choice of metric will affect the yield/pest burden relationship.

7) The plant's nutritional and water status. Stressed plants are likely to suffer more than normal ones with a similar aphid burden.

8) Plant cultivar. Very little work has been carried out on cultivars' tolerance to similar aphid burdens but this is likely to effect the overall relationship.

9) Presence or absence of plant pathogenic viruses in the plant or aphid. It is very difficult to separate direct and indirect effects of the aphids yet virus can only rarely be shown to be absent from experimental trials.

The sequence of work below attempted to allow for most of the above factors. Populations in cages were established and manipulated in three main ways shown synoptically in Fig. 2.

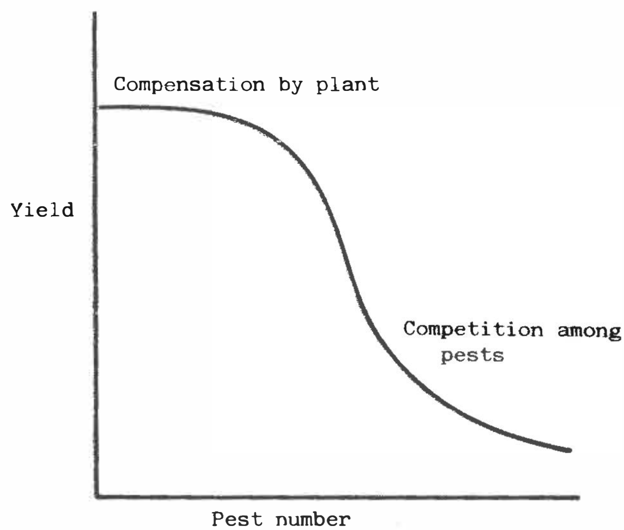

Fig. 1. The hypothetical relationship between yield and pest number.

3. RESULTS

3.1 & 3.2. Extent and nature of damage

Early work showed that a) *S. avenae* and *M. dirhodum* damage to wheat was in direct relation to the proportion of the population on and above the flag leaf b) flag leaf senescence was caused by both species c) yield losses of (*S. avenae*) 14% and 7% (*M. dirhodum*) were not in proportion to aphid numbers because of a). d) % grain protein was reduced by both species. e) patterns of grain weight reductions within the ear were similar to those expected from an assimilate drain (12). Figs. 3 and 4 and Table I.

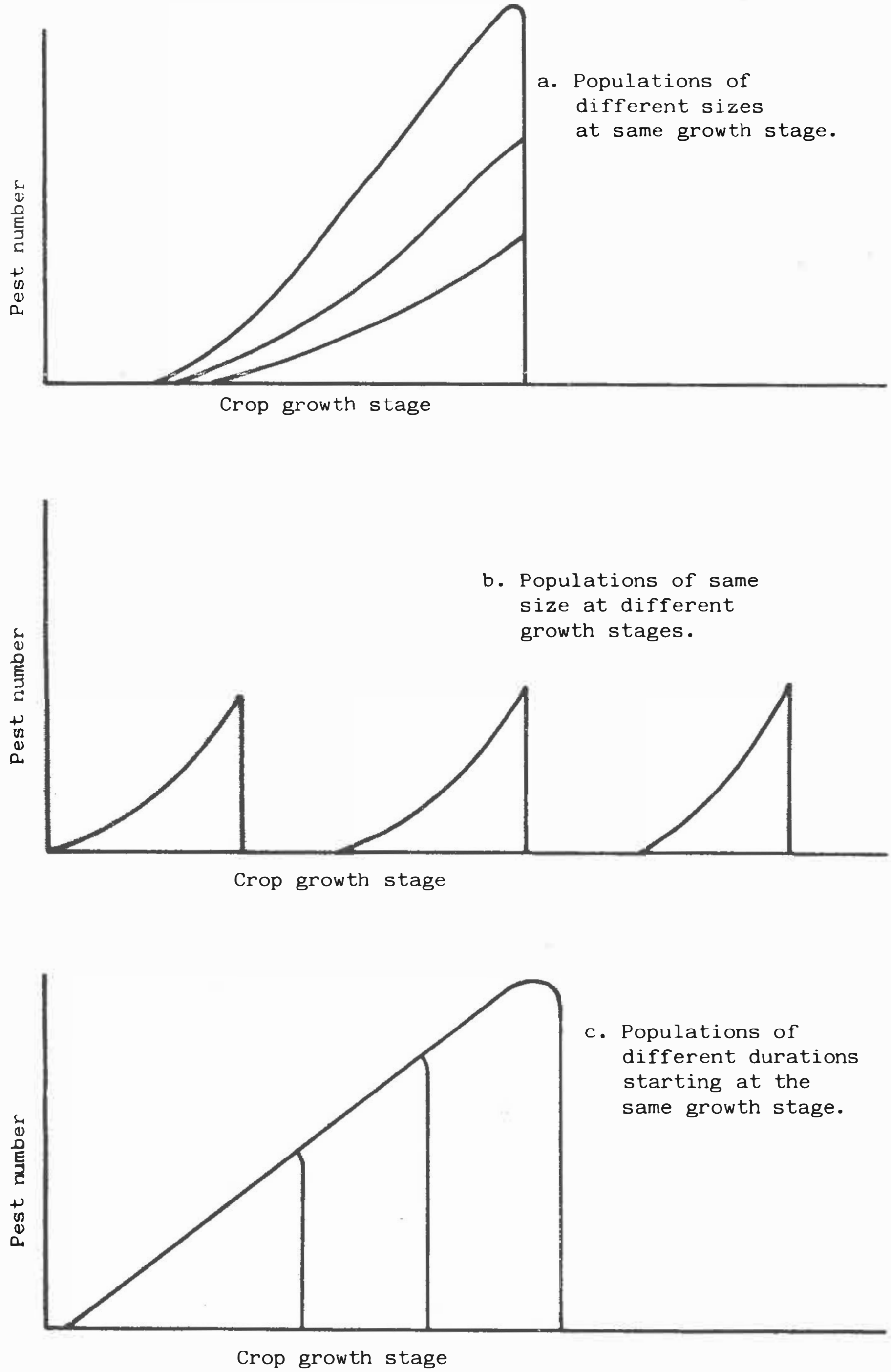

Fig. 2. Three ways of manipulating pest numbers to investigate the role of population size and crop growth stage on yield loss.

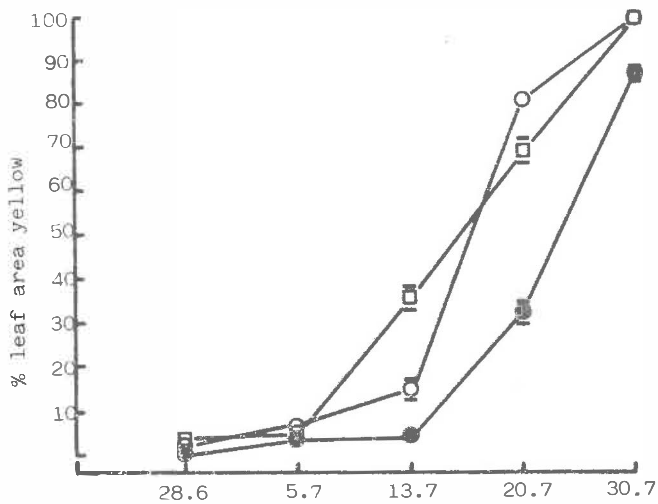

Fig. 3. Flag leaf senescence induced by cereal aphids. ●, control plants; O, S. avenae infested; ■, M. dirhodum infested. Mean % leaf area yellow ± S.E.

TABLE I. Effects of infestations of Sitobion avenae and Metopolophium dirhodum on the weight of grains in different ear regions of wheat (from Ann. appl. Biol. 79, 27-34).

Ear region	Floret position	Mean grain wt (mg) Control	S. avenae	M. dirhodum	S.E. (difference) Control/ S.avenae	S.avenae/ M.dirhodum	Control/ M.dirhodum
Basal	All	49.31	41.99	44.86	2.04**	2.06	1.95*
	1	49.37	41.69	44.62	2.11**	2.13	2.02*
	2	47.66	40.12	44.28	3.00*	3.03	2.87
Middle	All	54.00	44.70	48.16	0.90***	0.91***	0.86***
	1	56.38	46.27	50.74	0.93***	0.94***	0.89***
	2	58.44	48.19	52.53	0.99***	1.00***	0.94***
Apical	All	45.59	37.86	41.62	0.85***	0.86***	0.81***
	1	45.34	37.73	41.56	0.88***	0.89***	0.85***
	2	46.67	38.03	41.57	0.93***	0.94***	0.89***
Whole ear		1582.53	1360.38	1468.57	54.22***	54.77*	51.93*

*, **, *** P < 0.05, < 0.01, < 0.001, respectively.

3.3. Effects of feeding position

a) When M. dirhodum was confined to particular leaves in a growth room, leaf area duration was affected in those leaves to which aphids had access b) yield losses occurred only when the flag leaf was colonised but grain nitrogen was affected by feeding on leaves below the flag leaf, c) percentage grain protein declined even when flag leaves were not colonised d) in the field, multiple regressions of grain weight on aphid species/feeding site confirmed the lack of grain weight effects when lower leaves were colonised (Fig. 4 and Table II) (13).

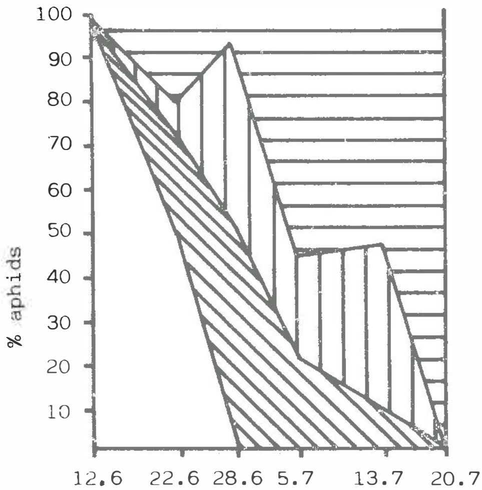

Fig. 4. The feeding distribution of Metopolophium dirhodum ▤, flag leaf; ▥, leaf 2; ▧, leaf 3; □, leaf 4.

3.4. Influence of growth stage on yield loss

a) With unequal aphid burdens of different growth stages.

In this S. avenae experiment, mean peak aphid units per ear were 11, 28 and 57 per treatment, respectively. Growth stages were: 52-71; 52-75; 52-91 (Fig. 5). All populations significantly reduced the mean weight per grain but the last infestation did not significantly further reduce yield compared with the second-longest infestation. The two longer (higher) treatments significantly reduced proportional and total flour yield and significantly darkened the flour compared with the control wheat. Bread making quality and levels of nicotinic acid and thiamine were changed, as were α-amylase levels and high molecular weight glutenin protein.

Different aspects of yield and quality did not change in parallel with one another in relation to increasing aphid burden (Table III).

b) With equal aphid burdens at different growth stages S. avenae populations at cumulative indices of c.170 per stem developed during GS 47-69 and 69-73. Percentage yield reductions relative to control were 34% and 13%, respectively (7) (Fig. 6). Early (GS 40-69) and late GS 65-73) M. dirhodum populations on wheat in 1981 did not differ significantly and bore cumulative aphid indices of c.210 each (Fig. 7). Only the early infestation significantly reduced grain weight (by 15%) and baking quality of the flour was unaffected. In 1982, similar populations had no effect on yield because of an infection of take-all fungus (Gaeumannomyces) (11). In 1983, three M. dirhodum populations of similar size but at three growth stages reduced yield (Fig. 8) (5).

3.5. Yield reductions in barley

Three M. dirhodum populations on spring barley at cumulative indices of 376, 394 and 194 per stem, respectively, developed during the periods

TABLE II. The grain weight and nitrogen content of wheat plants infested by Metopolophium dirhodum (from Ann. Appl. Biol. 90. 11-20).

	C	A3	A2	A1
Mean grain weight (g)	0.045	0.043	0.041	0.034
Mean grain number	41.00	43.00	51.00	42.82
% grain protein**	19.0	17.6	15.4	17.8
Total grain nitrogen (g)*	0.067	0.059	0.049	0.047
Total grain protein (g)**	0.382	0.336	0.279	0.268
% total nitrogen in: flag leaf	0.96	0.98	0.97	1.45
leaf 2	0.93	0.97	1.19	1.26
leaves 3 & 4	1.14	1.30	1.16	1.24
chaff	0.96	0.74	0.63	0.60

*Calculated as: treatment mean grain wt x overall mean grain no. x treatment % N.
**Calculated as: N x 5.7
C = control, A1 = free aphid access to all leaves. A2 = no access above leaf 2. A3 = no access above leaf 3.

TABLE III. Summary of the results of hierarchical analysis of variance, followed by Duncan's Multiple Range Test, on yield and quality measurements of control and aphid-infested wheat. Similar letters for a treatment indicate no significant difference (P = 0.05) (from Ann. appl. Biol. 98, 169-178).

Yield or Quality Measurement	Treatment, and growth stage when sprayed			
	1 (Control)	2 10.5.4(71)	3 11.1-11.2(77)	4 11.2-11.3(85)
% Flour extraction	a	ab	b	c
Flour colour	a	ab	b	c
a-amylase activity	a	b	b	b
% Nitrogen in grain	a	b	b	b
% Nitrigen in flour	a	a	a	a
Total nitrogen in grain	a	a	a	a
Baking value	a	a	a	b
Mean weight per grain	a	b	bc	c

GS 30-61, 55-75 and 71-80, respectively. Yield was reduced significantly in the first two treatments (by 16% and 11%, respectively) but not in the third (7).

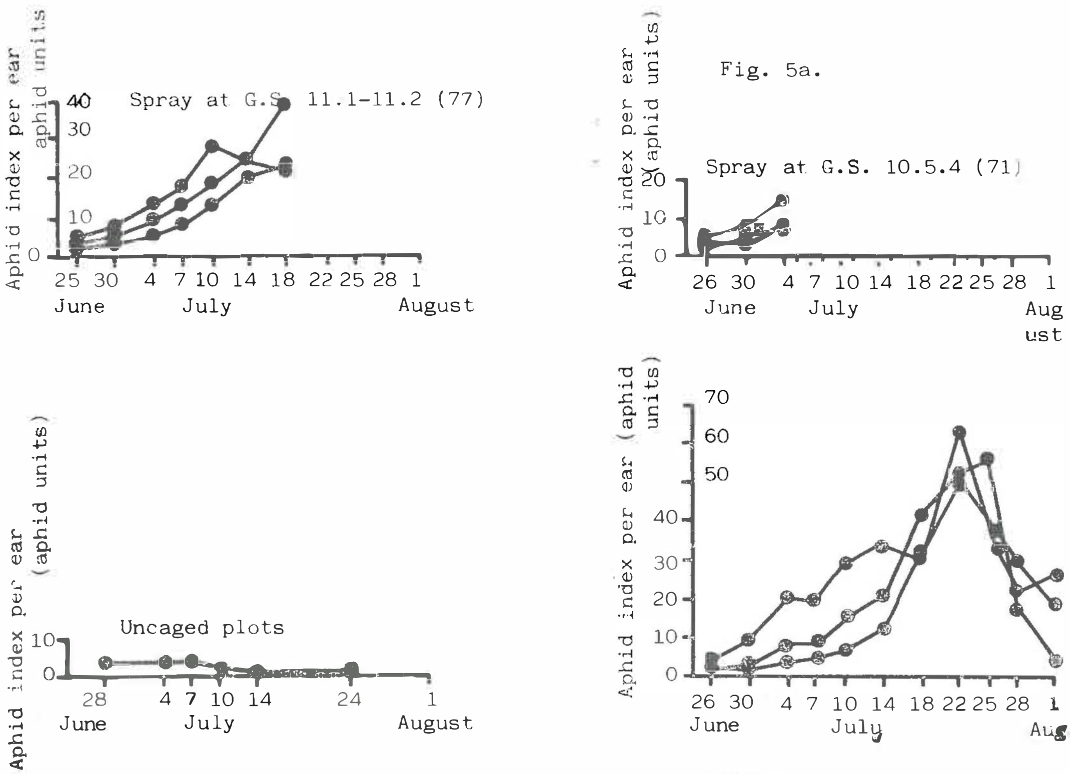

Fig. 5. Mean aphid indices (S. avenae) in three caged treatments (equivalent to Fig. 2c).

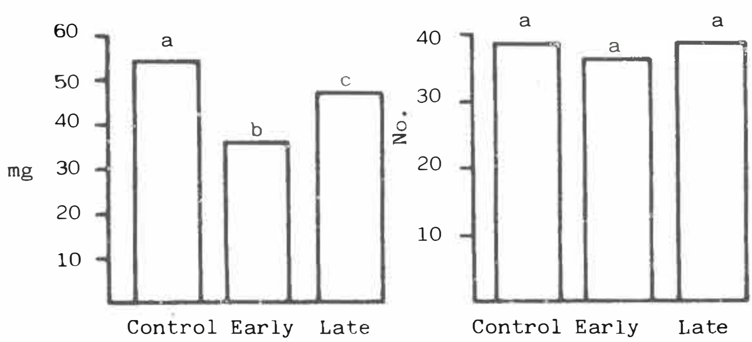

Fig. 6. Effects of S. avenae on grain weight and number (equivalent to Fig. 2b). Columns sharing the same letter do not differ at P = 0.05.

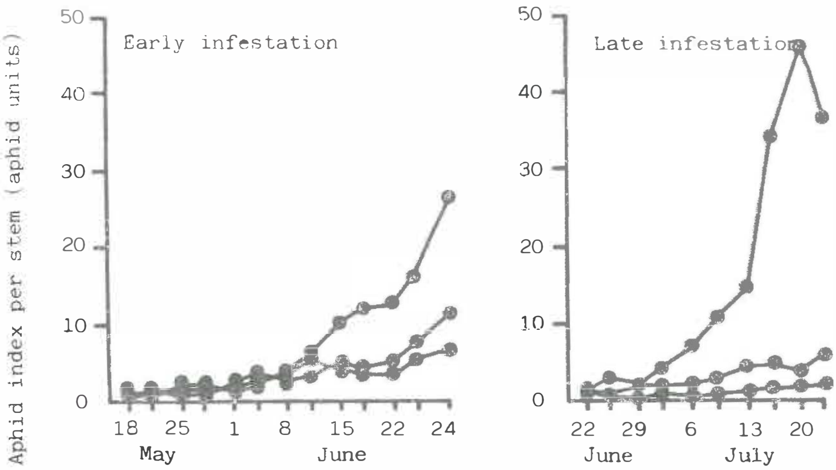

Fig. 7. Mean indices of M. dirhodum on wheat in field cages with an early (G.S. 40-69) and a late (G.S. 65-73) infestation (see Fig. 2b).

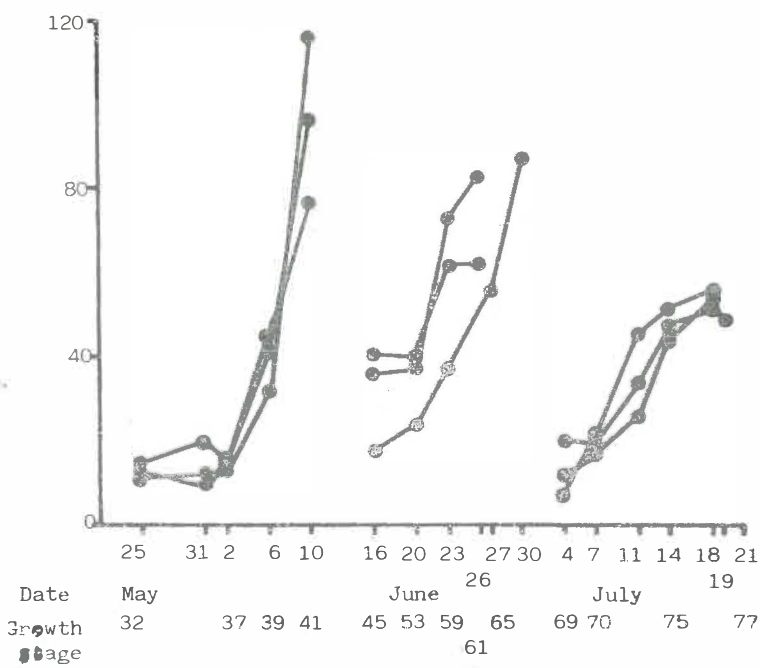

Fig. 8. Population development in three M. dirhodum treatments (see Fig. 2b).

3.6. A damage model for S. avenae on wheat

The model was built from data on aphid damage, control costs, grain prices and expected yield (10). Aphid populations were fed directly in, rather than simulated from reproductive and developmental data. The model used data on yield loss in relation to growth stage and aphid number and aimed to quantify the economic value of control at different stages of outbreaks of various intensities. The model calculated: the aphid population density (A) for each day (j) of the infestation (by interpolation between the aphid counts on particular sample dates), the daily and cumulative (d_j) yield losses

$$d_j = \sum_{i=1}^{i=j} A_i \; E_i$$

together with the amount of damage saved by an insecticide spray (s_j):

$$s_j = (1-d_t) - (1 - d_j)\,(1 - W)$$

where E_i is the proportional yield loss per aphid per day on day i; d_t the total calculated yield loss and W the proportional wheeling loss incurred during spraying. The latter, set at 3%, is obviously removed if the use of tramlins is simulated. The model also calculated the cumulative and avoidable damage in monetary terms (D_j and S_j respectively):

$$D_j = TGd_j$$

$$S_j = TGs_j$$

where T is the expected yield (t/ha) and G the grain price (£/t).

When the model was run with an aphid outbreak rising to 64 aphids/stem, based on two years' results on four winter wheat fields, the extent to which losses in grain weight increased could be seen (Fig. 9). As the amount of damage increased, the amount of expected (preventable) damage declined as, therefore, did the net value of an insecticide spray. In this example the return from spraying became a net loss one day before the aphid population reached its peak and one week before it declined to zero.

The total gross damage caused by aphids in this case was 13.3%. If an insecticide had been applied at the beginning of flowering (when there were 7 aphids/stem) a 12.8% gross level of damage would have been avoided. This figure is extremely close to a published average of 12.5% derived from field trials.

Analysis of survey data.

The aphid damage model was run for each year and study area/region using the appropriate costs for the insecticide used, and the timing and method of application. All costs and prices were expressed at 1982 levels with expected yields of 6t/ha throughout, to allow comparisons to be made between years. Aphid population development was assessed to be the same throughout each region. However, to allow for the inevitable variation within each region the analyses were always made to give not only average figures but also estimates derived from variations in the synchrony of aphid numbers and spray dates of ± 3.5 days.

Although there was large regional and yearly variation, the maximum profit obtainable was never reached. The average regional figures

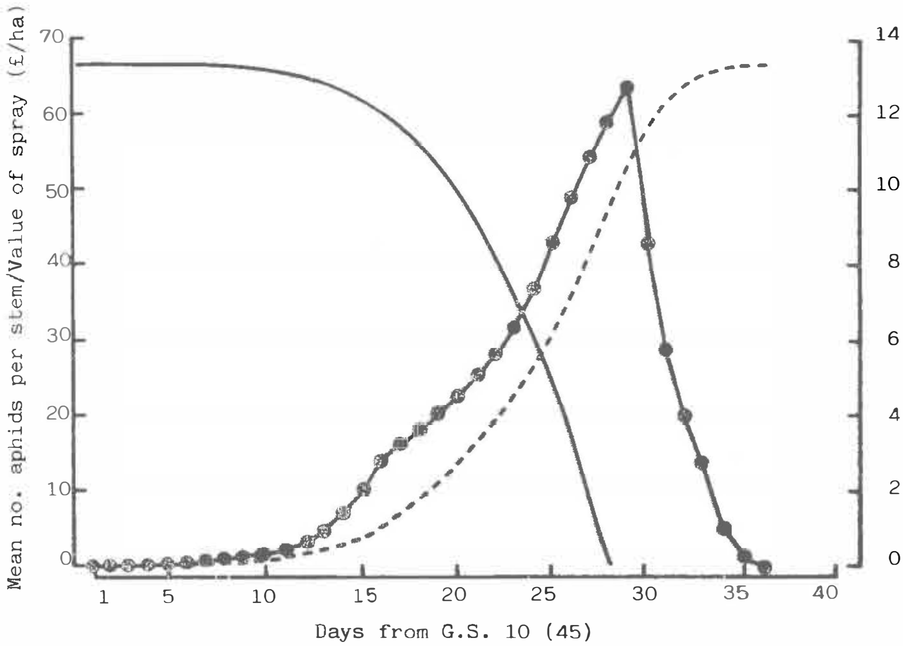

Fig. 9. Cumulative percentage crop damage (- - - -) and the value of (£/ha) of a crop spray (______) against an outbreak of aphids (●———●) (based on four populations in two years in Norfolk) (Treatment by tractor-applied insecticide costing £5.9/ha; grain price £117.50/t; expected yield 6t/ha).

(for the treated areas only) varied from £14/ha when £58/ha was attainable to a loss of £22/ha when the maximum return from the control measures chosen was a loss of £3/ha (Figs. 10-13). In percentage terms, the maximum profit obtained was only 45% of that attainable. While this analysis did not include all possible variables, it did show a large shortfall between the profit obtained and that attainable; in most cases a net average loss was indicated.

In all cases the main reason for the shortfall in profits was the delay in applying insecticides. The period during which insecticides were applied varied from two weeks in 1975 to six weeks in the Southern region in 1976 (when a net average loss was incurred) and only a relatively small percentage of the area of wheat treated was sprayed during the first week.

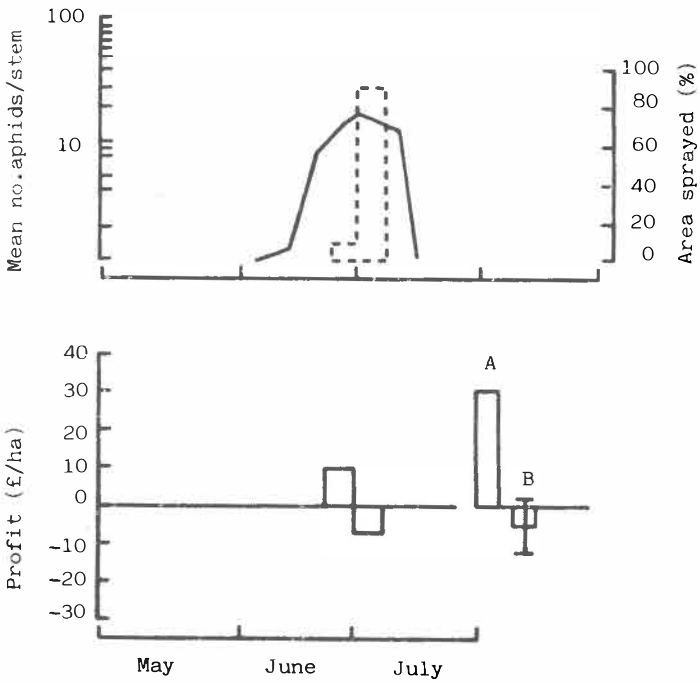

Fig. 10. South, 1975: Mean aphid numbers (———) and percentage area of crop sprayed each week (of total area sprayed). (- - - -) (upper half); the profit gained for each week, the average profit for the whole period of treatment (adjusted according to the area sprayed during each week of the infestation) with an estimate of the range of the average profit obtained, and the maximum profit possible (lower half) (Grain price and expected yield as Fig. 9; control costs based on the range of insecticides and methods of application used by the farmers surveyed).
A = maximum profit possible; B = average profit achieved.

3.7 Damage/forecast accuracy interactions

The aphid damage model was also used to assess forecasting schemes operating at different times and with different accuracies. The assessment was made by calculating the additional profit to be gained by following the advice of a forecast in comparison with that to be gained from a no-control or a prophylactic strategy. The prophylactic treatment in the analysis was assumed to be carried out early (at day 1 of the infestation) and the value of a forecast was calculated for each day of the infestation. The extent to which the benefit gained from a forecast declined as the season progressed is shown in Figs. 9-10. This decline was gradual at first, until there were approximately 5 aphids/stem in an outbreak, but then rapid.

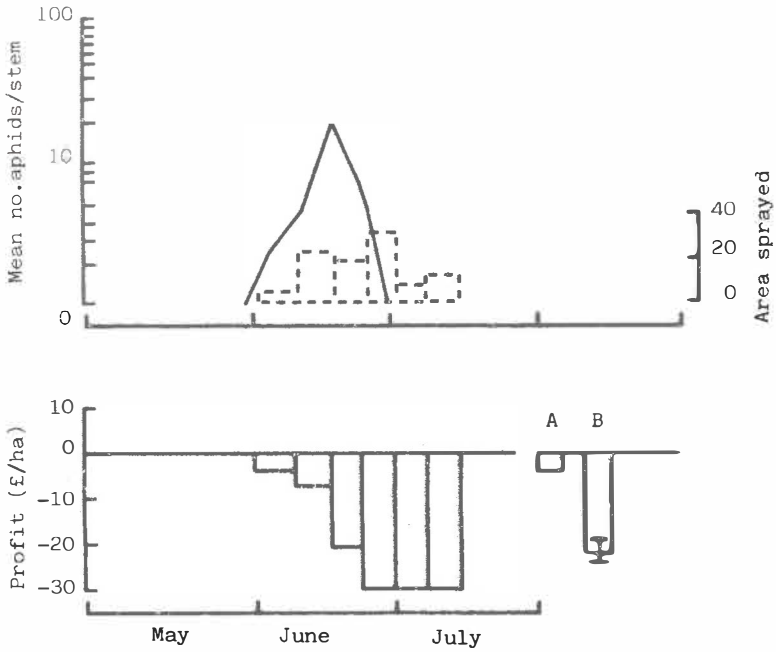

Fig. 11. South, 1976: details as Fig. 10.

The value of a forecast was also dependent on the size of the outbreak population and both the accuracy and type of the forecasting system. The value of a forecast where the outbreak population was large, reaching 64/stem (as in Fig. 9) is illustrated in Fig. 14; the forecast value remained high for over three weeks. However, with a smaller outbreak population, reaching 40/stem (Fig. 16) the value of a forecast against no control was negligible and its value against prophylaxis remained high throughout the infestation (Fig. 15). These differences were due to the different levels of damage calculated by the model (13 and 5% respectively). Consequently the lower level of return in an outbreak year for the situation in Fig. 16 was not adequate to compensate for the losses incurred by a prophylactic spray in a non-outbreak year.

A forecast of an aphid outbreak may not be completely accurate and the effects of two levels of accuracy, 100% and 80%, are shown in Fig. 14. In that example the poorer forecast remained a better strategy than no control and prophylaxis. However, in the example in Fig. 15, the poorer forecast, although better than prophylaxis throughout, was a poorer option than no control. A forecasting scheme may not be equally accurate in its "spray" and "no spray" recommendations. A forecasting strategy where only the "spray" recommendation was inaccurate has been considered (9) and found to be an economically robust system. That analysis did, however, compare forecasting with a prophylactic spray at the same date; as an infestation progresses, this system, when compared with an early prophylactic treatment, also decreases in value (Figs. 14 and 15).

The importance of the timing of a forecast and its accuracy can be summarised by considering two forecasting schemes; X, an early but inaccurate one, and Y, a late but accurate one (Fig. 14). Despite being two weeks apart in their timing they both have the same value under the conditions used under the above analysis. When outbreak populations are smaller (Fig. 15), forecast Y is significantly better. Also, as outbreak probability increases the better forecasting scheme switches from the late to the early one (Fig. 14).

3.8 Development of an advisory system based on the above models

The model represented, for example by Figs. 9 and 16 is being developed in 1985 by simplying it and incorporating and element of short-term aphid forecast. The model does not currently include a forecast as it uses actual aphid populations recorded, with interpolations. If a forecasting aspect were not introduced in a practical model, its use would be restricted in that it could indicate only that economic damage had begun, rather than that it was about to begin. The developments described below, therefore, require simple inputs on local weather conditions to assess the likelihood that a population will reach a particular level. This enables the model to calculate the appropriate minimum interval between crop inspections. In outline, the farmer would enter data in the following way onto his data sheet, notebook or his own micro-computer; alternatively, data would be entered onto the consultant's micro:

1. Count percentage of stems with one or more aphid present on flag leaf or ear
2. Assess growth stage
3. Estimate expected yield (t/ha)
5. Estimate or call up expected selling price for feed/milling/seed wheat.

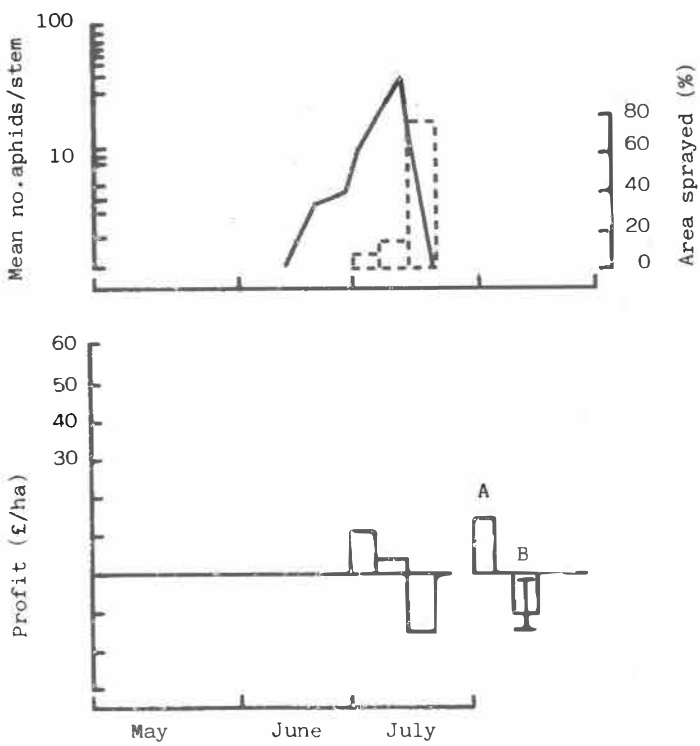

Fig. 12. South, 1977: details as Fig. 10.

The system then calculates the financial return, if any, from an immediate spray under the above-on-farm conditions. Three recommendations are possible:

1. Do not spray; no further opportunity of making a profit from aphid control that season
2. Spray urgently; recoverable yield loss imminent
3. Do not spray but return n days later and reassess the percentage of stems infested. In this case, the value for n would be determined by growth stage (data already entered) and by the weather (data already entered or added by central computer).

If the 1985 advice program proves to be successful, it may be extended to M. dirhodum and other species.

The above chronology of work on damage by S. avenae and M. dirhodum will then have successfully followed the sometimes difficult path from basic research to development of a working system, in this case with I.O.B.C. collaboration throughout.

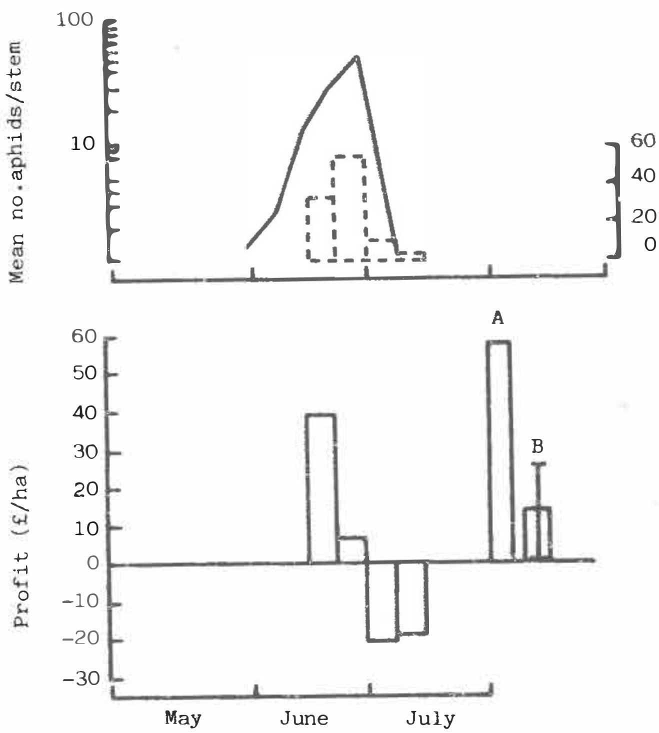

Fig. 13. East, 1976; details as in Fig. 10.

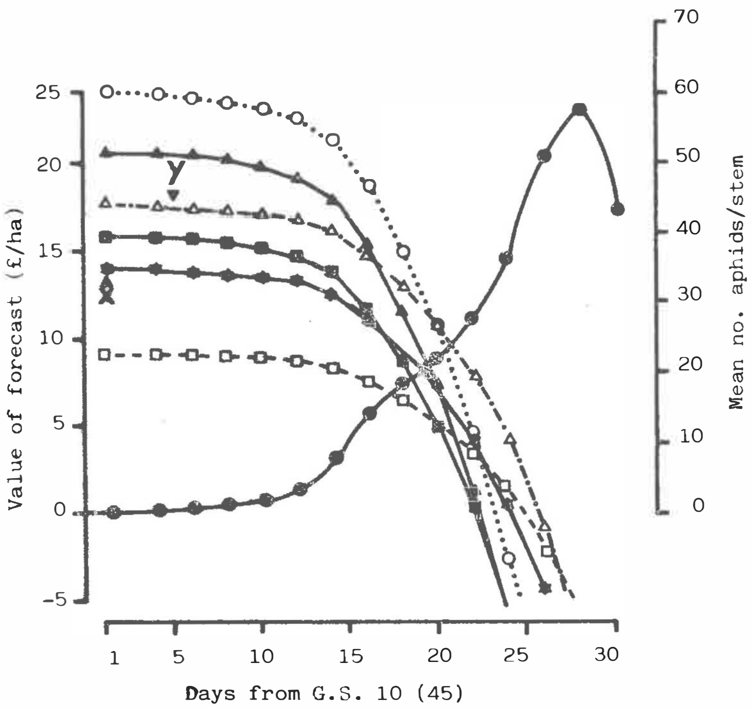

Fig. 14. The value (£/ha) of forecast-based control strategies where outbreaks of aphids are of the magnitude shown (--●--●--) and occur with a probability of 0.36 each year. Three types of forecasting schemes are depicted, the value of each being shown relative to prophylaxis and to a no-control strategy. O = a perfect forecast v. prophylaxis; Δ = a perfect forecast v. no control; ■ = an 80% accurate forecast v. prophylaxis; □ = an 80% forecast v. no control; ▲ = a forecast fully accurate in recommending 'no spray' but 80% accurate in recommending 'spray' v. prophylaxis; * = the same forecast v. no control. X is an early inaccurate forecast and Y is a late accurate one.

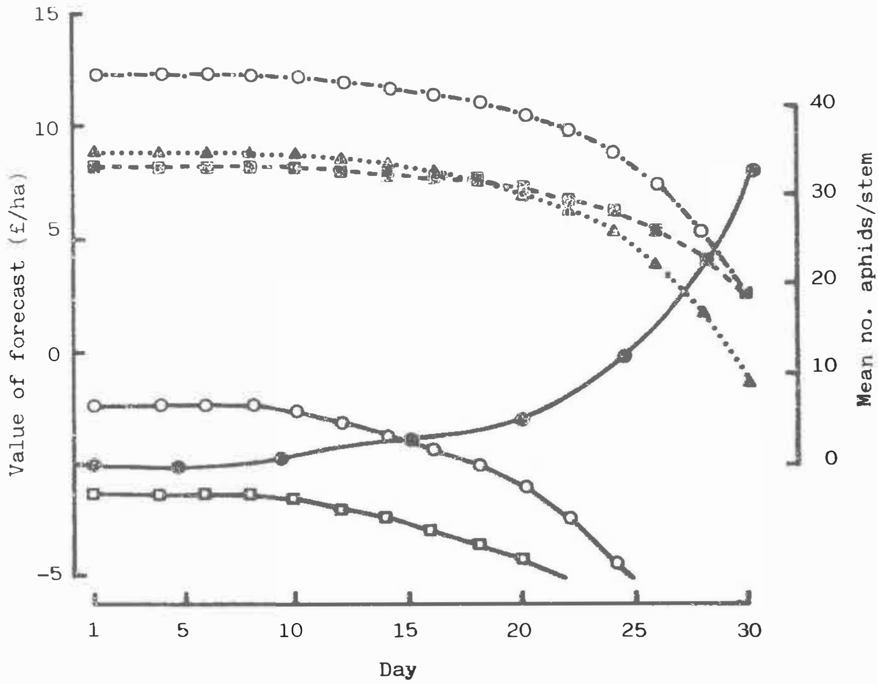

Fig. 15. An Fig. 9 but based on smaller outbreak populations.

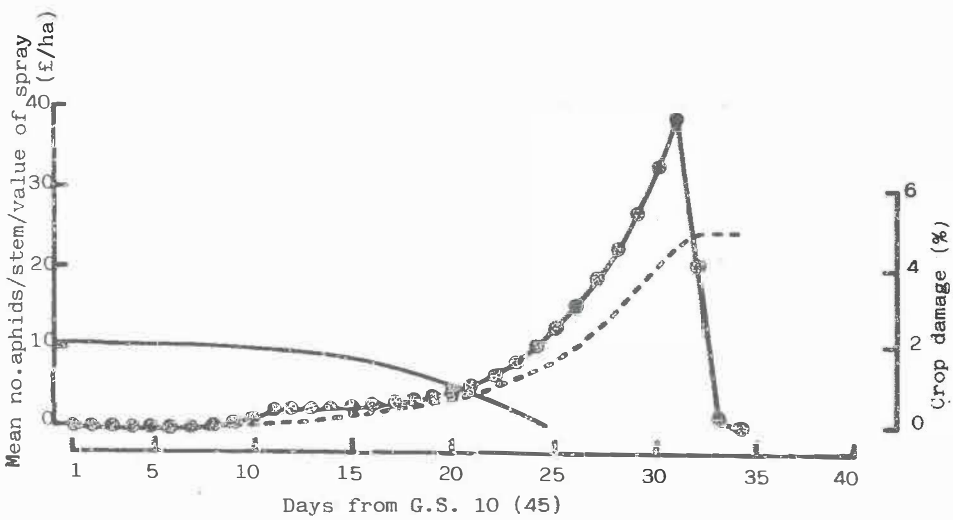

Fig. 16. Cumulative % crop damage (- - - -) and the value (£/ha) of a crop spray (———) against an outbreak of aphids (o———o) (based on the Sussex 1977 population but with treatment details as in Fig. 10).

B. U.K. M.A.F.F./I.O.B.C. COLLABORATIVE WORK

1. INTRODUCTION

The other main work on this topic in the U.K. has also been based on I.O.B.C. collaborative work, in this case based on naturally-occurring aphid outbreaks in northern and central Europe. The next section describes that work. It has been published in three papers (1,2,3).

The first paper paper described early work on the species of aphids attacking cereals in Great Britain, the time of arrival of different species in Rothamsted traps and on crops in the field, and early experiments on crop yield loss caused by aphid interactions on barley and wheat.

The second paper presented results of a co-operative experiment done jointly in the U.K. and other north west European countries to establish the threshold in terms of cereal growth stage and aphid numbers per tiller at which spraying with an insecticide becomes economically justifiable.

2. METHODS AND RESULTS

At a meeting of the International Organization for Biological Control Working Party on Cereal Pests in December 1973 it was agreed that those participants interested in cereal aphids should take part as a co-operative project in 1974. This took the form of an experiment designed to establish the effectiveness against aphids of a single spray of insecticide applied at the beginning of flowering.

Each experiment consisted of a minimum of four replications of one treated and one untreated plot. The treatment was one spray of pirimicarb applied at growth stage 10.5.1 i.e. the beginning of flowering. Pirimicarb was chosen because of its specificity against aphids. Plots were five metres square. Counts of aphids per ear and also per tiller were made just before spraying, and as often as possible thereafter until harvest and were based on 25 complete tillers per plot taken at ground level to eliminate selection bias. Forty-four experiments were completed, 18 of them in the Netherlands and 22 in the U.K.

In the U.K., experiments were based on five replications and, with the exception of one experiment, were done in the eastern and south-eastern parts of the country by members of the Agricultural Development and Advisory Service. All these experiments were on winter wheat and covered nine varieties. There were nine experiments on Maris Huntsman, four on Cappelle-Desprez, two each on Maris Nimrod and Maris Templar and single experiments on the varieties Atou, Bouquet, Chalk, Val and Maris Widgeon. The sprays were applied at the beginning of flowering which occurred mainly in the first half of June. In the Netherlands, 13 experiments were on variety Clement and two on Cyrano, and single experiments were done on Caribo, Lely and Manella.

As previous work had shown the possibility of yield loss occurring when a crop had a mean of five or more aphids per ear at flowering, with populations increasing, it was decided that this number should be taken as the base line or critical level for analysis of the experiments. In the U.K., aphid numbers rose to over five per ear in 11 experiments, and in the Netherlands, there were more than five aphids per ear on six experiments.

An analysis of the 22 U.K. sites taking out differences due to sites, showed that the overall mean yields were not significantly different (Table 5). However, the overall mean yield from the sprayed plots on those 11 sites with five or more aphids per head was significantly greater than that from the unsprayed plots (3.1 cwt per acre, 389 kg/ha). On the other 11 sites where there were less than five aphids per ear, there was no difference in yield between the treated and untreated plots. On the sites where most aphids occurred, the overall mean yield was much lower than on the remaining 11 sites, suggesting that these crops might have been under stress from some other factor before aphid infestation and build-up occurred. It has been shown that aphid reproduction is affected by water stress and its secondary effects in plants such as beans and Burssel sprouts. These results suggest that with cereals some stresses which may produce changes enhacing aphid reproduction act detrimentally on the plant itself.

Winter wheat experiments, U.K., 1974. Single spray at growth stage 10.5.1.

Mean yield of 11 sites with > 5 aphids per ear

Untreated	3562 kg/ha	(28.38 cwt/acre)
Treated	3951 kg/ha	(31.48 cwt/acre)
S.E.	± 108	± 0.86

Mean yield of 11 sites with 5 aphids per ear

Untreated	5981 kg/ha	(47.66 cwt/acre)
Treated	5877 kg/na	(46.83 cwt/acre)
S.E.	± 108	± 0.86

In the Netherlands 18 experiments were done but in only six of them were there more than five aphids per ear at flowering. In five of these six, the numbers of aphids at flowering were only, 6, 9, 9, 9 and 18 and these diminished rapidly. In the other experiment the number rose from 9 to 13 in two weeks. There were no significant differences in yield between treated and untreated plots and differences in yield were slight (Table 6).

TABLE VI Mean per cent increase in grain yield resulting from one spray at G.S. 10.5.1 for each category of aphid infestation 1974-77, (from Plant Path. 28, 143-149)

Category and description	No. of sites	Mean % increase
1. 5-10 aphids/ear at G.S. 10.5.1 and increasing	8	11.5
2. 10.1-30 aphids/ear at G.S. 10.5.1 and increasing	8	13.9
3. 5 or more aphids/ear at G.S. 10.5.1 and decreasing	11	1.5
4. 5 or more aphids/ear later than G.S. 10.5.1	8	3.9
5. Never more than 5 aphids/ear	14	0.7

The maximum was 9 per cent increase in one experiment, while the increase in all others fell within the range 95-106 per cent.

Winter wheat experiments, Netherlands, 1974
Single spray at growth stage 10.5.1

Mean yield of 6 sites with >5 aphids per ear

Untreated	5739 kg/ha	(45.73 cwt/acre)
Treated	5873 kg/ha	(46.80 cwt/acre)

Mean yield of 12 sites with > 5 aphids per ear

Untreated	6021 kg/ha	(47.98 cwt/acre)
Treated	6078 kg/ha	(48.43 cwt/acre)

Grain from each plot on the 22 U.K. sites was sieved into five fractions. Size group differences between treated and untreated plots were negligible on the 11 sites where aphid numbers were low (Untreated (U) 88.7 per cent, Treated (T) 88.6 per cent on the top two sieves) but more substantial on the other 11 sites (U 70.5, T 74.1).

In the Netherlands, 1,000 grain weights were calculated from treated and untreated plots at each of the 18 sites. Overall there was no difference in mean weights between treated and untreated plots (U 43.2, T 43.7). Unlike the U.K. results, and probably as a result of the very small aphid infestations, there were no differences in the means for the six sites with more than five aphids (U 42.2, T 42.7).

The third paper reported forty-nine experiments done during 1974-77 on commercially grown winter wheat crops in England and Wales to investigate the effects on grain yield of feeding on the ear by the grain aphid, Sitobion avenae. The results show that one spray of pirimicarb applied at the beginning of flowering when there were five or more aphids per ear and the number was rising gave an increase in grain yield of approximately 12.5 per cent. Much lower increases were recorded when sprays were applied later than this growth stage or when the number of aphids did not reach the specified level.

In each of the years 1974-77 the crop used was commercially grown winter wheat and experimental sites were selected where aphids were already present on the emerging ears. The farm sites where the experiments were done were situated in different areas of England and Wales. The majority of the sites were in the eastern and south-eastern counties of England where large areas of winter wheat crops are grown. The cultivars included those most frequently grown during the period, with cv. Maris Huntsman forming the bulk of the sample(21 sites) and 13 other cultivars occurring from one to four times.

The insecticide used was pirimicarb applied at the full commercial rate of 280 g/ha. In 1974 and 1975 unsprayed plots were compared with plots receiving one spray at the beginning of flowering, G.S. 20.5.1. There were five replications of each treatment in 1974 and six in 1975. In 1976 there were four treatments: control (unsprayed); one spray at the beginning of flowering, G.S. 10.5.1.; one spray at the end of flowering, G.S. 10.5.4 (= 68/69) (17); and one spray at the milky-ripe stage, G.S. 11.1 (= 73) (17). In 1977 one further treatment was added to the 1976 programme: one spray at complete ear emergence, G.S. 10.5 (= 58/59) (17) i.e., earlier than the beginning of flowering. In1976 and 1977 there were at least four replications of each treatment.

All sprays were applied by knapsack sprayer. Plots were 5 m square and samples were taken from within the central 3 m square. Counts of aphids were made on 25 randomly selected tillers per plotjust before the first spray was applied and at seven- to ten-day intervals thereafter; counts were made until populations reached zero. Samples were selected at ground level to eliminate bias. In 1975 the aphids on the ears and the remainders of each tiller were recorded separately. In 1976 and 1977 the aphids on flag leaves were also recorded separately. The aphid counts on ears only were used in formulating and substantiating the criteria for justifying spraying because little was known about the extent of the effects of aphid feeding on the flag and other leaves and because populations did not develop elsewhere as they did on the ears. For analysis, the aphid counts were divided into five categories according to the descriptions given in Table 4.

The crops were sampled at harvest by taking six sub-samples per plot each consisting of three contiguous rows one metre long. All samples were processed at the Plant Pathology Laboratory, being threshed on a stationary rig and cleaned by air aspriation and sieving. Total grain yields were calculated at a constant moisture content. In 1975, 1976 and 1977 one thousand grain weights were recorded; in 1974 and 1977 all samples were sieved into standard size components.

Table 4 shows the numbers of aphids per ear at G.S. 10.5.1, the peak count and the number of days which elapsed between making these two estimates. Where no figure is given for the peak count, the aphid population declined from the beginning of flowering.

Table 5 shows the mean grain yield in tonnes/hectare at 85 per cent dry matter for each of the treatments at each site. As 1000 grain weights and grain size determined by sieving reflected the mean yields of grain from individual treatments at each site, the sprays at heading (1977) and at the beginning of flowering (1974-77) producing the heaviest and largest grains, these figures are not shown.

Table 6 summarises the mean grain yield for each of the five categories of aphid infestation. Thus, where there were five or more aphids per ear at the beginning of flowering and the population increased, one spray gave a mean grain yield increase of 11.5 or 13.9 per cent depending on the size of the initial population. Control of aphid infestations in the other three categories resulted in increases in grain yield of less than four per cent.

Statistical analysis of the grain yield means weighted for number of sites in each category showed that there were no significant differences between years. When categories 1 and 2 combined were compared with categories 3, 4 and 5, a significant increase in yield ($P > 0.01$) was revealed; the mean increase in yield over the unsprayed plots for categories 1 and 2 combined is significant at the five per cent level.

A comparison of mean grain yields for treated plots where one aphicidal spray was applied at different growth stages of the plant (in 1976 and 1977) and where the aphid infestations fell into categories 1 and 2 showed that the spray applied at G.S. 10.5.1 increased mean yield over the untreated by 10.0 per cent; at G.S. 10.5.4 the increase was 4.3 per cent and at G.S. 11.1 the increase was 2.9 per cent. These results are based on 39 plot replicates. In 1977 there were additionally 13 plot replicates of the treatment where an earlier spray was applied at G.S. 10.5 giving a mean yield increase of 12.9 per cent.

The conclusions drawn from these collaborative experiments support the Southampton data, in particular with respect to the declining effects of populations at later growth stages. Proposed work by the M.A.F.F. in the U.K. now includes the possibility of evaluating the effects of early (pre-flowering) populations of S. avenae.

TABLE IV. Mean number of aphids per ear at G.S. 10.5.1 (Zadoks 60/61) and the subsequent peak (from Plant. Path. 28, 143-149)

Year and site number	Category of infestation	Mean aphids/ear at G.S. 10.5.1	Peak aphids/ear (days after G.S.10.5.1) (based on counts at 7-10 day intervals)	
1974				
1	2	11.3	28.1	(11)
2	2	13.6	15.3	(11)
3	2	10.3	29.3	(11)
4	2	10.8	17.3	(8)
5	3	13.3		
6	2	10.8	18.2	(16)
7	4	3.9	28.2	(7)
8	2	30.0	71.1	(16)
9	3	51.1		
10	5	0.4		
11	5	0.8		
12	4	3.6	12.3	(11)
13	5	0.1	1.5	(16)
14	5	0.1	1.3	(9)
15	5	0.3	1.3	(9)
16	5	1.0	1.5	(7)
17	5	0.7	4.4	(7)
18	3	6.9		
19	5	0.1	0.3	(18)
20	5	0.2	0.3	(18)
21	5	1.2		
22	5	0.7		
1975				
23	5	4.2		
24	3	7.4		
25	3	5.0		
26	3	6.6		
27	5	2.4		
28	1	6.7	25.1	(8)
29	3	7.4		
30	4	1.7	9.8	(7)
31	3	5.8		
32	3	12.2		
33	1	8.2	23.7	(14)
34	4	4.1	13.7	(11)
35	4	4.1	7.7	(21)
1976				
36	1	9.6	31.7	(6)
37	2	16.5	34.2	(11)
38	3	7.2		
39	1	7.9	23.0	(7)
40	1	7.3	43.0	(6)
1977				
41	1	5.0	16.7	(11)
42	3	7.6		
43	2	13.4	25.3	(7)
44	1	8.1	50.1	(8)
45	4	0.9	31.7	(10)
46	4	2.0	23.0	(7)

TABLE IV. continued ....

Year and site number	Category of infestation	Mean aphids/ear at G.S. 10.5.1	Peak aphids/ear (days after G.S.10.5.1)(based on counts at7-10 day intervals)	
1977 continued				
47	5	4.5		
48	1	5.0	22.9	(13)
49	4	2.0	6.4	(13)

TABLE V. Mean grain yields, 1974-77 (from Plant Path. 28, 143-149)

Mean grain yield in t/ha at 85% matter sprayed at following growth stage:

Year and site number	Category of infestation	Untreated	10.5	10.5.1	10.5.4	11.1	S.E. of treatment mean
1974							
1	2	1.72		2.49			0.24
2	2	2.92		2.86			0.19
3	2	1.96		2.82			0.19
4	2	3.80		4.12			0.33
5	3	3.73		5.30			0.16
6	2	2.45		2.79			0.13
7	4	6.00		5.79			0.30
8	2	1.87		2.65			0.12
9	3	6.66		5.79			0.34
10	5	7.71		8.41			0.07
11	5	7.30		7.31			0.18
12	4	5.04		5.59			0.42
13	5	5.17		5.50			0.43
14	5	5.90		5.59			0.31
15	5	3.04		3.06			0.10
16	5	6.25		6.26			0.35
17	5	7.16		6.62			0.24
18	3	3.03		3.27			0.15
19	5	6.56		6.37			0.30
20	5	4.43		4.28			0.18
21	5	6.69		6.49			0.27
22	5	5.58		4.76			0.15
1975							
23	5	5.11		6.08			0.45
24	3	2.39		2.30			0.14
25	3	4.04		4.32			0.08
26	3	1.65		1.71			0.06
27	5	5.64		5.93			0.13
28	1	4.72		4.87			0.16
29	3	4.75		4.77			0.28
30	4	5.62		6.29			0.24
31	3	6.03		5.80			0.17
32	3	6.18		5.78			0.06
33	1	5.07		5.74			0.08
34	4	5.81		5.66			0.19
35	4	4.92		5.15			0.14
1976							
36	1	2.92		3.63	3.24	3.00	0.33
37	2	4.10		3.96	3.87	4.34	0.28
38	3	3.82		3.89	3.80	3.48	0.27
39	1	2.51		3.33	2.46	2.95	0.17
40	1	4.26		4.80	4.45	4.79	0.25
1977							
41	1	4.72	5.96	5.41	5.05	4.73	0.26
42	3	3.92	4.35	4.12	4.23	3.68	0.18
43	2	2.86		2.75	2.94	2.72	0.19
44	1	3.74	4.23	3.79	3.83	3.42	0.27
45	4	4.23	4.57	4.67	4.71	4.09	0.19

TABLE V. continued ....

Year and site number	Category of infestation	Untreated	10.5	10.5.1	10.5.4	11.1	S.E. of treatment mean
1977 continued							
46	4	5.65	6.23	5.81	5.90	5.34	0.25
47	5	6.83	7.04	7.16	6.61	6.94	0.27
48	1	6.63	6.69	7.09	7.17	6.74	0.24
49	4	5.92	5.94	5.90	6.26	6.14	0.35

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THE PRELIMINARY CONTROL THRESHOLD FOR CEREAL APHIDS IN WINTER WHEAT IN WESTERN GERMANY

A preliminary report on three years' results of a joint experimental program

Th. BASEDOW, Chr. BAUERS and G. LAUENSTEIN

Institute of Phytopathology and Applied Zoology, University of Giessen, FRG Plant Protection Office of Schleswig-Holstein, Kiel, and Plant Protection Office of the Agricultural Board of Weser-Ems, Oldenburg/O., FRG

Summary

A report is given on the activities of a Western German project-group concerned with the control of the cereal aphids since 1980. The results and the premilinary conclusions are presented and discussed of 58 field experiments conducted from 1980 to 1982 in several wheat growing areas between Mainz in the South and Kiel in the North.

1. INTRODUCTION

Concerning the economy of cereal aphid control several critical aphid numbers have been published, which differ considerably.

Therefore, the project-group "cereal aphids" within the Working-Circle "Integrated Plant Protection" of the German Phytomedical Society decided to work out figures for the cereal aphid control, which are relevant for the modern production of winter wheat in the Federal Republic of Germany.

For this purpose from 1980 to 1982 58 field experiments were performed in Schleswig-Holstein, Lower Saxony, Nordrhein-Westfalia, Hesse and Rheinland-Pfalz. Though the investigations will be continued, the group has decided to publish the results gained up to now in a short form, to make them available to the advisory services (BASEDOW et al. 1983).

Besides the authors of this report the following colleagues took part in the joint program: R. BARTEN (Nortrup), H. GRAEL (Hodenhagen), D. HANISCH (Münster), M. HEIL (Frankfurt/M.), K. HUWALD (Hannover), G. KLEIMAND (Düsseldorf) and K. WINSTEL (Mainz).

2. METHODS

The experiments were layed out on winter wheat fields with varieties chosen according to local practice. Plot size was 25 m^2, with 4 replicates. Different plots were sprayed with the insecticide Pirimicarb (150 g a.i./ha) at different dates (gro wth stages), as practised by wheat growing farmers.

The aphids were counted weekly on ears and flag leaves in plots left without insecticides and partly also in sprayed plots, to test whether re-infestation occurred. During the initial period of aphid infestation, aphids were countend on 100 tillers per plot, when the attack increased only on 50 tillers per plot.

In most of the experiments the grain aphid Sitobion avenae F. was the most abundant species. Only in the Southern regions Metopolophium dirhodum was prevailing in several experiments. Rhopalosiphum padi L. was almost or totally absent in all experiments.

The aphids were counted on ears and flag leaves only, because the aphids sucking on lower leaves do not influence the yield significantly (WRATTEN 1978).

For the assessment of the grain yield (14% water content) and of the thousand kernel weight all plots were harvested with combined plot harvestors at dates as usual in agricultural practice.

3. PRELIMINARY RESULTS

In 24 (41%) of the experiments one spraying with Pirimicarb, mostly at the end of flowering, resulted in a significant yield increase of at least 1.5 dt/ha. This minimum increase clearly exceeded the spraying costs. At the average of the 24 experiments the yield was even increased by 5.7 dt/ha.

The highest increase of yield prevailingly occurred when the insecticide was sprayed at the end of flowering (growth stage 69). At this stage there were found one or more aphids per ear and flag leaf.

In further 21 experiments (36%), in which at the growth stage 69 there was found less than one aphid per ear and flag leaf, no yield increases were found.

On the other hand, in 13 experiments (23%) in the growth stage 69 there occurred on or more aphids per ear and flag leaf, but the application of the insecticide did not increase the yield.

From the 58 experiments considered we deduct the following statement for cereal aphid control in winter wheat in the FRG: "If at the growth stage 69 at least one cereal aphid is found per ear and flag leaf, it is in most cases economical to control the aphids in winter wheat by an insecticide.

Empirically, this control threshold was valid for 77% of the cases. In 23% the application of an insecticide did not result in a yield increase.

It must be stressed here, that this low control threshold, which in 77% of the cases gives an economically feasible control measure, is not identical with the economic threshold, which is defined differently. The economic threshold would be that number of aphids, which in the sensible growth stage of the wheat plant would cause a yield loss higher than the spraying costs. If this aphid number is reached, it is too late for a control measure, because the damage is already done. In our experiments we did not try to work out the economic threshold, because it is of more theoretical value. We only can state, that in our experiments the average maximum number of aphids, which resulted in an economical yield increase, was 13 aphids per ear and flag leaf. The maximum aphid number was reached at milky ripeness in most cases.

Though in our three year study the growth stage 69 proved to be the optimal stage for aphid control, results gained earlier show, that in some years an outbreak of the cereal aphids may also occur, if the threshold of one aphid per ear and flag leaf had not been reached at groqth stage 69. In this case, the aphid number starts increasing later (BAUERS and LINDENBERG, 1980). Therefore it is necessary to monitor cereal aphids in wheat fields up to the middle of growth stage 75 (milky ripeness). As preliminary control threshold for this stage according to field experience of 1979 (before the project-group was active), the number of 6 aphids per ear and flag leaf can be given.

Assessing aphid numbers

It is difficult and very time consuming to state the average number of "1aphid per ear and flag leaf". Therefore, a simplified method was tested, which has been developed and proposed in the GDR (FREIER and WETZEL 1978) and in The Netherlands (RABBINGE et al. 1980).

It was seen from the experiments, that the control threshold was reached, when 25% of ears and/or flag leaves were infested by aphids in the growth stage 69. In early milky ripeness the control threshold would be 80%.

For assessing the degree of the aphid infestation, 5 samples should be studied on each field, each sample consisting of 10 adjacent tillers. Sampling should be started at 5 m distance from the field border and should be continued with 10 m distance between samples, sampling being directed towards the centre of the field.

Sampling should begin in the growth stage 59 (end of heading).

Basing on the results gained up to now, the following scheme is proposed as an aid for the decision on cereal aphid control in winter wheat in Western Germany:

Growth stage 59

- less than 15% of ears/flag leaves infested = no treatment necessary, continue sampling
- 15% of ears/flag leaves infested = critical number, be well prepared for a control measure
- 20% or more ears/flag leaves infested = control is necessary

Growth stage 69

- less than 25% of ears flag leaves infested = no treatment necessary, continue sampling
- 25% or more ears/flag leaves infested = control is necessary

Growth stage 75

- less than 80% of ears/flag leaves infested = no treatment necessary
- 80% or more ears/flag leaves infested = control is necessary

If an infestation by Rhopalosiphum padi is observed, it is important to test whether only the field border is infested. If this is the case, only the field border should be sprayed.

Several authors have shown, that the predators occurring in the fields, especially certain Carabids and Coccinellids, in some years are capable of preventing an outbreak of the cereal aphids. Therefore, for cereal aphid control, selective insecticides should be chosen only, which are applied to be used at growt stage 59 and later, and which spare the natural antagonists of the aphids.

4. DISCUSSION

The control threshold of only one aphid per ear and flag leaf at the end of flowering, being the result of 58 field experiments, is the lowest figure in this respect published so far.

During the last meeting of the IOBC-Working Group "Integrated Control in Cereals" at Wageningen, The Netherland, in March 1984, criticism arose concerning the fact, that 23% of fields would receive an unnessecary insecticidal spray when applying the new control threshold (BODE and BASEDOW 1984).

But the Western German project-group had to find a figure, which would be reliable in the advisory practice. And there was no choice: either 27% of the farmers would loose the costs of spraying (ca.DM:50,--/ha), if using the low control threshold, or 3% of the farmers would have to suffer yield losses of DM 250,--/ha, when using a higher threshold of 2 aphids per ear/flag leaf. This was regarded as not being tolerable.

In contrast to other European countries, e.g. the U.K., at the end of flowering in Western Germany often less then one aphid per ear/flag leaf of wheat occur. Therefore, the use of the one-aphid-threshold is still to be regarded as being much better than the application of routine insecticide sprays for cereal aphid control, which would result in insecticidal treatments of far more than 27% of the wheat fields.

The preliminary results presented here will be finally considered and published subsequently, when the results of 1983/84 will be incorporated and when an overall statistical analysis will have been performed.

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APERCU DES TRAVAUX EFFECTUES EN BELGIQUE DE 1971 A 1983 EN VUE DE RATIONALISER LA LUTTE CONTRE LES PUCERONS DES CEREALES EN FROMENTS D'HIVER

G. LATTEUR,

Station de Zoologie appliquée de l'Etat, Chemin de Liroux, 8,
B - 5800 GEMBLOUX

I. INTRODUCTION

En Belgique, les pucerons des céréales ont commencé à attirer l'attention des milieux agricoles en 1968 après de fortes pullulations des populations de Sitobion avenae (F.).

Après des études préliminaires, nous avons entrepris, de 1971 à 1983, des recherches en collaboration avec Messieurs L. RIXHON et A. CROHAIN, de la Station de Phytotechnie de Gembloux et Messieurs les Agronomes de l'Etat des services extérieurs du Ministère de l'Agriculture.

Au cours de ces années, une masse importante de données ont été recueillies. Actuellement, une étude statistique, dirigée par le Dr. R. OGER du Bureau d'Informatique et de Statistique appliquées de Gembloux, est en cours. Elle devrait aboutir à un modèle rationnel de lutte contre les pucerons des céréales qui intègrera l'action des principaux auxiliaires.

2. METHODES

De 1971 à 1983, l'évolution des populations aphidiennes a été suivie dans 63 champs, toujours par le même observateur. Les comptages de pucerons étaient effectués chaque semaine, du début à la fin des infestations. Chaque espèce (S. avenae, Metopolophium dirhodum (Wlk .) et Rhopalosiphum padi (L.) était comptée séparément sur des talles en place. Le nombre de talles choisies pour les observations était compris entre 200 et 25 par parcelle (répétées 4 à 8 fois) selon le niveau d'infestation.

Les organismes aphidiphages présents sur les talles observées étaient également répertoriés : nombre de pucerons momifiés par Aphidiides et par Entomophthorales, oeufs, larves et adultes de coccinelles, larves de syrphides. Dans certains champs, des études plus précises sur l'action des Hyménoptères parasites et des Entomophthorales ont été réalisées en procédant au laboratoire à des élevages de pucerons récoltés au champ.

Les essais relatifs à l'influence des pucerons sur le rendement ont été réalisés dans des champs de froments d'hiver selon la méthode des blocs répétés de 4 à 8 fois et comprenant des parcelles dont la surface récoltée était comprise entre 150 et 200 m2. Dans les parcelles traitées, l'élimination des pucerons a été effectuée, de 1971 à 1975, avec du menazon, et de 1976 à 1983, avec du pirimicarb, tous deux des aphicides relativement spécifiques. Afin d'éviter les réinfestations sensibles de pucerons dans ces parcelles, une seconde, voire même une troisième application d'insecticide était réalisée si nécessaire. En tout, 40 essais ont été réalisés. Dans les parcelles témoins, l'évolution des populations aphidiennes était suivie du début à la fin naturelle des infestations comme décrit ci-avant.

3. RESULTATS

3.1. Evolution et importance des populations

Dans notre pays, les deux espèces qui dominent dans les froments sont M. dirhodum et S. avenae. Les populations de R. padi sont, quant à elles, la plupart du temps négligeables.

Les représentants de M. dirhodum et de S. avenae colonisent les froments ensemble vers la mi-mai, début juin, en provenance de leurs hôtes d'hiver. Les populations qui en résultent ont une évolution assez parallèle. mais celles de la première espèce regressent souvent quelques joursavant celles de la seconde.

Le maximum de développement des populations peut déjà être atteint vers le 10 juin, mais en général, c'est entre le ler et le 20 juillet qu'il est observé. Les densités moyennes maximums par talle que les populations de M. dirhodum et de S. avenae peuvent atteindre sont comprises entre quelque 1 et 20 individus.

Bien qu'il y ait souvent des variations dans l'importance des populations de champ à champ, nous avons remarqué que, dans une même année, la grande majorité des champs de nos zones céréalières recelaient des populations dont la densité était relativement semblable et dont l'évolution était parallèle.

3.2. Action des auxiliaires

Les auxiliaires sont en général d'autant plus efficaces dans la limitation des populations aphidiennes qu'ils sont présents tôt en leur sein.

Les premières momies d'Aphidiides sont la plupart du temps trouvées en même temps que les premiers pucerons des céréales ou peu après. Les données que nous avons recueillies au sujet de ces parasites semblent bien démontrer qu'ils peuvent être suffisamment nombreux en début de saison que pour éviter une multiplication dommageable de leurs hôtes. Nous estimons qu'il est nécessaire d'en tenir compte lorsqu'on tente de prévoir l'évolution des populations de pucerons.

Les Entomophthorales peuvent apparaître en même temps que les Aphidiides voire même avant, mais sont en général plus tardives. Leur action en début de saison n'est pas négligeable et certaines enzooties peuvent s'avérer très efficaces au sein de populations faibles. Cependant, dans la majorité des cas, elles sont surtout actives lorsque la densité aphidienne atteint et dépasse les 10 individus en moyenne par talle. Elles peuvent alors jouer un rôle décisif mais cependant trop tardif que pour éviter des dégâts dommageables.

Les larves de syrphides sont rarement décelées avant la mi-juin. Les densités que l'on observe se situent entre environ 1 et 10 larves pour 1000 pucerons. Elles sont très souvent présentes mais sont dans l'ensemble trop tardives que pour maîtriser des populations aphidiennes en multiplication active.

Les coccinelles adultes peuvent apparaître très tôt dans les céréales, vers la mi-mai, alors même qu'il n'y a pas ou très peu de pucerons. Leurs larves sont cependant nettement plus rares que celles des syrphides et plus tardives encore. Nous n'avons détecté leur présence en nombre relativement important qu'en 1976, année particulièrement chaude et sèche.

3.3. Influence des pucerons sur le rendement des froments

Dans le tableau 1 figurent les résultats des essais effectués dans le but de mesurer l'influence des populations aphidiennes (M. dirhodum + S. avenae) sur le rendement des froments d'hiver. On constate que, pour un même nombre maximum de pucerons atteint dans l'objet témoin, les différences de rendement correspondantes sont très variables. Cette observation semble bien démontrer que l'action des insecticides utilisés ne se limite pas toujours à éliminer les pucerons ou que l'action des pucerons est elle-même sous la dépendance de facteurs autres que la seule importance de leurs populations.

Tableau 1. Influence des pucerons sur le rendement des froments d'hiver.
(1) Différence moyenne de rendement en kg/ha entre l'objet traité et l'objet témoin.
(2) Nombre maximum moyen de pucerons atteint dans l'objet témoin.

Différence non significative (α = 0,05)				Différence significative (α = 0,05)			
Localité	année	(1)	(2)	Localité	année	(1)	(2)
Clavier	1971	+ 161	2	Doel 1	1972	+ 661	20
Gembloux	1972	+ 49	6	Doel 2	1972	+ 479	18
Koolskamp	1972	- 147	1	Milmort	1972	+ 700	25
Nivelles	1972	- 74	6	Ooïke	1972	+ 491	27
Vellereilles	1972	- 66	7	Tongres	1972	+ 723	38
Clavier	1973	+ 223	5	Milmort 1	1973	+ 519	6
Doel	1973	+ 105	7	Milmort 2	1973	+ 298	5
Gembloux	1973	- 93	2	Milmort 1	1974	+ 336	17
Tongres	1973	+ 42	4	Milmort 2	1974	+ 305	17
Sars-la-Buis.	1973	+ 273	5	Milmort	1976	+ 225	9
Nivelles	1973	+ 104	2	Milmort	1977	+ 821	17
Tourinnes	1973	+ 176	7	Milmort	1979	+ 900	24
Wortegem	1973	+ 44	2	Ath	1981	+ 797	25
Clavier	1974	+ 253	4	Ligney	1981	+ 595	18
Gembloux	1974	- 102	3	Ooïke	1981	+ 527	16
Nivelles	1974	+ 68	2	Tourinnes	1983	+ 383	6
Sars-la-Buis.	1974	- 152	3				
Tourinnes	1974	- 202	2				
Tongres	1974	+ 112	3				
Milmort	1975	+ 76	12				
Milmort	1978	- 200	1				
Milmort	1980	+ 293	5				
Gilbeek	1982	- 165	3				
Thuin	1982	+ 46	3				
Moyenne		+ 34	4	Moyenne		+ 547	18

Sur la figure 1, construite à partir des résultats du tableau 1, on a tracé une courbe qui représente le type de relation existant entre l'importance des colonies aphidiennes et leur influence sur le rendement. On remarque que cette dernière semble légèrement plus que proportionnelle au nombre de pucerons. Ainsi par exemple, une population qui, au cours de son évolution atteint un maximum de 5 pucerons occasionnerait une diminution de rendement moyenne de l'ordre de 70 kg/ha, un maximum de 10 pucerons entraînerait une perte d'environ 180 kg/ha, etc. Cette courbe permet de déterminer le seuil à partir duquel une population aphidienne est en moyenne économiquement dommageable.

Nous avons vérifié si, comme cela fut observé par nos collègues hollandais, l'influence d'une même population aphidienne augmentait avec le niveau de production du froment. Dans ce but, nous avons, à partir des résultats des essais ayant procuré des augmentations significatives de rendement, calculé l'influence relative des pucerons sur la production du froment. L'influence relative des pucerons a été obtenue en divisant l'augmentation de rendement enregistrée par l'indice puceron correspondant (Tableau 2). En comparant les données des colonnes 3 et 6 du tableau 2, et mis à part les résultats obtenus à Milmort 1 et 2 (1973) et à Tourinnes (1983), il n'apparaît nullement que la nuisance relative

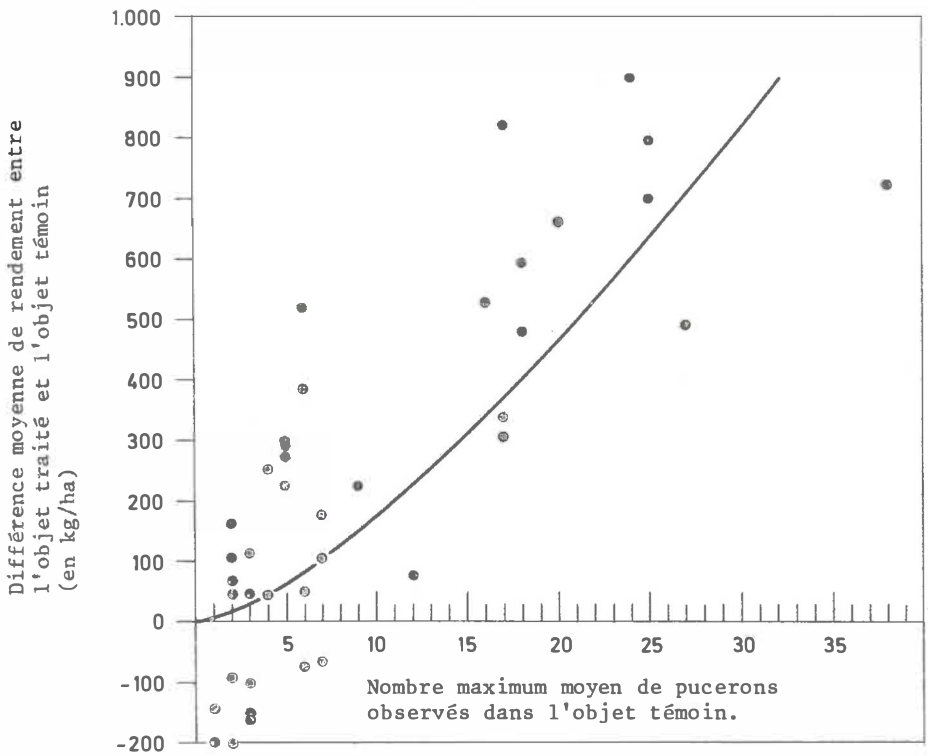


Fig. 1. Influence des pucerons (M. dirhodum + S. avenae) sur le rendement des froments d'hiver.

des pucerons soit proportionnelle au niveau de production du froment. La tendance qui se dessine est plutôt inverse.

4. ORGANISATION DE LA LUTTE RATIONNELLE CONTRE LES PUCERONS

En Belgique l'organisation de la lutte rationnelle contre les pucerons a trois objectifs :
1) déterminer les agriculteurs à n'utiliser contre ces déprédateurs que les deux seuls insecticides agréés à cet effet, le pirimicarbe et la phosalone, tous deux relativement spécifiques ;
2) éviter qu'un traitement insecticide se fasse systématiquement lors de l'application des fongicides à l'épiaison. A cette époque, vers la mi-juin, les populations aphidiennes dépassent très rarement le niveau de 1 individu en moyenne par talle et toute prévision sur leur évolution est quasi impossible. D'autre part, cette intervention ouvre la voie à une seconde car elle ne préserve pas la céréale de nouvelles invasions d'ailés et appauvrit considérablement le milieu en auxiliaires ;
3) prévoir l'évolution des populations aphidiennes avec suffisamment d'acuité que pour minimiser le risque de prendre une mauvaise décision.

Afin de satisfaire au 3ième objectif, l'évolution des populations aphidiennes et de leurs auxiliaires est suivie avec précision dès le mois de mai chaque semaine dans 10 à 15 champs dispersés dans les zones céréalières du pays. Notre prognose est basée sur les observations suivantes :
1) des populations de 5 individus (M. dirhodum + S. avenae) en moyenne par talle peuvent être tolérées puisqu'elles n'entraînent qu'une perte moyenne d'environ 70 kg/ha (fig.1).

Tableau 2. Influence relative des pucerons par rapport à l'importance du rendement du froment d'hiver.
(1) Rendement moyen (kg/ha) de l'objet témoin classé par ordre décroissant.
(2) Augmentation de rendement significative (α = 0,05) enregistrée dans l'objet traité par rapport à l'objet témoin (kg/ha).
(3) Indice-puceron (°) du témoin (M. dirhodum + S. avenae) calculé depuis la date du 1er traitement aphicide jusque la disparition naturelle des pucerons.
(4) Influence relative des pucerons = $\frac{(2)}{(3)}$

Localité	année	(1)	(2)	(3)	(4)
Milmort	1976	8.716	225	134	1,7
Milmort 1	1974	8.564	336	334	1,0
Milmort 2	1974	8.478	305	334	0,9
Milmort 1	1973	8.285	519	99	5,2
Tourinnes	1983	8.029	383	66	5,8
Milmort 2	1973	7.975	298	79	3,8
Ligney	1981	7.396	595	258	2,3
Milmort	1979	6.933	900	513	1,8
Ooïke	1981	6.438	527	293	1,8
Milmort	1972	6.231	700	388	1,8
Ath	1981	6.152	797	369	2,2
Doel 1	1972	5.655	661	258	2,6
Doel 2	1972	5.370	479	220	2,2
Tongres	1972	5.188	723	393	1,8
Ooïke	1972	5.000	491	265	1,8
Milmort	1977	4.817	821	282	2,9

(°) Indice puceron = la somme du nombre moyen de pucerons observés par talle et par jour pendant la période considérée.

2) le coût d'un traitement équivaut actuellement, lorsqu'on totalise le prix du produit, celui de l'utilisation du tracteur et du pulvérisateur et celui des pertes minimum inévitables lors du passage des engins, à quelque 170 kg de froment / ha, non compris le bénéfice que l'agriculteur est en droit d'espérer de cet investissement et dont il est seul juge. Cela correspond à une population moyenne maximum de 10 individus par talle ;
3) dans la majorité des cas, les populations aphidiennes ne commettent pas de dommages économiquement sensibles aux froments (tableau 1).

Tant que les populations ne dépassent pas le niveau de 5 individus en moyenne dans les champs surveillés, le conseil de ne pas intervenir est maintenu. Lorsque cette limite est dépassée dans un de ces champs, la gravité de la situation est évaluée dans les 2 ou 3 jours qui suivent en se basant sur la vitesse de multiplication aphidienne, sur la précocité relative des pucerons par rapport au stade phénologique de froment et sur l'action des auxiliaires, en particulier des Aphidiides. La situation du moment est comparée avec celles qui ont été observées précédemment et enfin, les conseils sont formulés et diffusés par les média (radio, télévision, journaux agricoles). Il est en plus recommandé aux agriculteurs d'évaluer l'importance des populations afin de minimiser le risque de prendre une mauvaise décision. Ce système de prognose est en voie d'être modélisé.

STUDIES IN THE ECOLOGY AND CONTROL OF CEREAL APHIDS IN WINTER WHEAT IN CENTRAL SPAIN

P. CASTANERA & C. GUTIERREZ

I.N.I.A. Depto. Proteccion Vegetal, Aptdo. 8.111 - 28040. MADRID

1. Location and Experimental design

Experiment have been carried out during 1980-84 at "El Encin", Alcala de Henares, Madrid, to study the ecology and damage assesment of cereal aphids.

Every year winter wheat was sown after either Triticum turgidum or Hordeum vulgare on a 0,6 ha. field. The cultivars used were Pané 247 in 1980-82 and Talento in 1983-84. A rondomised block design was used each year with three replicates (Plot size 20 x 20 m) in 1980-81 and four replicates in 1982-84, being the plot size 10 x 10 m the last two years. Sampling of the aphid populations and the application of pesticides were faciclitated by the provision of tramlines.

The treatment was one spray applied at growth stage (G.S.) 60-65 of Zadoks Scale, the chemicals used were:

- Pirimicarb, at 140 g. a.i./ha.
- Dimethoate, at 350 cc. a.i./ha.

2. Aphid species and population development

Monitoring of the aphid population started at the beginning of april and weekly estimatition were initiated from the end of april by counting their numbers on 10 or 5 shoots at each of four sites/plot when the plot size was 20 x 20 m or 10 x 10 m respectively. Parasitised aphids and stenophagous predators were collected at the same time.

The aphid species which developped significant populations from about booting (G.S., 41) to medium milk stage (G.S., 75) are shown in the Table 1.

Table 1. - Mean number of aphid/tiller at flowering (G.S., 60-61) and the subsequent peak.

Year / Aphid species	1980		1981		1982		1983	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Sitobion avenae (F)	2,9	8,3(14)	0,7	0,8(14)	2,1	2,5(7)	0,3	2,1(21)
Metopolophium dichodum (Wlk)	0,4	0,3(14)	-	-	0,2	0,2(21)	-	0,03(21)
Rhopalosiphum padi (L.)	0,3	0,1(14)	0,2	-	0,02	-	0,03	0,09(21)
Diuraphis noxia (Mord.)	-	-	-	-	-	-	-	0,9(21)

(1) : Mean aphids/tiller at Growht stage (G.S.) 60-61
(2) : Peak aphids/tiller (days after G.S. 60-61)

The extinction of the aphid populations usually occurred one week after it peaked.

Alate production is unlikely to have contributed significantly to the population decline because population density was relatively low at the population peaks and there was no sudden increase in number of potential emigrants (alati form fourth instars or alate) as would be expected prior to emigration.

The incidence of parasitoids and predators was low throughout the season every year, though mummy and aphid densities tended to rise and fall in synchrony.

High temperatures seem to be the main cause of the population decline, since maximum temperature were usually > 30°C during the second week of June, coinciding with the extinction of the aphid population.

3. Effect of chemical control on yield

Pirimicarb and Dimethoate were applied with a tractor-drawn spray boom in 1980-82 and with a knapsack sprayer in 1983-84. Aphid population were estimated just before spraying. Re-infestation did not occur in any year.

Assesments of yield were obained by cutting two 1,50 x plot length strips with a combine harverster from each plot, out of the sampling area, in the second week of July. The yield obtained are given in Table 2.

Table 2. - Total mean yield (15% R.H.), number of grain per ear and 1000 grain weight in 1980-83.

Treatment	Yield kg/ha $\pm$ S $\bar{x}$	N° grains/ ear $\pm$ S $\bar{x}$	1000 grain weight (g)
1980			
C	1845 $\pm$ 120	36.9 $\pm$ 0.6	35.5
P	2238 $\pm$ 333	40.7 $\pm$ 2.4.	37.9
D	2281 $\pm$ 359	40.3 $\pm$ 2.2	37.8
1981			
C	1046 $\pm$ 62	40.9 $\pm$ 2.4	25.9
P	1304 $\pm$ 125 °	42.5 $\pm$ 0.8	27.4
D	1241 $\pm$ 72 °	42.8 $\pm$ 1.6	27.3
1982			
C	2558 $\pm$ 159	40.8 $\pm$ 0.9	38.7
P	3028 $\pm$ 180	42.3 $\pm$ 0.4	38.9
D	2851 $\pm$ 210	41.6 $\pm$ 0.4	38.8
1983			
C	836 $\pm$ 74	17.9 $\pm$ 0.1	16.2
P	795 $\pm$ 41	18.4 $\pm$ 0.7	15.6
D	799 $\pm$ 81	18.9 $\pm$ 1.5	15.6

The analysis of variance did not show any significant differences in yield between treatments in any year but in 1981, though increases in yield were obtained in 1980 and 1982 in the treated plots. Significant difference in yield at 5% level (°) between treated and untreated plots were obtained in 1981 with very low aphid population. This unexpected decrease could be attributed to the synergic effect of the aphid population with the bad physiologycal state of the wheat at flowering due to a severe drought (194.3 mm of rainfall between January and June) this hypothesis was not confirmed in 1983, which was a rather similar year with 194.6 mm of rainfall between January and June and similar temperatures in May and June, however no significant decrease in yield of control plots was observed.

In 1984 the aphid population peaked (10.6 aphid/tiller) twelve days after flowering and no significant decrease in yield of control plots was observed, a more detailed analysis of the data is being prepared.

Therefore, it can be concluded that Sitobion avenae is the key aphid pest in central Spain, the aphid population density is usually low remaining in the crop for a short period of time (from booting to medium stage). There is not a clear key factor in the antagonists fonud in this area, it is rather a group of species acting as regulators of cereal aphid population. Weather is an important, if not the most important, factor to consider in the population development of cereal aphids on this area.

Significant decreases in yield of the control plots have been only observed one out of five years. so that if seems that chemical control of the direct damage of the aphid population is not needed most of the year.

SOME INFORMATION ABOUT CEREAL APHIDS IN FINLAND

B. LINDQVIST

Agricultural Research Centre, Institute of Pest Investigation
SF-31600 JOKIOINEN

In the last 4 years the number of aphids has been very low and therefor there has not been any greater yield losses because of aphid infestation.

The winter egg counting in March (1984) already showed that the aphid infestation will be low in the summer.

The most dominant aphid on cereals is *Rhopalosiphum padi*. *Sitobion avenae* and *Metopolophium dirhodum* occurs in smaller numbers. *R. padi* occurs on wheat, oat and barley, *S. avenae* occurs on wheat and *M. dirhodum* occurs mostly on oat.

About 25 aphids pers head or shoot has been used as the critical level motivating the use of insecticides in Finland. This summer that level was not reached at any places except for very few places in the eastern parts of the country. At those places where the critical level was reached it was reached so late that the aphids did not cause any greater harm to the cereals.

The first aphids (*R. padi*) on cereals (1984) were observed May 30. About a week later came colder and rainy period which seemed to stop the migration of aphids. The heavy rains even washed away a part of the aphids that already had migrated to the cereals.

Migrating aphids were sampled from the air with a suction trap and with a yellow water try. Both showed a migration peak at the beginning of august (1984).

LA LUTTE INTEGREE CONTRE LES DEPREDATEURS DES CEREALES EN FRANCE

L. LESCAR ET A. DE LA ROCQUE

I.T.C.F., 8, Avenue du Président Wilson
75116 PARIS

1. INTRODUCTION

Un effort particulier a été réalisé ces dernières années en France par l'A.C.T.A., l'I.T.C.F., l'I.N.R.A. et la P.V. pour raisonner au maximum la lutte contre les principaux déprédateurs des céréales à paille. Des centaines d'essais ont été réalisés dans les différentes régions de France et l'action concertée des différents organisations agricoles a notamment abouti à l'élaboration d'une brochure de vulgarisation concernant la lutte contre les ravageurs des céréales (Pucerons, Cécidomyies, Agromyza, Limaces, etc.). Dans cette brochure, les auteurs ont mis tout en oeuvre pour faire comprendre aux agriculteurs et de façon très simple, la nécessité de raisonner la lutte pour qu'elle soit rentable.

La France possède également un réseau de surveillance (réseau "CERESMAR") qui sert à collecter des informations "de masse" concernant les pucerons des céréales. Ce réseau comptait en 1982 plus de 4500 parcelles visitées durant 12 à 15 semaines à partir du stade "redressement" par 1500 observateurs. Ceux-ci ne fournissent que des fréquences d'infestations globables (espèces confondues), mais cela est suffisant pour préciser le rique et réaliser les avertissements. En ce qui concerne les cécidomyies de l'épi, des avertissements sont réalisés dans des régions céréalières grâce à des réseaux de piégeage.

Plusieurs questions restent posées, ce qui amène l'I.T.C.F., en collaboration avec les autres organisations agricoles, à poursuivre ses travaux dans différentes directions.

2. METHODES DE LUTTE

Les objectifs généraux sont :
- la définition et la quantification précise des critères permettant d'évaluer le niveau du risque: seuil de nuisibilité, incidence des conditions climatiques... (limaces, pucerons à l'automne et au printemps).
- la comparaison de l'efficacité de différents produits (pucerons, mouche grise, limaces, cécidomyies...)

2.1. Les limaces

Il s'agit d'élaborer une méthode de surveillance et d'améliorer les techniques de lutte. La nature des travaux est:
- l'étude de la biologie des principales limaces responsables des dégâts,
- la mise au point d'une méthode de surveillance des populations,
- l'incidence des techniques de préparation du sol sur le niveau des populations,
- l'amélioration de la lutte chimique, l'étude des formulations, le choix de périodes d'interventions, les modalités d'épandage.

2.2. Les pucerons à l'automne vecteurs de la J.N.O.

- Etude de l'épidémiologie du virus de la jaunisse nanisante de l'orge. Le problème à résoudre est l'estimation du délai entre l'arrivée des ailés et le début de la phase explosive de multiplication du virus.
- Comparaison de l'efficacité de différents traitements aphicides.

2.3. La mouche grise (Hylemia coarctata)

- Etude de traitements de semences et d'applications en cours de végétation.

2.4. La tordeuse (Cnephasia)

- Recherche de produits de remplacement du parathion, insecticide efficace mais dont la toxicité est très élevée.

2.5. Pucerons en cours de montaison et à l'épiaison

Il s'agit essentiellement d'étudier l'intérêt des pyréthrinoïdes dans la lutte contre les ravageurs courant montaison et à l'épiaison.

2.6. Les cécidomyies

Essai d'efficacité comparée d'insecticides lorsque le blé est attaqué à la fois par des pucerons et des cécidomyies. Recherche, parmi les aphicides bien tolérés par des abeilles, de ceux qui pourraient présenter également une bonne activité sur les cécidomyies.

3. PREVISION DE PULLULATIONS DE PUCERONS

A partir des données du réseau de surveillance du Service de la Protection des Végétaux, des pièges à succion (tours du réseau ACTAPHID) et d'observations au champ, il s'agit de mettre au point un modèle de prévision des infestations de pucerons des céréales au printemps à l'aide de paramètres climatiques. Cette étude nécessite un suivi rigoureux préalable des infestations de pucerons observées en culture et leur comparaison avec les captures effectuées dans les pièges à succion. Travail coordonné par C. DEDRYVER (INRA RENNES).

4. BIOCENOSE DES CEREALES

La tendance actuelle est aux traitements insecticides systématiques (diméthoate) dont on peut redouter les effets dits "secondaires", bien qu'ils n'aient pas été mis en évidence jusqu'à présent sur céréales à paille. Une étude est entreprise depuis 1981, et pour 6 ans, par l'I.T.C.F. en collaboration avec l'INRA et le Service de la Protection des Végétaux, l'ACTA et l'AGPM. Elle doit permettre d'estimer l'incidence des interventions phytosanitaires sur l'évolution des ravageurs, et l'ensemble de la faune auxiliaire dans le cas de rotations maïs-blé. Cette année 1982 est considérée comme le début véritable de l'expérimentation. Il est prévu ensuite de l'appliquer à une rotation maïs-blé.

SITUATION OF THE INTEGRATED CONTROL OF CEREAL APHIDS IN THE NETHERLANDS

R. RABBINGE

Departement of Theoretical Production Ecology and Laboratory of Entomology, Agricultural University, Wageningen.

1. MONITORING AND SAMPLING

A good monitoring and sampling system should be simple and easy to handle even by lay man; it should be based on sound biological knowledge and insight; it should be reliable within means that it results can be trusted; it should be labour extensive which means that a limited amount of time should be spent in observation and sampling; it should be compatible with other agronomical measures; it should be improved iteratively, and it should only cost a low sum of money.

In order develop a good monitoring method for cereal aphids one has to find an acceptable compromise for all those criteria. Simple and little time concerning is often not in agreement with reliability and accuracy. Thus the present method was developed.

Early warnings for cereal aphid, so, in the period before or at flowering are not very reliable, since the relation between aphid infestation level at ore before flowering and damage due to cereal aphids is very uncertain. The relation between aphid numbers at flowering in the wheat crop and the numbers at the peak of the population, usually at late milky ripe (DC = 77, Rabbinge et al., 1979; Cater et al., 1982), is uncertain. Thus a warning or control advice on basis of observations at flowering should be given only when already considerable numbers of cereal aphids have entered the wheat crop at that time. Simulation models may help to predict the upsurge and the peak of the population of cereal aphids, but they rely for a large extent on the initial number of cereal aphids found in the field. To determine this number several methods have been proposed (Vickerman et al., 1979). A method in which suction trap catches are used to initiate the simulation models has been demonstrated to be reliable when adequate information on the presence and effect of natural enemies is available (Carter et al., 1982). the same conclusion is drawn when actual field counts are used. Then knowledge of the numbers of cereal aphids and their natural enemies is necessary. Because of this an observation method was needed which is simple, easy to apply and labour extensive. Trapping and remote sensing techniques may seem attractive but do not take sufficiently into account the differences between fields in aphid numbers, crop development stages and yield expectation. Small differences may have considerable consequences when high yield levels are considered. (Mantel et al., 1982). Therefore a direct observation technique is needed.Such a technique has been developed (Rabbinge and Mantel, 1981; Vereijken, 1979).

This technique, based on incidence counts (percentage with aphids infested culms is determinated instead of actual counts), has shown to be reliable when the cereal aphid species Sitobion avenae, Metopolophium dirhodum and Rhopalosiphum padi are considered separately or in combination (Rabbinge and Mantel, 1981). this method applied in fields according to a well defined sampling procedure is now being used by farmers themselves in the Netherlands, and on experimental basis by farmers in Switzerland, Belgium, France, England and Sweden. (Rabbinge and Rijsdijk, 1983).

The determination of cereal aphids infestations forms a part of the monitoring activities needed in a supervised control system for pests and diseases in winter wheat (Rijsdijk et al., 1979). As with cereal aphids disease severity is also determined through incidence counts (Anonymous, 1982).

The time necessary for one observation is not more than 30 minutes for a field with a size up to 30 ha. The number of observation is circa 4 times per season and during one sampling and observation activity all important cereal diseases and cereal aphids are considered. Thus this method offers a complete monitoring system of crop growth, crop development and of pests and diseases. To help farmers to decide when observations should start, to prescribe observation frequency and to advice for spraying central guided monitoring may help.

2. POPULATION DYNAMICS OF CEREAL APHIDS

Population growth of cereal aphids has been studied in several countries of Western Europe, because of the considereable increase in the importance of cereal aphids as yield-reducing factors (Carter et al., 1980). Several simulation models of cereal aphid populations have been developed and evaluated (Carter et al., 1982; Rabbinge et al., 1979), and have been used to explain the population upsurge and collapse. The major reasons for rapid increase lie with the condition of the crop: high nitrogen availability (nitrogen levels of more than 2,5% of dry mass) stimulates reproduction and reduces development time and mortality. (Verijken, 1979). The collapse of the population is due mainly to the shift in condition of the crop at the late milky ripe stage. Emigrants, winged aphids, appear and leave the fields. The resulting population decrease is amplified by natural enemies, parasites, predators and fungal pathogens (Rabbinge et al., 1979). Detailed sensitivity analyses of simulation models of cereal aphids (mainly S. avenae), have shown the importance of different external factors on population development (Carter et al., 1982). Crop development and the initial number of aphids (at flowering) are the major factors determining rate of populations growth and time of collapse. Thus, predictive models and methods have been developed based on visual observations or sampling of the aphid density at flowering. These models appear reliable in predicting the population peak in crop development stage Decimal Code 77 (Rabbinge and Rijsdijk, 1983). Although all detailed model studies and experimental work concerns S. avenae, the great correspondence between the cereal aphid species, as far as population growth is concerned, is such that the same predictive rules can be used for all cereal aphids (Ankersmit and Carter, 1981).

Recently investigations have been made on the potentials of natural enemies to prevent an upsurge of the cereal aphid population. Detailed simulation studies, field experiments and laboratory studies (Rabbinge et al., in prep.); Ankersmit, 1982; Shirota et al., 1983 have shown that these perspectives are limited. Nevertheless work on functional responses of parasites and predators and on the effect of patchy spatial distribution of aphids on effectiveness of natural enemies continues and will hopefully lead to reasonable potentials of natural enemies in delaying or reducing the peak of the cereal aphid population.

3. DAMAGE ASPECTS

Potential yield in winter wheat is determined by crop physiological characteristics and incoming radiation. In the sixties predicted potential yields varied between 10.000 kg ha $^{-1}$ to 14.000 kg of kernels ha $^{-1}$, depending on site and harvest index. It took some time for actual yields to reach the potential yield, but now more farmers are becoming able to produce more than 8000 kg of winter wheat ha $^{-1}$. Plant breeding led to the introduction of very lodging-resistant, highly nitrogen-responsive varieties with an excellent harvest index (.50-.55). Agronomy practices here improved, with appropriate soil treatment, sowing bed preparation, nitrogen fertilization and use of growth regulators all leading to a form of wheat cultivation that produces very high yields. This combinaition of agronomic measures determines the attainable yield level. When water is abundantly available and weather conditions are moderate, yield variation is large only if yield reducing factors are active and important. It has become clear during the last decades that pests and diseases are the major yield-reducing factors, and a trend towards preventive overspraying started in the early eighties in parts of Western Europe. However, in fields with low yield expectation due to inappropriate agronomic measures, spraying activity should be limited. A poor crop can't become a rich crop by increasing spraying activity. A pesticide will not increase kernel number or number of tillers but can only protect a crop against pests and diseases.

Yield decrease due to cereal aphids depends on number and residence time of cereal aphids on the crop (Rautapää, 1966). Analyses of a long series of experimental data have shown that both aphid index (The integrated number of cereal aphids in time) and peak density (the number of aphids per tiller at crop devepment stage 77) have a high correlation with yield loss (Rabbinge and Mantel, 1981). Detailed analysis has shown the different components of yield loss. Primary suction damage, due to assimilate consumption, and secondary damage due to honeydew covering the leaves, can be quantified. It has been demonstrated experimentally, with a good theoretical basis, that honeydew has a direct effect on leaf photosynthesis and transpiration (Rabbinge et al., 1981) and that it promotes senescence. The importance of the effect on photosynthesis and crop growth rate has been analyzed, with simulation studies, and appears to be considerable. Simulation result (Rabbinge et al., in prep.) and analysis of field data (Mantel et al., 1982) demonstrate the contribution of each damage components total yield loss at different yield levels.

At a yield level of circa 5500 kg ha $^{-1}$, assimilate consumption accounts for 59% of the total yield loss due to aphid damage, while at circa 7500 kg ha $^{-1}$ level only 16% can be ascribed at high levels. In Table 1 an estimate is made of damage due to different components. It is demonstrated that, especially at high yield loss. This is confirmed by the results of a computer simulation model (Rabbinge et al., in prep.). High yield levels are mainly due to an extended kernel filling period and a reduction of this period will result in a yield loss of up to 200 kg ha $^{-1}$ day $^{-1}$. Normally the effect on length of kernel filling period is not discrete but promotion of senescence does influence the net growth rate during an extended period.

Yield in kg ha $^{-1}$ x 100	Yield loss in kg ha $^{-1}$	Suction damage due to cereal aphids in kg ha $^{-1}$	Honeydew effect in kg ha $^{-1}$	Ageing of the plant	Shortening kernel filling period (days)
< 55	∿ 157	∿ 100	∿ 20	∿ 0	0
55-65	∿ 303	∿ 157	∿ 110	∿ 40	0
65-70	∿ 459	∿ 157	∿ 120	∿ 180	∿ 1
70-75	∿ 702	∿ 157	∿ 130	∿ 420	∿ 2
> 75	∿ 995	∿ 157	∿ 140	∿ 700	∿ 3

Table 1. Composition of yield loss in kg ha $^{-1}$ due to cereal aphids in winter wheat at different production levels and a peak density of 15 aphids per tiller.

This yield level dependent damage relation does result in damage thresholds which among other factors depends heavily on expected yield.

At yield levels lower than 5000 kg/ha, still very normal in many places in Europe, a considerable number of cereal aphids (more than 15 per tiller) can be tolerated whereas the tolerance at high yield levels, which are becoming more and more normal in Europe, is much more limited.

SITUATION OF THE INTEGRATED CONTROL OF CEREAL APHIDS IN SWEDEN

K. ANDERSON

Swedisch University of Agricultural Sciences, Research Information Centre, Division of Plant Protection, Box 44, S-230 53 ALNARP

1. Species of aphids and species of cereals

Barley and oats

Without any comparison the oat bird cherry aphid (R. padi) is the most important species. However together with the oat bird cherry aphid also the grain aphid (S. avenae) and the rose grain aphid (M. dirhodum) occur in low numbers. Roughly, heavy attacks - more than 50 aphids per tiller in many fields over wide areas - occur twice a decade (two years out of ten). It should be stressed, that the oat bird cherry aphid is a pest of big economic importance on barley and oats in the scandinavian countries and that there seems to be a big difference between this of Europe and the continent.

Wheat

The grain aphid is the most important one. The rose grain aphid (M. dirhodum) is common, but heavy attacks are uncommon (such a year was 1979, when this species was a heavy pest on the continent too). Also the oat bird cherry aphid can be found on wheat but usually only in low or very low numbers. Exceptions may be years when the aphid is very frequent on barley and oats, but the populations do never reach the same peak numbers as in barley and oats. Just as to the rose grain aphid the oat bird cherry aphid prefer living on leaves and steme and stay there even after heading and anthesis.

Rye

The population densities are usually much lower than in other cereal crops. Only a few field experiments have been carried out and according to what we now know, chemical control is not or only very seldome justified. Probably the grain aphid is the most important one on rye, but is years when when the oat bird cherry aphid is very frequent even this species can be found on rye.

2. The importance of aphid population

The grain aphid on wheat

Results from field experiments have shown that the yield loss is not only dependent on population density but the yield level too. Our results are in good agreement with those from the Netherlands an which are in use in the Epipre model.

The oat bird cherry aphid

Our experiments have demonstrated, that it is rather easy to find significant linear relationsships between population density (attacks in field trials)

and yield loss. This relationship varies between years and probably with pesticide used. Longterm and broadspretrum insecicides such as pyrethroids seem to give a somewhat higher constant and regression coefficient (probably due to effects on other pests). The linear relationships can be summarized as follows
y= (0,1-0,2) x + (1-2)
Y= yield lose in dt (100 kg) per ha
x= number of aphids on an average per tiller

3. Control thresholds recommended for aphids on cereals

Grain aphid on wheat

Expected yield dt/ha	Deveopment stage 59 aphids per tiller	59 % infested tillers	69 aphids per tiller	69 % infested tillers	73 aphids per tiller	73 % infested tillers
75	1	25	2	50	5-6	80
65-75	1	25	4	70	8-10	90
55-65	2	50	5-6	80	10-15	90
55	2	50	8-10	90	10-5	90

The thresholds are based on aphids on heads and flagleaves only. The threshold values are expressed partly as number of aphids per tiller (head) partly as % infested tillers (heads).

Oat bird cherry aphid on barley and oats.

15-20 aphids on an average per tiller.
Exceptions: Areas with high risks of barley yellow dwarf virus or fields late sowed or the grain aphid is the dominating species: 10 aphids on an average per tiller.

4. Period of infestation

Oat bird cherry aphid

The aphid is dependent on their winterhosts in Sweden. Migration takes place in early june in the most southern parts of country, in middle of june in the middle parts of Sweden. At this time the crop normely has reached growth stage 30-35 (decimal scale). The aphid population then increase in number towards stage 70-73 (about 2 weeks after the heading is finished), when the population more or less suddenly collapse.

The grain aphid

Follows the same development scheme as on the continent. Means that it usually reaches its peak number at stage 75-77. The rose grain aphid. If this is the only or quite dominating species it seems as if the aphid population can increase in number towards perhaps stage 80. This was the case in 1979.

5. The impact of cereal yield

The grain aphid on wheat

The relationship between yiels lose and cereal yield used in Epipre is in agreement with swedish result (yield lose increase with the yield level). As already mentioned, the threshold values recommended are adapted to the expected yield level.

The oat bird cherry aphid

No relationship between yield level and yield lose has so far been found.

SOUS GROUPE " ECOLOGIE "

SUBGROUP " ECOLOGY "

RAPPORT DE SYNTHESE SUR LES ACTIVITES DU SOUS-GROUPE "ECOLOGIE DES PUÇERONS DES CEREALES"

C.A. DEDRYVER, G.W. ANKERSMIT, Th. BASEDOW, E. BODE,
N. CARTER, P. CASTAÑERA, R. CHAMBERS, A. DEWAR,
S. KELLER, G. LATTEUR, B. PAPIEROK, W. POWELL,
R. RABBINGE, N.W. SOHERTON, K. SUNDERLAND,
N. WILDING et S.D. WRATTEN

Summary

This is a report of the activities of scientists belonging to the sub-group "aphid ecology". In six chapters, the main results obtained by the members of the sub-group concerning cereal aphid biology, entomophthorales, parasitoïds, specific predators, polyphagous predators and models, are pointed out and discussed.

INTRODUCTION

La création du sous-groupe "Ecologie des pucerons des céréales" au sein du groupe de travail "Lutte intégrée en céréales" de l'OILB, remonte à 1975. Elle répondait à la nécessité de disposer d'une vision géographiquement large de la biologie et de l'écologie des pucerons des céréales et de leurs principaux ennemis naturels, par le moyen de résultats scientifiques comparables que l'on puisse utiliser dans l'établissement de systèmes efficaces de prognose contre ces pucerons.

Si les recherches effectuées sur ces sujets depuis bientôt une dizaine d'années ont été guidées par des impératifs essentiellement nationaux, souvent différents d'un pays à l'autre, les fréquentes réunions des membres du sous-groupe ont amené ceux-ci à bien se connaître et à harmoniser progressivement (et encore aujourd'hui imparfaitement) méthodes et techniques d'études employées. De ce fait la comparaison de nombreux résultats devient possible. La somme des recherches entreprises constitue un important travail d'écologie au cours duquel la plupart des facteurs entrant en jeu dans la dynamique des populations des pucerons des céréales ont été abordés.

Le rapport ci-dessous a été rédigé à partir de documents et publications fournis par les membres du sous-groupe, en particulier le chapitre 5 sur les prédateurs polyphages est largement inspiré d'un rapport précédemment établi par S.D. WRATTEN. Il ne résume qu'imparfaitement et de manière exhaustive les recherches entreprises et résultats obtenus. Du bon fonctionnement futur du sous-groupe, dépendra le renforcement de secteurs de recherche jusqu'ici négligés ou peu abordés.

	Printemps	Automne
Coulogne (62)		
1976	+	+
1977	+	+
1978	-	+
1979	+	+
1980	+	+
Mur-de-Bretagne (22)		
1979	+	+
1980	+	-
1981	-	+
1982	+	

TABLEAU 1 : colonisation (+) ou absence de colonisation (-) des *P. padus* à Coulogne et à Mur-de-Bretagne.

(D'après DEDRYVER, 1983)

1 - BIOLOGIE GENERALE DES PUCERONS DES CEREALES

Nous évoquerons dans ce chapitre quelques-uns des principaux résultats sur la connaissance des cycles des pucerons des céréales, de l'action des facteurs climatiques et de la plante-hôte sur la dynamique de leurs populations, obtenus aussi bien par des travaux d'écologie de terrain que par des expérimentations de laboratoire. Du fait du caractère vaste du sujet, les différentes parties en seront moins détaillées que dans les chapitres suivants.

1.1. - CYCLES BIOLOGIQUES DES PUCERONS DES CEREALES

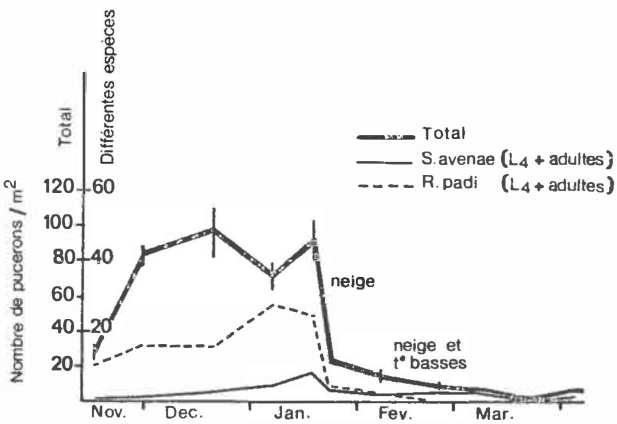
Quels sont les cycles biologiques des pucerons des céréales ? Cette question est fondamentale mais, paradoxalement, on ne peut actuellement y répondre que pour un nombre très limité de régions, et encore, sans avoir une vue très précise des choses :

En France, dans les régions océaniques de l'Ouest, les 3 espèces (Metopolophium dirhodum, Sitobion avenae et Rhopalosiphum padi) hivernent, de manière anholocyclique, sur repousses de blé et d'orge, et probablement sur toutes sortes de graminées présentes en hiver, sauf dans le cas d'hivers particulièrement rigoureux, type 1978-1979. En dépit de cette anholocyclie très générale, on trouve, en cherchant bien, des M. dirhodum holocycliques sur Rosa et des R. padi holocycliques sur Prunus padus, dans les rares endroits où cet arbuste est présent. Par contre, on n'a jamais trouvé de S. avenae holocycliques. Dans la région parisienne, il semble que l'anholocyclie soit également la règle, mais que les chances de "réussite" de ce type d'hivernation soient moins bonnes et, plus généralement, diminuent d'Ouest en Est du fait de la rigueur croissante du climat hivernal local . Signalons enfin que dans le Nord et l'Est de la France, l'hivernation de M. dirhodum sur Rosa et de R. padi sur P. padus semble fréquente, en plus du maintien hivernal de populations anholocycliques (tabl. 1).

En Grande-Bretagne, les modalités d'hivernation des pucerons des céréales ont été étudiées par HAND (1980) ainsi que DEWAR et CARTER (1984) à Rothamsted et dans le Hampshire et il semble que les principaux résultats qu'ils ont obtenus soient valables pour toute la partie Sud de l'Angleterre : S. avenae et R. padi y paraissent assez largement anholocycliques et passent l'hiver sur le ray-grass. Si celui-ci est pâturé au cours de l'hiver, les pucerons n'hivernent pas complètement, s'il ne l'est pas (cas des jeunes ray-grass), au moins S. avenae survit jusqu'en mars (fig. 1.). M. dirhodum n'est pas trouvé en hiver sur graminées et paraît essentiellement holocyclique sur Rosa.

Si l'on excepte la Scandinavie, pour laquelle des études

Fig. 1 : densité de pucerons sur jeunes Ray-Gras en hiver 77-78. (D'après HAND, 1980).



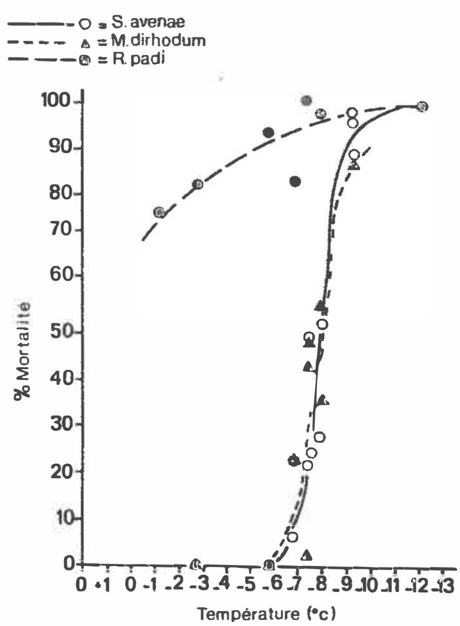


Fig. 2 : mortalité de pucerons adultes aptères après un séjour de 3 heures à différentes températures inférieures à 0°C. (D'après WILLIAMS, 1980).

(LEATHER, 1981) ont montré l'holocyclie complète de ces pucerons, on ne dispose, pour les autres régions d'Europe, que de renseignements assez fragmentaires, comme l'étude menée par BODE (1981), de la phase holocyclique de R. padi sur P. padus en Allemagne.

1.2 - ACTION DE LA TEMPERATURE SUR LES PUCERONS

Les variations du taux intrinsèque d'accroissement naturel des pucerons des céréales en fonction de la température ont été étudiées à Rothamsted (DEAN, 1974) ; par la suite, on s'est surtout intéressé, en liaison avec les problèmes d'hivernation, à la tolérance des pucerons des céréales aux basses températures.

D'après les travaux de WILLIAMS (1980) à Southampton (fig. 2), R. padi est beaucoup plus sensible aux basses températures que M. dirhodum et S. avenae. Pour R. padi, plus de 80 % de la population est tuée entre -2 et -3° C et 100 % est tuée à-6° C. Pour M. dirhodum et S. avenae, la mortalité commence aux environs de -6° C, elle n'est totale qu'entre -9 et -12° C. Il a également été mis en évidence le rôle de la rapidité des variations de températures dans la mortalité due au froid : plus le "coup de froid" est brutal, plus la mortalité est forte, de même des pucerons "habitués" pendant plusieurs jours à des températures basses (+ 6° C) supportent beaucoup mieux le gel que les autres.

1.3 - QUELQUES ASPECTS DU ROLE DE LA PLANTE-HOTE

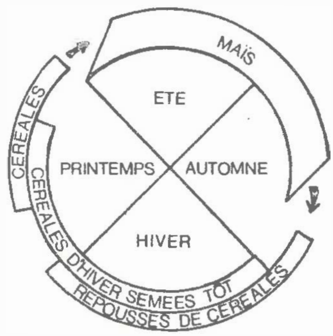
Sur le blé et les autres céréales à pailles, VEREIJKEN, (1979) à Wageningen, a montré le rôle de l'âge de la plante sur la fécondité et la mortalité de S. avenae et R. padi. Avant la fin de la floraison , la fécondité est maximale et la mortalité minimale, pour les deux espèces ; à la maturité laiteuse, l'épi devient moins favorable à S. avenae et franchement défavorable à R. padi. Des résultats allant dans le même sens ont été obtenus en Grande-Bretagne par WATT (1979).

L'effet de vieillissement de la plante-hôte se traduit également (ANKERSMIT ET DIJKMAN, 1983) par une augmentation constante de la proportion d'ailés produite par S. avenae sur l'épi de blé, entre l'épiaison et la maturité pâteuse. Lorsque celle-ci est atteinte, la totalité de la population évolue très rapidement en formes ailées.

Enfin, toujours sur le blé, VEREIJKEN (1979) a montré que la quantité d'azote apportée par la fertilisation paraît influer sur la fécondité de S. avenae dans le sens d'une fécondité croissante pour des doses d'azote de plus en plus élevées.

Sur le maïs, MOREAU et DENECHERE (1976) ont mis en évidence, à Versailles, la résistance des jeunes plants (2 feuilles) à l'installation de R. padi.

Fig. 3 : Anholocycle de R. padi (D'après DEDRYVER, 1981)



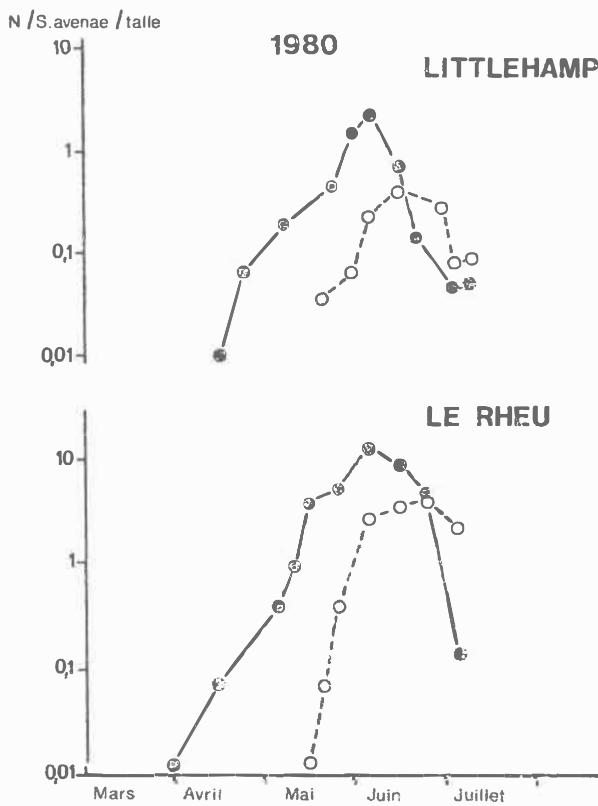


Fig. 4 : développement des populations de S.avenae sur semis de blé précoces (—•—) et tardifs (--- o ---) à LITTLEMHAMPTON et au RHEU.

1.4.- ROLE DES SUCESSIONS CULTURALES ET DE L'EVOLUTION DES TECHNIQUES DE CULTURE

L'extrême abondance des graminées cultivées ou spontanées dans tous les assolements européens, ajoutée aux tendances à l'anholocyclie que semblent, dans beaucoup de régions, manifester les pucerons des céréales, fait que l'on assiste tout au long de l'année à une multiplication parthénogénétique continue de ces pucerons, sur des hôtes successifs, sans que bien souvent, il n'y ait de réelles possibilités de rupture de cycle (fig.3).

1.4.1.- Rôle de la date de semis du blé d'hiver

C'est une conséquence directe des possibilités d'hivernation anholocyclique des pucerons, qui n'est donc valable que pour les régions ou celle-ci se produit fréquemment. Signalée dès 1972-1973 par LATTEUR (1976) à Gembloux, le rôle de la date de semis du blé d'hiver sur la dynamique printanière des pucerons des céréales, a été étudié, de 1980 à 1982 à Rothamsted par DEWAR, en 1980 à Littlehampton par CHAMBERS et al (1982), au Rheu par DEDRYVER et TANGUY (1984). Comme le montre l'exemple de la figure 4, on a une grande similitude des phénomènes à Littlehampton et au Rheu. Plus généralement, sauf lorsque l'hiver est particulièrement rigoureux, comme en 1978-1979, dans les régions européennes à climat océanique, les semis précoces de blé ou d'orge sont contaminés par les pucerons avant l'hiver et servent de réservoirs pour les populations anholocycliques hivernantes. Le résultat en est le plus souvent que les semis précoces supportent déjà des populations de pucerons non négligables au tout début du printemps, alors que les semis tardifs sont encore indemnes, et que les pics de populations sont plus élevés sur les semis précoces que sur les semis tardifs. Une autre conséquence de la colonisation automnale des semis précoces par les pucerons, et en particulier par R. padi est l'infection antéhivernale de ces semis par le virus de la Jaunisse Nanisante de l'Orge qui y occasionne des dégats beaucoup plus importants que sur semis tardifs.

1.4.2. 6 Les hôtes relais, maïs et graminées fourragères

Le rôle du maïs comme hôte relai des pucerons des céréales en été et en automne, semble très important dans les régions où il est abondamment cultivé, comme l'ont montré MOREAU dans le Bassin Parisien, et DEDRYVER et al (1983) dans l'Ouest de la France. Dans des régions plus septentrionales, où les surfaces de maïs sont plus faibles, HAND et CARRILLO (1982) en Grande-Bretagne, et ANKERSMIT (comm. pers.) aux Pays-Bas, ont également mis en évidence le rôle de cette culture qui abrite entre juillet et octobre de très importantes populations essentiellement constituées de R. padi. Dans ces dernières régions, ainsi que dans les zones plus septentrionales où le maïs n'est pas cultivé, il semble que ce sont les graminées fourragères qui constituent les principaux réservoirs estivaux de pucerons, comme l'a montré VICKERMAN (1978) dans le Hampshire.

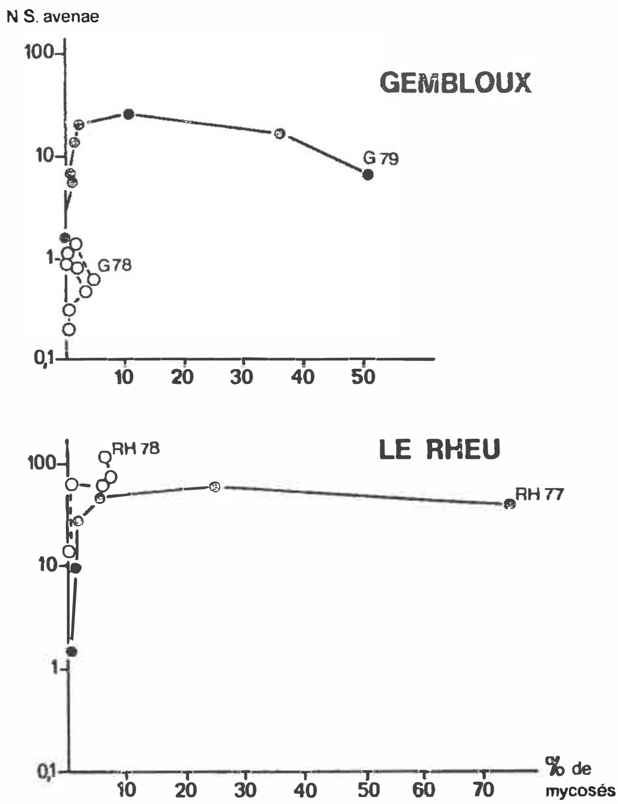


Fig. 1 : évolution de deux épizooties et de deux enzo-oties à Entomophthorales sur S. avenae étudiées à Gembloux et au Rheu.
(D'après LATTEUR, non publié et DEDRYVER, 1981).

1.5. - QUELQUES QUESTIONS SUR LES PROBLEMES GENERAUX RELATIFS A LA BIOLOGIE DES PUCERONS DES CEREALES

* On n'a pas suffisamment de références pour cartographier les cycles biologiques des pucerons dans la plupart des régions d'Europe. Cela paraît pourtant nécessaire car les dynamiques de population résultant de l'holocyclie et de l'anholocyclie sont assez différentes, du fait, entre autres, de la séparation temporelle qui s'instaure entre les pucerons et leurs ennemis naturels en cas d'holocyclie.

* Connaissant la résistance au froid des pucerons, on peut déjà cerner les régions où l'anholocyclie est possible, par examen des isothermes, à condition d'avoir quelques notions des transferts climatiques entre la zone "2 m sous abri" et le niveau du champ.

* Comment estimer l'importance écologique des réservoirs (repousses, graminées fourragères) ?

* Comment estimer l'échelle géographique des migrations printanière ?

2 - LES ENTOMOPHTHORALES

Ces champignons sont signalés par de nombreux auteurs comme d'importants ennemis naturels des pucerons des céréales dans la majeure partie de l'Europe non méditérranéenne, aussi bien dans les régions à climat océanique franc ou dégradé, telles la Bretagne, (DEDRYVER, 1981), les Iles Britanniques (DEAN et WILDING, 1971), la Belgique (LATTEUR, 1977), le Nord de la France et la Région parisienne (PAPIEROK et al, 1983), que dans des pays plus continentaux, tels que l'Allemagne (BODE, 1980) et la Suisse (KELLER et SUTER, 1980). On admet cependant que leur impact sur les populations de pucerons est d'autant plus fort et plus régulier que les régions sont plus proches de la mer ou plus généralement humides, du fait de la très grande dépendance de ces pathogènes vis-à-vis de l'humidité relative de l'air.

L'impact des entomophthorales sur les populations de pucerons a été jusqu'à présent difficile à cerner précisement, du fait de problèmes méthodologiques liés à la quantification exacte de la fraction des populations tuée par les mycoses. Le comptage des cadavres de pucerons, au champ, reflète une mortalité passée, voire cumulative sur quelques jours (temps que mettent les cadavres à se déliter au champ), mais il prend en compte la structure de la population mycosée, ce qui est important en dynamique de population. A l'opposé, l'élevage au laboratoire d'un échantillon de pucerons collectés vivants au champ, a l'avantage de donner une image temporellement exacte du parasitisme, de permettre de distinguer plus facilement les différentes espèces de champignons en cause, mais l'image du parasitisme obtenue se limite le plus souvent à la fraction de la population constituée par les stades larvaires agés et les adultes,

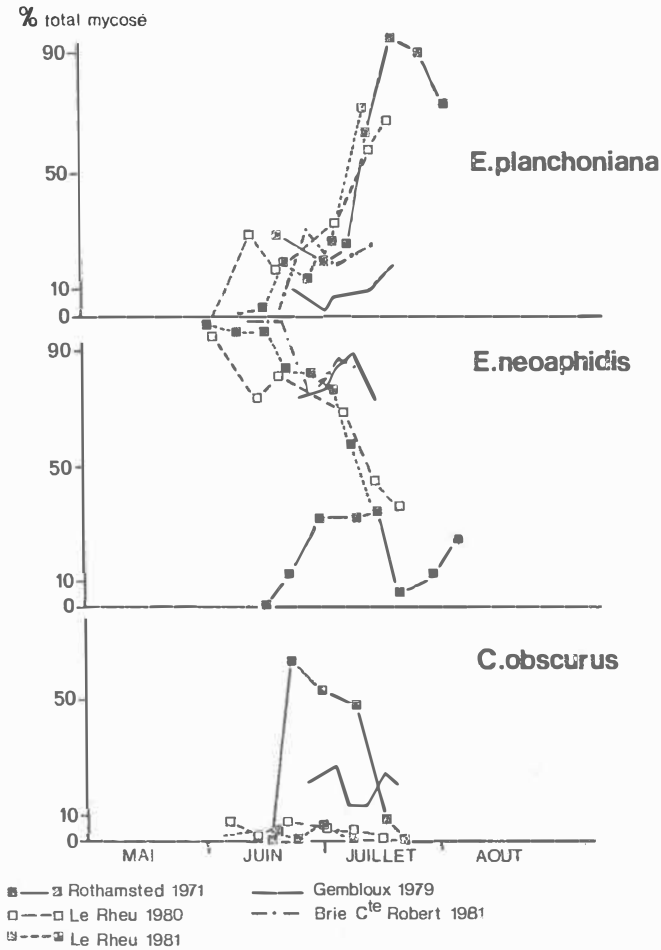


Fig. 2 : spectre d'activité de trois espèces d'entomophtorales sur les pucerons des céréales dans 4 stations différentes.
(D'après WILDING, 1972; DEDRYVER, LATTEUR et PAPIEROK, <u>non publié</u>).

dans la mesure où il est difficile, voire impossible, de récolter un échantillon de la population conforme à la structure de celle-ci.

2.1. - IMPORTANCE ECOLOGIQUE DES ENTOMOPHTHORALES

2.1.1. - Aperçu géographique de l'impact des entomophthorales

Le tableau 1 indique les pourcentages maximum de pucerons mycosés obtenus au cours de diverses expérimentations effectuées dans plusieurs régions d'Europe. Bien qu'il soit impossible de comparer sérieusement des situations qui diffèrent à la fois par leur implantation géographique et par l'année de leur étude, on peut dégager certaines tendances. Dans toutes les stations d'étude, un pourcentage important des populations peut être tué par les Entomophthora, l'impact de ces pathogènes paraissent spécialement fort et surtout régulier dans les régions très océaniques comme la Bretagne.

Sur la figure 1, sont représentées les évolutions des pourcentages de pucerons mycosés et du nombre du pucerons, en fonction du temps, dans deux stations géographiquement très différentes, Le Rheu (DEDRYVER, 1981) et Gembloux (LATTEUR, n.p.). L'allure des épizooties (G 79, Rh 77) et des enzooties (G 78 et Rh 78) est très comparable dans les deux localités. Dans les deux cas d'épizooties bien nettes, plus de 50 % des pucerons sont tués par les entomophthorales.

La figure 2 indique le spectre d'activité des principales espèces pathogènes des pucerons des céréales, tel qu'il a pu être étudié dans diverses régions d'Europe. Dans toutes les stations d'étude (Rothamsted, Gembloux, Darmstadt, Le Rheu, Brie Comte-Robert) on trouve les trois même pathogènes : Erynia neoaphidis, Conidiobolus obscurus et Entomophthora planchoniana. L'étude de ce spectre d'activité, malheureusement établi le plus souvent pour des années différentes selon les stations, met en évidence différences et similitudes selon les régions :

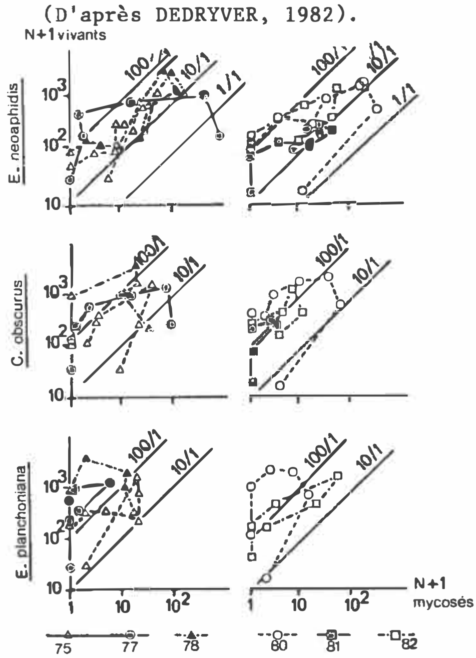
Dans toutes les stations, sauf Rothamsted, E. neoaphidis est le pathogène dominant, sinon unique, en début de saison (juin et première quinzaine de juillet) et la part prise par cette espèce dans le phénomène épidémiologique diminue généralement ensuite au cours du temps, en restant la plupart du temps assez forte. En juillet, c'est E. planchoniana qui prend de l'importance pour devenir dominante dans la deuxième quinzaine du mois, à Rothamsted en 1971 et au Rheu en 1980. On a montré que E. neoaphidis était plutôt caractéristique des périodes humides et E. planchoniana des périodes plus chaudes et "un peu" plus sèches.

Les différences les plus importantes entre stations paraissent concerner l'espèce C. obscurus, dont l'impact paraît insignifiant au Rheu (vérifié sur 8 ans), moyen à Gembloux et fort à Rothamsted.

2.1.2 - Impact au champ sur les populations

La figure 3 montre que, au Rheu, sur 8 années d'expérimen-

Fig. 3: S. avenae : courbes de co-développement du nombre de pucerons mycosés (abcisse) et du nom-total de pucerons vivants (ordonnée) pour chaque espèce d'entomophthorale.
(D'après DEDRYVER, 1982).



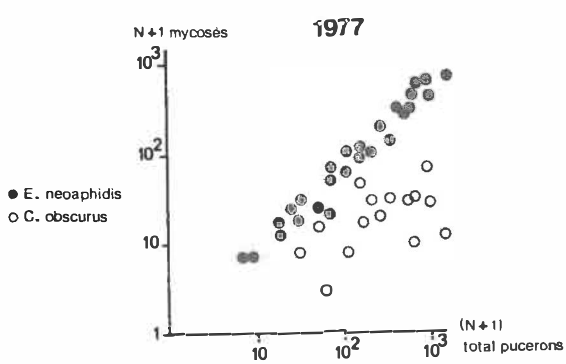


Fig. 4: relations entre le nombre de S. avenae mycosés par E. neoaphidis et C. obscurus et le nombre total de pucerons. (D'après DEDRYVER, 1981).

tations, l'impact des entomophthorales a été nul durant deux saisons (1976 et 1979), du fait de la sécheresse du climat, qu'on assisté à des épizooties nettes dont l'effet sur les populations de pucerons est indéniable, au cours de deux autres années (1977 et 1980) et que le reste du temps les entomophthorales ont provoqué des enzooties dont l'effet sur les populations semble difficile à cerner et ne paraît pas à lui seul déterminant.

La figure 4 compare l'action sur les populations de pucerons des céréales de deux espèces d'Entomophthorales, en conditions d'épizooties, E. neoaphidis et C. obscurus. On voit que dans les conditions climatiques (Le Rheu, 1977) et biologiques (pullulation de pucerons) de l'étude, au moins une espèce , E. neoaphidis, a une action pratiquement indépendante de la taille des "colonies" de pucerons et détruit aussi bien les grosses que les petites. Cette espèce paraît donc devoir être efficace en cas de pullulations de pucerons, sous réserve de conditions climatiques favorables, alors que cela ne semble pas être le cas de C. obscurus qui tue une proportion de pucerons d'autant plus faible que les populations de ceux-ci sont fortes.

En plusieurs localités on a mis en évidence des différences d'action des diverses espèces d'Entomophthorales, soit selon l'espèce de puceron (M. dirhodum et S. avenae), soit selon la position des pucerons sur la plante (feuillage ou épis). Les résultats obtenus divergent passablement mais s'accordent généralement sur le fait que M. dirhodum semble particulièrement sensible aux entomophthorales.

2.2. - PRODUCTION D'INOCULUM ET TENTATIVES D'UTILISATION EN LUTTE BIOLOGIQUE

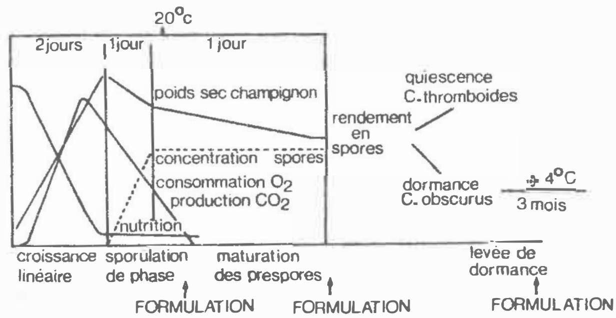
2.2.1. - Production d'inoculum in vitro

Sur la base des résultats d'études d'épidémiologie au champ, deux espèces de pathogènes ont fait l'objet de tentatives de production de masse dans des buts de lutte biologique : il s'agit de C. obscurus qui est une espèce moyennement pathogène, mais qu'on peut produire et conserver sous forme de spores durables, et E. neoaphidis, qui présente l'avantage d'être une espèce apparemment très pathogène pour les pucerons des céréales dans de nombreuses régions, mais dont on ne peut produire que le mycelium. Les recherches sur C. obscurus ont été effectuées à l'Institut Pasteur de Paris (LATGE et al, 1982), elles ont porté sur la technologie de la production des spores durables, sur leur conservation, la levée de leur dormance, leur germination et sur la définition du pouvoir pathogène des conidies. Celles sur E. neophidis ont été menées par la même équipe de l'Institut Pasteur, mais aussi par G. LATTEUR à Gembloux (LATTEUR et GODEFROID, 1982) et par N. WILDING et son équipe à Rothamsted.

C. obscurus :

Des rendements importants en spores (2×10^6/ml) ont été obtenus en fermenteur (LATGE et al, 1982) dans un milieu à base d'huile et d'extraits solubles de maïs (fig. 5). Ces procédés, mis au point en fermenteurs de 20 l, ont été transposés à l'échelle industrielle

Fig. 5: production de spores durables de <u>Conidiobolus</u> s.p. en fermenteur (D'après LATGE et <u>al</u>, 1982).



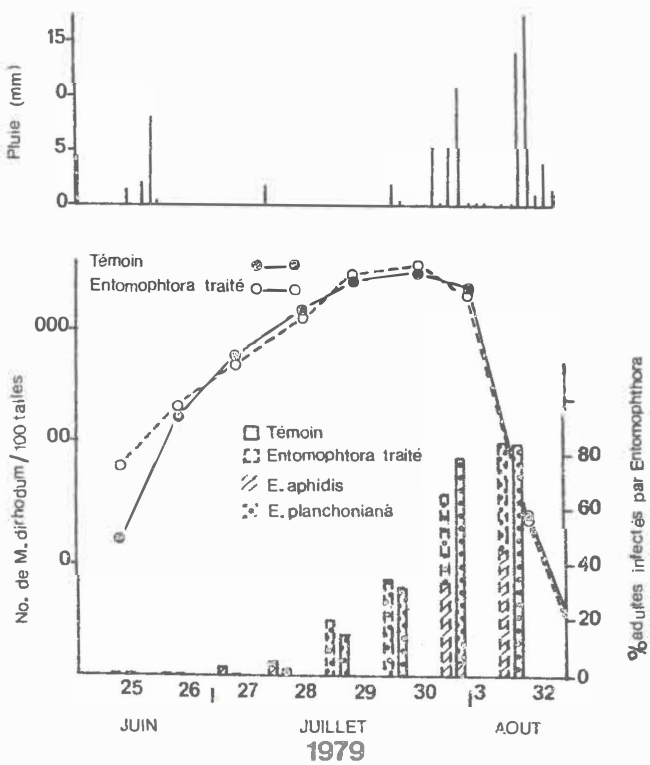


Fig. 6 : Mycoses de <u>M. dirhodum</u> en parcelles traitées ou non avec <u>E. neoaphidis.</u>

(D'après DEAN et <u>al</u>, 1980)

avec des rendements encore acceptables (10^6 sp/l) mais peu de fermentations ont réussi du fait de contaminations consécutives à la longueur du processus (7 à 8 j.). Un autre procédé de fermentation plus court (4 à 5 j.) a été mis au point mais n'a pas été transposé à l'échelle industrielle.

L'étude de la physiologie de ces spores a permis de définir leurs conditions de stockage, d'enrobage en argile, de levée de dormance et de germination. On n'a pas résolu les problèmes soulevés par l'étalement de la durée de germination des spores (au moins une quinzaine de jours).

Des essais de lutte biologique effectués en serre ont mis en évidence l'impossibilité pour ce pathogène de réduire des fortes populations de pucerons. Des essais effectués en champs de céréales, dans diverses régions d'Europe (Zurich : S. KELLER, Gembloux : G. LATTEUR, Littlehampton : J. HALL, Rothamsted : N. WILDING, Le Rheu : C.A. DEDRYVER, Brie Comte-Robert : B. PAPIEROK), ont permis de contrôler la survie des spores en dormance au champ (bonne dans toutes les localités sauf à Zurich où elles n'ont probablement pas supporté les basses températures hivernales), et les modalités de leur levée de dormance au printemps.

D'une manière générale, les applications de spores durables en plein champ n'ont jamais permis d'augmenter les taux de mycose naturels des pucerons.

E. neoaphidis :

Une souche isolée par G. LATTEUR au Brésil, a fait l'objet d'études de production à Gembloux et à l'Institut Pasteur de Paris, en raison de sa bonne pathogénie, de ses faibles exigences nutritionnelles et son taux de croissance élevé. Alors que sa production a pu être effectuée dans les deux laboratoires avec un rendement élevé (0,38 g de mycelium par g de nutriment apporté), ce mycelium n'a jamais pu être conservé pendant plus de deux mois dans les meilleurs des cas (SILVIE, 1984), alors que le mycelium issu de pucerons se conserve pendant bien plus longtemps (tabl. 2).

Comme dans le cas de C. obscurus, l'épandage en champs de céréales de ce mycelium pour lutter contre les pucerons, n'a pas donné de résultat mesurable sur l'évolution des mycoses. Par contre, des épizooties ont pu être obtenues en serre (DEDRYVER, 1982).

2.2.2. - Emploi d'inoculum issu de pucerons

Cette technique est employée, essentiellement dans des buts d'études épidémiologiques, par N. WILDING à Rothamsted (DEAN et al, 1980). Elle consiste à introduire dans des populations de pucerons au champ, soit des pucerons en incubation de mycose, soit des broyats de cadavres mycosés, dans l'espoir d'accroître l'impact d'une espèce (E. neoaphidis dans la plupart des cas) dans ces populations. Les résultats obtenus en 1979 (fig. 6) montrent qu'en cas de conditions climatiques peu favorables aux Entomophthorales, on a une certaine compétition entre espèces : le pourcentage de pucerons infectés est

		M. dirhodum (%)	S. avenae (%)
Rothamsted	1971	53	30
	1980		24
	1982		6
	1983	10	
Gembloux	1977	52	88
	1978	1	0.4
	1979	18	6.5
Rennes	1977	90	80
	1978	30	5
	1980	50.7	54
	1981	42	42
Brie Comte Robert	1981	36	8

TABLEAU 1 pourcentages maximum de pucerons mycosés trouvés sur blé entre mai et juillet dans différentes stations d'Europe.

T°	Diminution de la quantité de conidies de		
	20%	50%	80%
+ 5°C	160 jrs	225 jrs	345 jrs
+ 20°C	63 jrs	90 jrs	150 jrs
+ 25°C	58 jrs	75 jrs	85jrs
+ 30°C	18 jrs	42 jrs	60 jrs

TABLEAU 2 : Survie de E. neoaphidis issu de pucerons en fonction de la température (d'après Latteur, non publié).

le même dans tous les traitements et dans les témoins, mais la part du champignon introduit est plus importante dans les parcelles traitées. Ces mêmes expériences, renouvelées en 1983 dans des cages de nylon et non pas à l'air libre, ont permis d'obtenir des taux de mycose de 40 % au lieu de 10 % chez les témoins, pour *M. dirhodum*.

2.3 - QUESTIONS D'ACTUALITE A PROPOS DES ENTOMOPHTHORALES

Le rôle des entomophthorales dans les fluctuations de populations de pucerons des céréales est indéniable dans les régions océaniques de l'Europe occidentale. Paradoxalement, il y a eu peu de tentatives précises de quantification de leur action dans une optique biométrique, pourtant nécessaire à des études de dynamique de population.

Leurs exigences climatiques et nutritionnelles en font des microorganismes dont le maniement est extrêmement délicat, dans une optique de lutte biologique. Les échecs enregistrés sur le terrain, en dépit de la qualité des recherches de laboratoire sur leur physiologie, en sont la preuve.

Ne doit-on pas s'orienter vers une meilleure exploitation de l'inoculum naturel, là où il est efficace, dans une double optique de protection et de prévision ?

* protection : se repose l'éternelle question du rôle des fongicides sur les entomophthorales, bien démontré au laboratoire par DELORME et FRITZ (1978), et WILDING et BROBYN (1980), mais pour lequel on manque, surtout en céréales, d'une méthodologie d'étude sur le terrain.

* prévision : on dispose d'un type d'agent de régulation de population, dont l'action dépend en fait d'un petit nombre de facteurs : les principales composantes du climat et la densité de population de pucerons. Ne faut-il pas s'orienter vers la modélisation de leur action, modélisation qui aura l'intérêt de mettre en évidence les zones d'ombres dans les connaissances qu'on a de l'épidémiologie de ces champignons, donc de focaliser vers ces points un futur travail scientifique ?

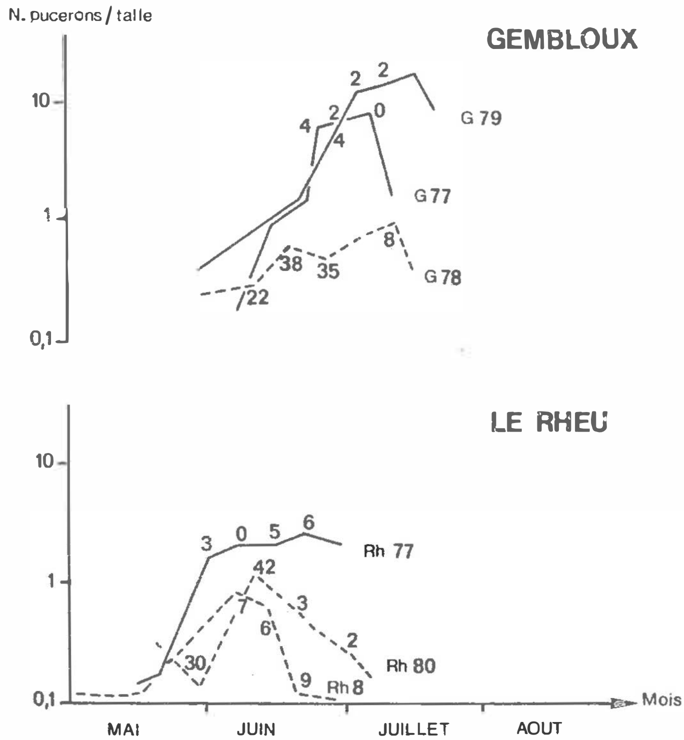


Fig. 1 : pourcentage de parasitisme par hyménoptères (chiffres) et populations de M. dirhodum observés à Gembloux et au Rheu. (D'après LATTEUR et DEDRYVER, non publié).

3 - LES HYMENOPTERES PARASITES

Contrairement à ce qui se passe pour les Entomophthorales, les hyménoptères parasites sont signalés partout en Europe comme un important facteur de limitation des populations de pucerons des céréales. Comme pour les Entomophthorales, lorsqu'on essaie d'apprécier quantitativement l'impact de ces hyménoptères, on se heurte à des problèmes de méthodologie dans la mesure où le comptage des momies au champ abouti probablement à une très mauvaise estimation de la mortalité par parasitisme à un moment donné : il y a un effet cumulatif car les momies restent plusieurs jours sur le végétal avant d'éclore, et l'hyperparasitisme, qui n'est décelable qu'à l'éclosion des parasites, n'est pas pris en compte. La dissection des pucerons récoltés permet d'avoir une bonne idée du parasitisme, mais pas des diverses espèces de parasites en cause. Enfin, l'élevage au laboratoire de pucerons collectés au champ a les mêmes avantages et inconvénients que ceux évoqués dans le cas des Entomophthorales.

3.1. - PREMIERES ESTIMATIONS DE L'IMPACT DES HYMENOPTERES PARASITES AU CHAMP

La figure 1 permet de comparer diverses situations étudiées à Gembloux (G. LATTEUR) et au Rheu (C.A. DEDRYVER) et se rapportant à *M. dirhodum*. L'estimation du parasitisme a été faite dans tous les cas selon la même méthode (élevage). Dans les deux stations, les variations interannuelles dans les pourcentages de parasitisme sont très fortes. Ce sont les années où les pourcentages de pucerons parasités sont les plus forts que les populations de pucerons sont les plus faibles. (Gembloux, 1978 ; Le Rheu, 1980 et 1981). Inversement, à un parasitisme faible sont associées des populations de pucerons plus abondantes (Gembloux, 1977 et 1979, Le Rheu, 1977).

Plus généralement, dans la plupart des stations (Gembloux, Le Rheu, Wageningen), on note la présence de momies bien avant les premiers pucerons mycosés, ce qui suggère une possibilité d'action précoce de ces parasites, et bien souvent, l'arrivée des parasites au champ à peu près en même temps que les pucerons.

3.2. - SPECTRE PARASITAIRE DES PUCERONS DES CEREALES DANS DIFFERENTES REGIONS

Le tableau 1 regroupe les principales espèces de parasites primaires trouvées sur pucerons des céréales dans quatre stations très éloignées les unes des autres : Gembloux (LATTEUR, 1980), Madrid (CASTAÑERA, 1982), Rothamsted (POWELL, 1982), Le Rheu (DEDRYVER, n.p.). Partout on signale les mêmes espèces, à l'exception de *Toxares deltiger*, uniquement signalé en Grande-Bretagne, et d'*Aphidius matricariae*, rencontré au Rheu comme parasite de *R. padi* presque exclusivement.

On a rassemblé sous le nom "*Aphidius uzbekistanicus*", les diverses espèces ou sous-espèces suivantes, morphologiquement très semblables: *A. uzbekistanicus*, *A. rhopalosiphi*, *A. frumentarius*.

Le "groupe uzbekistanicus" représente toujours une part importante du complexe parasitaire des pucerons des céréales, quelle que soit la station d'étude : au minimum 26 % des déterminations, au maximum 94 %. Dans de nombreux cas (7 sur 11), le groupe "uzbekistanicus" représente plus de 50 % du total des parasites sortis. L'importance des deux autres aphidiides, A. ervi et A. picipes semble extrêmement variable selon les lieux et selon les années, probablement en partie du fait du contexte cultural local (ils ne sont pas spécifiques des pucerons des céréales). Enfin, les Ephedrus sp. et Praon sp., souvent signalés, paraissent peu importants. Toxares deltiger, abondant certaines années à Rothamsted (1979 et 1980) forme ses momies au sol et peut passer complètement inaperçu en cas de collectes de momies sur les plantes. Cependant, on n'en a pas trouvé au Rheu en 1980 et 1981 en élevant au laboratoire des pucerons récoltés vivants sur le blé.

3.3. - ETUDES EPIDEMIOLOGIQUES AU CHAMP

3.3.1. - Hivernation - Infestation des cultures

L'infestation des céréales à paille par les hyménoptères parasites paraît assez précoce dans la plupart des cas. Dans les régions où les pucerons des céréales sont strictement holocycliques, le problème de l'hivernation de leurs hyménoptères parasites reste posé (diapause hivernale à l'état de momie ?), là où ils sont totalement (Le Rheu) ou partiellement (Rothamsted) anholocycliques, on a pu, soit montrer sans contestation possible qu'ils étaient actifs tout l'hiver et qu'on trouvait des pucerons parasités pendant toute cette saison (Le Rheu, tabl. 2), soit en avoir de fortes présomptions (Rothamsted, tabl. 3).

3.3.2. - Rôle du niveau de végétation

Dans certains cas, au Rheu (tabl. 4) et à Rothamsted (tabl. 5), on a pu montrer que le pourcentage de pucerons momifiés par rapport à la population totale d'une espèce (S. avenae), estimé par comptage au champ, était plus fort sur le feuillage que sur les épis. Ceci ne paraît pas vérifié lorsqu'on estime le pourcentage de parasitisme par élevage de pucerons au laboratoire : bien qu'il semble qu'entre autres, A. uzbekistanicus passe plus de temps à explorer le feuillage que les épis (GARDNER, 1983), il apparaît que les différences observées par le comptage de momies au champ peuvent s'expliquer par la montée progressive des S. avenae non parasités sur épis. Notons qu'à Gembloux, on n'a jamais trouvé de telles différences.

3.3.3. - Sensibilité des différentes espèces de pucerons

Il ne semble pas qu'à un même niveau de végétation (le feuillage), une espèce soit préférée à une autre, au moins par les parasites considérés globalement. Des observations en ce sens, faites au Rheu, ont été confirmées par une expérience effectuée à Rothamsted (NICOLAS, 1983), et qui a consisté à exposer à un flux de parasites

		A.u	A.e	A.p	A.m	P.v	E	T.d	total éclos
Gembloux	1978	54.8	5.5	31.7	0	7.2	0.8	0	126
Madrid	1980	49.5	47	0	0	3.5	0	0	115
	1981	39.5	60.5	0	0	0	0	0	48
	1982	76.5	23.5	0	0	0	0	0	68
Rothamsted	1979	27.3	27.3	0	0	9.1	0	36.4	11
	1980	26	11.1	1.2	0	7.4	0	54.3	81
	1981	93.7	2.7	1.3	0	0.5	0	1.8	224
Le Rheu	1978	26.2	7.9	63.3	1.8	0.9	0	0	229
	1979	61.5	23.1	7.7	0	7.7	0	0	13
	1980	55.5	7.5	31.3	1.7	2	2	0	841
	1981	56.4	7.3	33.6	0.3	1.8	0.5	0	381

TABLEAU 1 : importance relative, en pourcentages du total éclos, des principales espèces de parasites sur pucerons des céréales dans quatre laboratoires.

(A.u : *Aphidius uzbekistanicus*, A.e : *A. ervi*, A.p : *A.picipes*, A.m : *A. matricariae*, P.v : *Praon volucre* , E. : *Ephedrus sp.*, T.d : *Toxares deltiger*.

D'après LATTEUR, 1979; CASTANERA, 1982; POWELL, 1982).

		Sains	ω	L_1	L_2	L_3	L_4	Momies	Mycosés	% Par.	% Myc.
				Stade du parasite							
1976-77	Oct.	8				1		1			
	Nov.	15									
	Déc.	267		1	2	1				1.5	0
	Janv.	40				2		3		12	0
	Fév.	205			1	2		3		3	0
	Mars	664	4	8	9	3	7	4		5	0
	Avril	252		3	1		3	2		3.5	0
1977-78	Oct.	6	1						1		
	Nov.	160	4	2		1		2	3	5	2
	Déc.	172	2	6	1	2	1	1	4	7	2
	Janv.	151				1		2	1	2	0.6
	Fév.	75				2		1		4	0
	Mars	37	3	5		3		2		26	0
	Avril	9			2	2	2	1			
1978-79	Oct.	526	8	11	2	7		2	36	5	6
	Nov.	236	3	16	5	3		7	6	12	2
	Déc.	88	2	8	2	2	1	4	5	17	4.5
	Janv.	3									

TABLEAU 2 : Structure des populations de parasites dénombrés à la dissection des individus de *R. padi*, nombre de *R. padi* tués par mycose et pourcentage total de parasités et de mycosés trouvés au Rheu.

(D'après DEDRYVER et GELLE, 1982).

Date de récolte	Nombre de pucerons récoltés	Nombre de parasités	% de parasitisme
20/3/1980	42	15	35.7
9/4/1981	129	38	29.5

TABLEAU 3 : Niveau de parasitisme de populations de S.avenae, ayant passé l'hiver sur blé.

(D'après POWELL, 1982).

Date	Stade du blé (échelle de FEEKES)	% de pucerons momifiés sur feuilles	sur épis
7/6/1977	10.5	0.42	0.26
14/6/1977	10.5.4	2.9	0.82
21/6/1977	11.1	7.9	1.9
28/6/1977	11.2	8.6	2.4

TABLEAU 4 : Localisation des momies de S.avenae sur les plants de blé.

(D'après RABASSE et DEDRYVER, 1983).

	comptage au champ		élevage de pucerons	
	Nombre de S.avenae	% de momies	Nombre de S.avenae	% de momies
épi	129	4.4	50	14
feuille culmaire	183	8.0	50	10
feuille 2	39	18.8	-	-
feuille 3	34	-	-	-

TABLEAU 5 : estimation du parasitisme de *S.avenae* par deux techniques différentes, le 18 juillet 1983 à Rothamsted (NICOLAS, 1983).

Date	couleur	non parasité	parasité
25/6/80	vert	34	29
	brun	13	0
26/6/1980	vert	35	16
	brun	48	2

TABLEAU 6 : nombre de larves du quatrième stade de *S.avenae* parasitées et non parasitées, en fonction de leur couleur. Le parasitisme est estimé par dissection.

(D'après ANKERSMIT et *al*, 1981).

en champ, des quantités égales de S. avenae et de M. dirhodum sur plantules de blé : on ne trouve pas de différences dans les taux de parasitisme. On peut cependant se poser la question de savoir ce qui se passe en cas de décalage important dans les périodes de développement des deux espèces de pucerons. Les parasites issus d'une espèce parasiteront-ils l'autre avec la même efficacité ? On possède déjà des éléments de réponse : à Wageningen (ANKERSMIT, comm. pers.), on a montré que des A. rhopalosiphi issus de S. avenae parasitent mieux ce dernier puceron que M. dirhodum. Les différentes espèces de parasites ne manifestent-elles pas des préférences ? A Rothamsted (DEAN et al., 1981), il semblerait que A. uzbekistanicus parasite de préférence M. dirhodum. Au Rheu (RABASSE et DEDRYVER, 1984) et à Rothamsted (DEAN et al., 1981), il semble que A. picipes manifeste une préférence pour S. avenae.

3.3.4. - Sensibilité de différents clones de pucerons

A Wageningen (ANKERSMIT, et al., 1981), on a montré que les formes brunes de S. avenae paraissent plus résistantes à A. rhopalosiphi que les formes vertes. Les premiers semblent posséder des facteurs favorisant l'encapsulation puis la désagrégation des oeufs du parasite (tabl. 6).

3.3.5. - Tentatives de lâchers de parasites au champ

Dans la mesure où les pics de population de pucerons (M. dirhodum et S. avenae) ne peuvent se produire qu'avant la maturité pâteuse, on peut penser qu'un retard dans le début de la multiplication, des pucerons, ou un ralentissement de cette multiplication, du fait des parasites, devrait se traduire obligatoirement par des maxima de population moins élevés. C'est dans le but de renforcer ou d'avancer cette action précoce par des hyménoptères parasites que des essais d'introduction ont été faits en champs de blé aux Pays-Bas par ANKERSMIT (n.p.) concernant A. rhopalosiphi et P. volucre et en Grande-Bretagne par POWELL (n.p.) concernant A. uzbekistanicus.

Dans le premier cas (Wageningen), on a en 1980 et 1981, lâché environ 500 A. rhopalosiphi et 5 000 S. avenae à l'hectare, et en 1982, quelques milliers de P. volucre et de S. avenae à l'hectare. Ces différentes introductions ont été effectuées avant le 15 mai, de manière à tenter d'établir des foyers de parasitisme précoce. En 1981 et 1982, les lâchers ont été des échecs, en 1980, on a obtenu quelques momies deux semaines après la date du lâcher, puis 25 % de L4 de S. avenae parasitées le 25 juin.

Dans deux parcelles situées près de Rothamsted, ce sont des M. festucae parasités par A. uzbekistanicus qui ont été introduits, soit dans du ray-grass sous couvert de blé, soit dans une parcelle comportant des bandes alternées de blé et de ray-grass. A. uzbekistanicus a été par la suite retrouvé en plus grande quantité qu'ailleurs, dans le blé sous couvert de ray-grass. Consécutivement, les populations de S. avenae y ont été plus faibles.

	Température (°C)				
	10	15	18	20	25
A. rhopalosiphi	38	20	18	14	11
A.picipes	-	19	-	14	-
P.volucre	31	21	19	-	13
S.avenae	17	11	-	9	8

TABLEAU 7 : durées de développement, en jours, de différents hyménoptères parasites et de S.avenae , en fonction de la température.

(D'après ANKERSMIT, 1982).

3.4. - ETUDES DE LABORATOIRE SUR LA BIOLOGIE DES HYMENOPTERES PARASITES

De telles études ont été effectuées à Southampton par VORLEY (1983), à Norwich par GARDNER (1983), elles sont en cours à Rothamsted (POWELL) et au Rheu (KRESPI *et al.*, 1984), sur *A. uzbekistanicus.* A Wageningen, elles ont été effectuées sur *A. rhopalosiphi* (SHIROTA *et al.*, 1983) : les durées de développement du parasite sont beaucoup plus longues que celles de leurs pucerons hôtes (tabl.7). Malgré une fécondité très forte, ils ont, pour une température donnée, un taux d'accroissement intrinsèque (r) plus faible que celui de leurs hôtes. La courbe de réponse fonctionnelle des parasites à la densité de pucerons (fig. 2) indique qu'une femelle d'*A. rhopalosiphi* peut parasiter au maximum 64 % de l'effectif d'une colonie de *S. avenae* si celle-ci comprend environ 40 individus. Pour des densités de pucerons plus fortes (100 pucerons par colonie), on ne dépasse pas 50 % de parasitisme. Ces deux caratéristiques (r et réponse fonctionnelle) font que *A. rhopalosiphi* ne semble pas à lui seul pouvoir détruire une population de pucerons en croissance, par contre, il semble pouvoir largement contribuer à ralentir la multiplication des pucerons, voire à détruire les colonies.

3.5. - QUESTIONS D'ACTUALITE A PROPOS DES HYMENOPTERES PARASITES

Comme pour les Entomophthorales, la lutte biologique directe en champs de céréales, au moyen de ces parasites, semble actuellement exclue, donc on en est réduit :

1) à essayer de favoriser leur action naturelle.
2) à mieux prendre en compte leur action naturelle dans la lutte intégrée par le biais de la modélisation.

1 -Favoriser leur action naturelle

+ Il est nécessaire de mieux connaître l'impact des traitements aphicides, et surtout des traitements aphicides précoces, sur ces hyménoptères parasites .

+ Ceci interfère avec le fait que au moins deux aphidiides, *A. ervi* et *A. picipes,* ne sont pas spécifiques des pucerons des céréales, ce qui sous-entend que les assolements ont un rôle important et qu'il faut élargir le problème des traitements phytosanitaires à d'autres cultures que les céréales.

2 - Meilleure prise en compte de leur action naturelle

+ Faut-il approfondir l'étude de leur dynamique de population au champ ?

On est frappé par le fait que la variabilité interannuelle, aussi bien dans l'impact global des parasites qu'au niveau du spectre parasitaire (telle année, *A. uzbekistanicus* dominera, l'année suivante ce sera *A. picipes*...) pour un même lieu, paraît aussi forte que la variabilité géographique. Dans certaines stations (Rothamsted, Le Rheu, etc...), on possède suffisamment de données pour

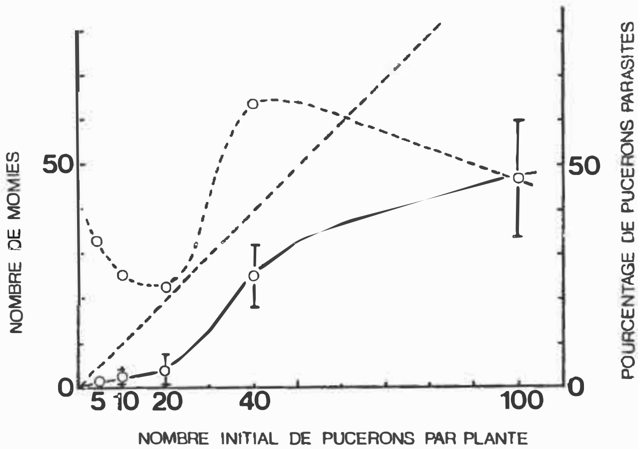


Fig. 2 : réponse fonctionnelle de A. rhopalosiphi (traits pleins) et pourcentage de parasitisme (pointillés) en fonction de la densité de l'hôte.

(D'après SHIROTA et al, 1983).

tenter de mettre ces variations en relation avec des facteurs biotiques, climatiques ou culturaux, ce qui peut aboutir à un certain type de modèle.

La question restera posée de savoir si les divers de modélisations qu'on peut appliquer aux hyménoptères parasites aboutiront à quelque chose de concret au niveau d'une prévision de risques, du fait de la multiplicité des espèces en cause et surtout de l'hyperparasitisme.

+ On risque encore de manquer d'informations pendant longtemps sur la biologie des hyperparasites, en particulier sur leurs besoins en température et leur fécondité.

	C_7	P_{14}	A_2	A_v	C_{11}	S_{24}	C_{14}	H.h.
Gembloux	+	+						
Darmstadt	+	+						
Littlehampton	+	+	+		+	+		
Antibes	+	+		+				
Madrid	+	+		+			+	+

TABLEAU 1 : principales espèces de coccinelles rencontrées en blé d'hiver dans 5 localisations différentes.

C_7: Coccinella 7 - punctata ; P_{14}: Propylea 14-punctata;

A_2: Adalia bipunctata ; A_v: Adonia variegata;

C_{11}: Coccinella 11 - punctata; S_{24} : Subcoccinella 24 - punctata;

C_{14}: Coccinella 14 punctata;

H.h. : Hiperaspis hoffmanseggi.

	E.b	M.c	S.p	S.c	S.a	S.r	C.c
Gembloux	+	+	+				+
Darmstadt	+						+
Littlehampton		+			+	+	+
Antibes	+	+		+			+
Madrid	+	+	+	+			+

TABLEAU 2 : principales espèces de Syrphes et de Chrysopes rencontrées en blé d'hiver dans 5 localisations différentes.

E.b; : Episyrphus balteatus ; M.c. : Metasyrphus corillae;
S.p. : Scaeva pyrastri ; S.c. : Sphaerophoria scripta;
S.a. : Scaeva albomaculata ; S.r. : Syrphus ribesii;
C.c. : Chrysopa carnea.

4 - LES PREDATEURS "SPECIFIQUES"

Ces insectes sont pratiquement tous uniquement prédateurs de pucerons, à l'opposé des polyphages (Chap. 5). Cependant, lorsqu'on tente d'estimer leur rôle dans la limitation des populations de pucerons des céréales, on se heurte à des difficultés bien pires encore que celles rencontrées dans le cas des Entomophthorales et des Hyménoptères parasites : elles tiennent à l'estimation de leur densité réelle dans le champ et à celle de leur consommation de pucerons.

Ce sont des individus mobiles dont le rythme d'activité n'est pas constant au cours de la journée, dont la population sur la plante dépend de celle des pucerons, mais probablement aussi des circonstances climatiques et atmosphériques. L'estimation de leur densité s'effectue assez grossièrement, soit par ramassage au filet fauchoir (mais quelle est la validité de l'échantillon récolté ?), soit par comptage direct au champ lors de l'estimation des populations de pucerons, soit, enfin, en les récupérant jusqu'à épuisement : on passe plusieurs fois dans la parcelle, en récupérant les prédateurs, jusqu'à ce qu'on ne trouve plus. Comme nous le verrons par la suite, aucune de ces méthodes n'est pleinement efficace.

Ces prédateurs ne laissent pas ou peu (pour les petits stades larvaires) de traces de leur consommation de pucerons, si bien qu'on ne peut se baser que sur des données expérimentales pour estimer celle-ci. Rien n'est moins évident car, si pour certains prédateurs la consommation maximale a été étudiée dans des conditions de laboratoire (C.7 punctata par RAUTAPÄA (1975), Semiadalia 11 punctata par FERRAN (1982), etc...), on ignore tout de ce qui se passe réellement au champ.

Outre la détermination des principales espèces trouvées localement, trois voies de recherches ont été abordées :
- la méthodologie d'échantillonnage au champ ;
- la quantification de la consommation de pucerons au champ ;
- l'étude au laboratoire de la biologie et de la consommation.

4.1. - PRINCIPALES ESPECES RENCONTREES EN EUROPE

Les tableaux 1 et 2 indiquent les principales espèces de coccinelles, syrphes et chrysopes récoltées dans les champs de blé dans cinq régions d'Europe, la Belgique (Gembloux : LATTEUR), l'Allemagne de l'Ouest (Darmstadt : BODE), le Sud de l'Angleterre (Littlehampton : SUNDERLAND et al.), le Sud de la France (Antibes : FERRAN et al.) et le Centre de l'Espagne (Madrid : CASTAÑERA).

Parmi les coccinelles, deux espèces sont signalés dans tous les cas, Coccinella septempunctata et Propylea quatuordecimpunctata. C 7 punctata est presque partout rencontré en grand nombre et est considéré comme l'espèce la plus fréquente en cultures de céréales à pailles. Les autres espèces semblent, soit rencontrées plus épisodiquement, soit caractéristiques des régions méditerranéennes, comme Adonia variegata, signalée à Antibes et à Madrid.

Chez les Syrphes, on retrouve également deux espèces signalées partout (Episyrphus balteatus) ou presque (Metasyrphus corollae). D'après CHAMBERS et SUNDERLAND, (1982), les syrphes semblent être les prédateurs les plus "réguliers", c'est-à-dire ceux dont l'abondance paraît sujette aux plus faibles variations interparcellaires et interannuelles.

Une seule espèce de Chrysope est signalée (partout) comme prédatrice de pucerons, il s'agit de Chrysopa carnea. Son activité semble variable selon les années.

4.2. - ECHANTILLONNAGE AU CHAMP

Le comptage direct des formes larvaires et adultes (coccinelles) de prédateurs, à l'occasion de l'estimation des populations de pucerons, a été employé par BASEDOW, DEDRYVER (avec ramassage des prédateurs) et CASTAÑERA (avec ramassage et élevage) entre autres. Cette méthode a l'avantage de permettre de relier une densité de prédateurs à un nombre de talles, donc à une unité de surface et à une densité de pucerons : elle est très imprécise dans la mesure où un seul passage dans le champ ne permet pas de récupérer tous les prédateurs pour une unité de surface donnée.

Le filet fauchoir permet d'échantillonner très vite une grande unité de surface, mais c'est là son seul avantage : on ne ramasse pas tous les prédateurs, et en particulier ceux situés à la partie basse des plantes. On ne peut pas non plus relier le nombre de prédateurs trouvés à une unité de surface ou à une population de pucerons.

Une amélioration de la méthode de comptage direct au champ a été proposée récemment par l'équipe d'Antibes (FERRAN, LAPCHIN, IPERTI) : il s'agit d'une adaptation aux insectes terrestres de la méthode de LURY (1947). Elle consiste à passer plusieurs fois successivement dans une même sous-parcelle en récupérant tous les prédateurs trouvés à chaque passage. Deux passages successifs permettent de prendre en compte environ 50 % des larves et adultes de C 7 punctata et des larves de syrphes, et 85 % des adultes C. carnea. Les prédateurs sont ramenés au laboratoire, pesés, un sous-échantillon est disséqué, et le reste est relâché au champ.

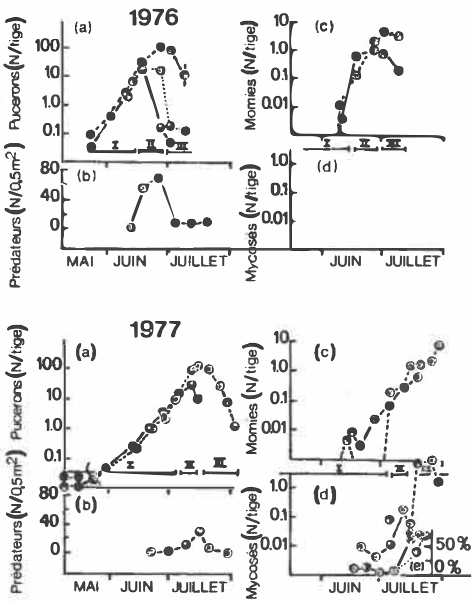
Cette méthode est lourde d'emploi et ne peut être appliquée sous sa forme actuelle à des contrôles de routine, mais paraît bien adaptée à une étude fine de la prédation au champ.

Dans tous les cas, l'échantillonnage des prédateurs reste faussé par les différences dans le comportement de ces prédateurs au cours de la journée, ou selon les circonstances atmosphériques.

4.3. - IMPACT AU CHAMP DES PREDATEURS SUR LES POPULATIONS DE PUCERONS

CHAMBERS et al., (1983) en Grande-Bretagne, ont tenté d'es-

Fig. 1 : Pucerons, prédateurs, momies et mycosés en 1976 et 1977 à LITTLEHAMPTON . Cages (---); champ ouvert (———); cage installée tardivement (......). (D'après CHAMBERS et al, 1983)



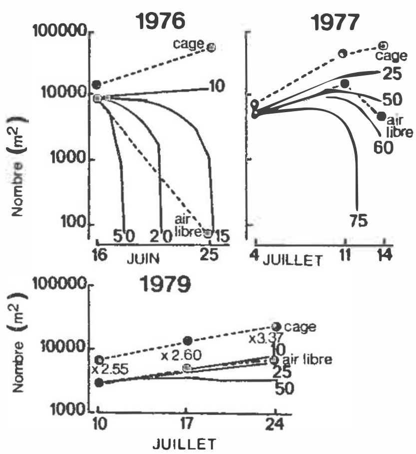


Fig. 2 Populations de pucerons en cages et en parcelle ouverte durant leur phase d'expansion (-----). Populations calculées (———) en fonction de différentes consommations journalières de pucerons par les prédateurs. (D'après CHAMBERS et al, 1983).

timer indirectement cet impact en utilisant des cages de tulle qui étaient disposées dans un champ de blé après l'infestation de celui-ci par les pucerons, mais avant l'arrivée des prédateurs spécifiques. Dans la plupart des cas (fig. 1), on observe des différences importantes dans l'évolution des populations de pucerons à partir du moment où les prédateurs arrivent dans la parcelle. Ces différences observées entre populations à l'intérieur et à l'extérieur des cages sont mises sur le compte des prédateurs dans la mesure où les mycoses et parasites semblent avoir à peu près le même effet dans les deux situations. Chaque cas est ensuite relié à des hypothèses sur la consommation des prédateurs (fig. 2). Dans tous les cas, les hypothèses de consommation journalière sont compatibles avec les résultats de laboratoire.

4.4. - ETUDES AU LABORATOIRE DE LA BIOLOGIE DE CERTAINS PREDATEURS

La biologie de E. balteatus a été récemment étudiée par ANKERSMIT (n.p.) à Wageningen. Il semble que l'oviposition de cette espèce commence au dessus de 15° C. Seuls, quelques oeufs sont pondus à 15° C. A 20° C une larve consomme au total 200 L 3 de pucerons pour se développer. A des températures plus basses, il semble que leur consommation soit un peu plus faible. Leur activité prédatrice est essentiellement nocturne, et, durant la phase de culmination des populations de pucerons, elles peuvent consommer jusqu'à 40 L 3 par nuit. Il ne peut apparemment se développer qu'une seule génération sur blé dans les conditions climatiques de la Hollande, une autre se développe ensuite sur le maïs, mais le taux de parasitisme des pupes est d'autant plus fort que la saison avance.

En ce qui concerne les coccinelles, la consommation des larves et adultes de C 7 punctata a été étudié en Finlande par RAUTAPÄA (1975) et en Grande-Bretagne par MAC LEAN (1980) (tabl. 3). Il a été montré à Antibles (FERRAN, 1982) que le poids et la consommation des coccinelles S. 11 notata étaient liés de manière linéaire. Des études ont en cours pour adapter les relations au cas de C 7 punctata ; si elles aboutissaient, la quantification du prédatisme de cette coccinelle au champ pourrait s'effectuer par le pesage des individus.

4.5. - QUELQUES QUESTIONS AU SUJET DES "PREDATEURS SPECIFIQUES"

\+ Il reste très difficile d'estimer leur densité, en particulier des jeunes stades larvaires de syrphes et de coccinelles.

\+ Les meilleures méthodes d'estimation sont très contraignantes.

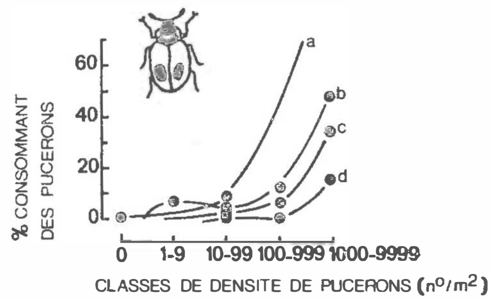
\+ A densités de prédateurs égales, le taux de consommation paraît différer selon les années.

\+ Dans une optique de prévision, il est nécessaire de pouvoir relier une population de prédateurs, assez tôt en saison, à une prédation ultérieure. Au moins dans le cas des coccinelles, cela paraît très difficile dans la mesure où le nombre de larves puis d'adultes de la génération formée sur le blé ne dépend pas uniquement de l'importance de l'immigration des adultes de la génération précédente qui peuvent ne pas pondre et quitter la culture faute de pucerons, ou bien dont les oeufs peuvent être détruits, etc...

+ quel est, à court, moyen et long terme, l'efficacité des traitements insecticides sur les prédateurs ? On peut en avoir une idée par les observations de MOREAU (1982), à Versailles sur maïs, mettant en évidence une certaine diminution du nombre de prédateurs spécifiques dans les parcelles traitées aux insecticides.

Fig. 1 : relation entre le pourcentage de prédateurs contenant des restes de pucerons et la densité de pucerons des céréales.

(D'après SUNDERLAND et VICKERMAN, 1980).



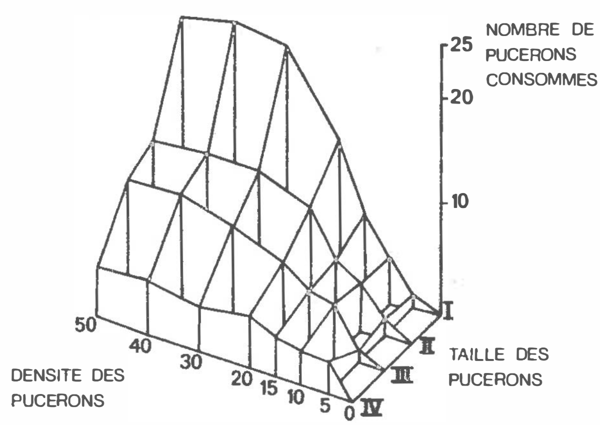


Fig. 2 : réponse fonctionnelle de A.dorsale à 4 classes de taille de pucerons. (D'après GRIFFITHS, 1983).

5 - LES PREDATEURS POLYPHAGES

Il s'agit d'arthropodes appartenant à de nombreux groupes : Arachnides(araignées) ou Insectes (coleoptères et dermaptères) essentiellement. C'est la découverte de fragments de pucerons dans le tube digestif de certains d'entre eux par SKUHRAVY (1959) et VICKERMAN et SUNDERLAND (1975) qui a mis en évidence leur caractère prédateur de pucerons.

5.1. - PRINCIPALES ESPECES EN CAUSE ET REGIME ALIMENTAIRE

Les araignées de la famille des linyphiides sucent leurs proies et l'on ne retrouve pas de restes de pucerons dans leur tube digestif (T.D.). Chez les dermaptères jusqu'à 29 % des Forficula auricularia capturés en champs de céréales peuvent contenir des restes de pucerons (CARRILLO, n.p.). La plupart des espèces prédatrices polyphages sont des coléoptères : LUFF (1974) reporte que 26 % des Pterostichus malidus contiennent des pucerons dans leur T.D. et SUNDERLAND (1975) trouve des pucerons dans le T.D. de 30 à 40 % des Agonum dorsale, de 5 à 17 % des Harpalus rufipes, jusqu'à 16 % des Feronia melanaria, jusqu'à 50 % des Nebria brevicollis et de 5 à 23 % des Bembidion lampros. SUNDERLAND et VICKERMAN (1980) ont récolté de très nombreuses espèces de prédateurs polyphages en céréales au cours de 6 années d'expérimentation, par aspirateur portable (D. VAC), par piégeage à l'aide de pots de Barber et par recherche directe sur le champ, de mai à septembre de chaque année. Dans cette étude, 12 000 individus ont été disséqués dans le but d'y trouver des restes de pucerons, ce qui a permis de tracer un tableau comportant la proportion d'individus de chaque espèce contenant des restes de pucerons. Ce tableau ne tenait pas compte de l'abondance des prédateurs et ces auteurs ont proposé un "indice de prédation", obtenu en multipliant la densité des prédateurs (estimée par recherche directe au champ) par la population de chaque espèce contenant des restes d'aphides. Ayant établi leur classification "brute", SUNDERLAND et VICKERMAN (1980) ont utilisé les mêmes données de dissection pour tenter de mettre en évidence des relations entre la densité des proies et le pourcentage de prédateurs en ayant effectivement consommé (fig. 1).

5.2. - ESTIMATION DE LA CONSOMMATION ET DE L'EFFICACITE DES PREDATEURS POLYPHAGES

Il n'existe, en général, que peu de données fiables concernant la consommation de ce type de prédateurs, au laboratoire, en présence d'un excès de proies : GRIFFITHS (1983) a tenté l'établir la courbe de réponse prédatrice d'un coléoptère, A. dorsale à la densité de population de sa proie. Il a montré que l'efficacité prédatrice d'A. dorsale augmentait beaucoup avec la densité de jeunes stades larvaires de pucerons (L1), et très peu avec celle des stades larvaires agés ou des adultes (fig. 2).

D'autres données non publiées, collectées à Southampton, concernent Demetrias atricapillus, B. lampros et Forficula sp.. Les deux premières consomment jusqu'à 7 larves d'un stade moyen, par jour, à 15-20° C, et *Forficula* sp. est capable de faire mieux. Des données sur les linyphiides (araignées) obtenues par FRASER (CARTER *et al.*, 1982) révèlent des mortalités de pucerons de 3 % en début de saison et jusqu'à 80 % en fin de saison. LOUGHBRIDGE et LUFF (1983) ont montré que *H. rufipes* pouvait consommer ses proies sur les plantes, se trouvant sur les céréales la nuit lorsque la température était au-dessus de 6° C, et pouvait consommer jusqu'à 130 pucerons par jour.

Une première estimation du rôle de ces prédateurs a été effectuée en corrélant leur densité au champ et celle de leurs proies. Au cours de leur étude des écosystèmes céréaliers du Sud de l'Angleterre, POTTS et VICKERMAN (1974) ont récolté une importante somme de données à partir des aspirateurs portables et des pièges de Barber. Pour différentes cultures et à différentes époques, les corrélations entre les nombres de pucerons des céréales et la diversité de la faune sont négatives et significatives. Ils ont trouvé, de plus, une corrélation positive entre l'indice de diversité de la faune d'invertébrés trouvés dans les mêmes champs, et la proportion d'individus appartenant à des espèces reconnues prédatrices de pucerons. Ces relations ont été établies à des moments où beaucoup des classiques "prédateurs-spécifiques" de pucerons étaient à de bas niveaux de population, de sorte que ce sont essentiellement les polyphages qui étaient impliqués dans les relations "nombre de pucerons/diversité".

CHAMBERS *et al.* (1982) ont noté que les populations de pucerons du début de l'été étaient significativement plus fortes au milieu des champs semés ~~précocement~~ que vers les bordures, et que cette différence n'existait pas en ce qui concerne les parcelles semées plus tardivement. Dans les pots de Barber, les captures de prédateurs polyphages sont plus fortes sur les bordures des champs qu'au centre dans les semis précoces, mais pas dans les semis tardifs. Ceci implique ces prédateurs dans la réduction du nombre de pucerons. Au contraire, le nombre de prédateurs spécifiques de pucerons, tels que les coccinelles, est corrélé positivement avec le nombre de leurs proies, quoique le taux d'accroissement des pucerons lui soit corrélé négativement. Cette différence dans les corrélations entre proies et nombre de prédateurs dépendant du type d'ennemis naturels suggère que les ennemis spécifiques manifestent une réponse numérique aux variations de densité de leurs proies, assez tardivement au cours du développement de ces dernières, et, une fois arrivés, commencent à affecter le taux de croissance des populations de pucerons. Plus tôt en saison, l'hétérogénéité spatiale dans la densité des prédateurs polyphages, qui n'est pas causée par des variations dans la densité des pucerons, indique que, localement, la prédation potentielle peut être forte. Une réponse numérique agrégative de ces prédateurs n'est pas à exclure, mais il y a de si nombreux groupes, à régimes alimentaires tellement variables, qu'on ne peut s'attendre à des corrélations positives avec une seule espèces de proie.

Une autre manière d'estimer indirectement le rôle des prédateurs polyphages est de réduire leur nombre par traitements insecticides de sol et par isolement de parcelles à l'aide de barrières de

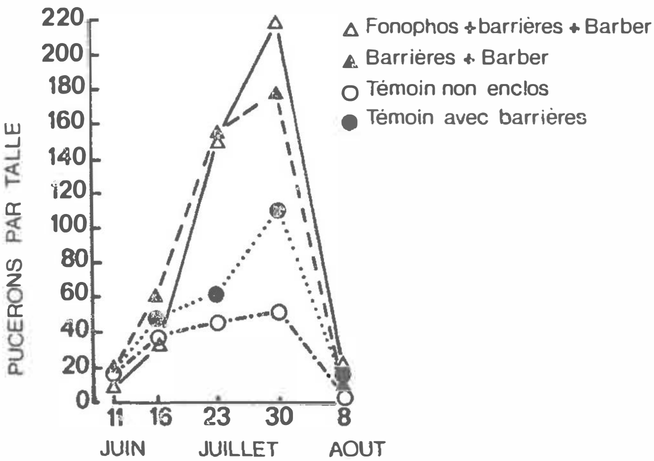


Fig. 3 : populations de pucerons résultant de 4 traitements différents modifiant l'impact des prédateurs.

(D'après SUNDERLAND et al, 1980).

polyéthylène. Ces dernières empêchent tous déplacements entre parcelles mais permettent les mouvements à l'intérieur ou à l'extérieur de celles-ci. EDWARDS et al. (1979) ont établi deux types de barrières de polyéthylène de 60 cm de haut en mars, avril et mai en Grande-Bretagne. Chaque parcelle est entourée d'une bande de polyéthylène et certaines ont des pièges de Barber et ont reçu un traitement insecticide alors que d'autres ont uniquement des pièges de Barber. Dans ces dernières, il n'y a que les Carabes qui soient éliminés en permanence, alors que dans les autres (traitements insecticides) ce sont toutes les catégories de prédateurs polyphages qui sont réduites. La suppression de tous les prédateurs a un effet, sur les populations de pucerons, de même que la simple suppression des carabes. Un travail similaire a été fait par SUNDERLAND et al., (1980) (fig. 3). Des expérimentations de ce type produisent généralement une série de densités différentes de prédateurs, qui permettent d'établir des régressions. De telles analyses montrent des corrélations négatives hautement significatives entre les nombres de pucerons et de prédateurs. D'autres corrélations négatives entre les nombres de pucerons des céréales et ceux des prédateurs polyphages ont été obtenus en Suède par CHIVERTON et al. Leurs premiers travaux concernaient R. padi mais, en 1983, le même genre de corrélations a été obtenu pour S. avenae. Des premières corrélations négatives entre des nombres de pucerons et ceux d'un prédateur, Agonum dorsale, ont été établies par BURN.

5.3. - QUELQUES QUESTIONS A PROPOS DES PREDATEURS POLYPHAGES

Il a été clairement établi qu'un nombre important de carabes, staphilins, forficules et araignées se nourissent de pucerons des céréales et ont, au moins pour certains, une forte activité prédatrice potentielle.

* Comment peut-on quantifier plus précisement leur action : cela ne peut se faire que par des études de biologie et de comportement débouchant sur une modélisation des relations prédateurs-proies, comme l'a effectué GRIFFITHS (1983) pour Agonum dorsale. On risque malheureusement d'en arriver à la conclusion de GRIFFITHS, montrant qu'un seul prédateur n'est pas à lui seul efficace, mais que l'important est la prédation globale effectuée par un cortège d'insectes. On imagine la complexité de tels modèles travaillant sur plusieurs prédateurs à la fois (et le caractère hasardeux de leurs prévisions !).

* Comment peut-on, soit amplifier leur action naturelle, soit au moins ne pas la gêner ?

Il paraît important de poursuivre les recherches sur le rôle des différents types des traitements insecticides sur les populations de prédateurs polyphages en céréale, en prenant en compte, non seulement la matière active utilisée, mais la date et la fréquence des traitements.

L'action de certains herbicides, déjà étudiée par POTTS et VICKERMAN (1974) devrait également faire l'objet d'études plus approfondies.

Enfin le rôle des techniques culturales, des rotations ainsi que celui des sites d'hivernation doit être mieux estimé. L'étude de ce dernier a été entrepris en Grande-Bretagne par SOHERTON.

6 - LES ETUDES DE MODELISATION

Les recherches entreprises sur les principaux paramètres de la biologie des pucerons des céréales ont, comme on l'a vu au chapitre 1 permis de quantifier assez précisement les besoins de ceux-ci en température, ainsi que les grands traits de leurs relations avec la plante-hôte. Ces résultats, ainsi que ceux, plus fragmentaires, obtenus sur la dynamique de certains de leurs ennemis naturels, ont permis l'élaboration depuis une dizaine d'années de modèles visant à simuler une partie ou la totalité de la dynamique d'une population aphidienne au cours du temps.

Ils sont deux types : Modèles déterministes
Modèles de régression.

6.1. - LES MODELES DETERMINISTES

Certains ont un but essentiellementpredictif : A partir d'une contamination initiale d'un champ de blé, mesurée par comptage de pucerons au champ ou par étalonnage des données de piège à succion, on simule le développement journalier de populations de pucerons en fonction de la température et de la formation de pucerons ailés supposés quitter la parcelle (fonction de la phénologie de la plante). Les ennemis naturels sont assez grossièrement pris en compte, et seulement à condition de réinitialiser le modèle plusieurs fois en cours de saison ce qui revient à multiplier les échantillonnages que, justement, on veut éviter. De tels modèles ont été développés aux Pays-Bas et en Grande-Bretagne par RABBINGE *et al* (1979) et CARTER.

Ils ont l'avantage de pouvoir être conçus sans, ou avec peu d'études préalables sur le terrain. Ces études de terrain ne devenant indispensables, par la suite, que pour valider le modèle. Ils donnent d'assez bons résultats en cas d'action faible ou nulle des ennemis naturels. Dans le cas contraire, ils surestiment généralement fortement les populations ce qui peut être considéré comme un avantage ou une faiblesse selon le point de vue auquel on se place.

Une version très simplifiée d'un de ces modèles est utilisée depuis 1980 dans le système de prévision intégré EPIPRE (RIJSDIJK et al, 1981).

D'autres modèles déterministes ont un but explicatif

Conçus sur le même principe que les précédents, ils ont pour but d'expliquer le plus finement possible l'action d'un facteur donné de régulation de population : d'un ennemi naturel en général. Ce sont des modèles itératifs dans lesquels le nombre de pucerons rescapés d'une journée de parasitisme ou de prédatisme est sensé produire celui de la journée suivante. Un modèle de ce type a été calculé en Grande-Bretagne par VORLEY (1983) pour quantifier l'action de deux hymenoptères parasites, *A. rhopalosiphi* et *A. picipes* sur *S. avenae*. A chaque unité de temps le modèle est réinitialisé à partir de données de parasitisme issues de dissection de populations de pucerons. La comparaison de simulations avec et sans parasites permet de quantifier l'impact de ceux-ci sur les populations.

Un autre modèle de ce type a été calculé par GRIFFITHS (1983) pour tenter de quantifier la prédation d'*A. dorsale*. Il montre que ce prédateur est efficace quelle que soit sa densité et celle des pucerons pourvu que le taux de reproduction journalier de ces pucerons ne dépasse pas 1,1.

6.2. - LES MODELES DE REGRESSION

Ces modèles sont basés sur des régressions simples ou multiples entre un facteur à expliquer qui peut être le maximum de pucerons produits au cours de la saison, la quantité de pucerons piégés au cours d'une période déterminée, etc... et des facteurs explicatifs d'ordre climatique ou biotique (populations de pucerons à un moment donné, estimations diverses de l'action des ennemis naturels, etc...).

Ces modèles nécessitent une longue série de données biologiques de référence donc un certain nombre d'années d'expérimentations en champ préalables à leur élaboration. Ils ont l'avantage d'être localement efficaces et d'être directement utilisables en prévision. Ils présentent les inconvénients de ne pouvoir être opérationnels que de nombreuses années après le démarrage de l'opération de recherche de terrain et de nécessiter des adaptations hasardeuses si l'on veut les utiliser en dehors de la région où ont été collectées les données biologiques qui ont servi à les établir.

Un modèle de ce type a été établi pour l'Ouest de la France par PIERRE et DEDRYVER (1984). Il est employé à l'échelle locale depuis 1982. L'arbre de décision élaboré en Grande-Bretagne par DEWAR et CARTER (1984) se rattache également à ce type de modèle.

6.3. - QUELQUES QUESTIONS A PROPOS DES MODELES

* Sur le rôle explicatif des modèles

Celui-ci sera d'autant meilleur qu'on possèdera d'avantage de renseignements sur les facteurs entrant en jeu dans le modèle : les limites actuelles à l'utilisation de modèles sont biologiques plus que mathématiques. L'existence au niveau d'un champ de blé d'innombrables intéractions entre climat, plantes, pucerons et ennemis naturels rend illusoire la recherche d'une explication globale du système. Par contre, on peut attendre beaucoup de modèles tendant à expliquer l'action d'un facteur (climatique ou biologique) sur une population de pucerons.

* Sur le transfert entre l'explication d'un phénomène et sa prévision

Le principal problème concerne l'impossibilité de connaître l'évolution du climat à moyen terme, ce qui empêche d'utiliser pour une prévision, tout facteur climatique ayant une répercussion quasi-immédiate sur le facteur qu'on veut étudier : c'est le cas de l'humidité relative pour les entomophthorales.

* Sur les possibilités pratiques d'utilisation des modèles en prévision.

Il est nécessaire de collecter une quantité minimale de données biologiques pour faire tourner un modèle. Les exigences inhérentes à cette collecte (précision et fréquence des observations) peuvent être incompatibles avec la qualification ou la disponibilité des personnes chargées de l'effectuer, ou bien avec la rentabilité même des efforts demandés par rapport aux gains attendus.

Enfin l'utilisation de modèles nécessite une bonne maitrise et un large emploi des moyens de calculs modernes, ce qui n'est pas encore le cas partout.

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INVERTEBRATE POLYPHAGOUS PREDATORS AND CEREAL APHIDS

K.D. Sunderland, R.J. Chambers, D.L. Stacey and N.E. Crook
Glasshouse Crops Research Institute, Littlehampton, W. Sussex, BN17 6LP, UK

Summary

This paper reviews the evidence for polyphagous predators being of economic importance in aphid control, describes the current state of knowledge about the relative importance of the many species involved and suggests practical ways in which their numbers and effectiveness may be increased.

1. THE EFFECT OF THE POLYPHAGOUS PREDATOR FAUNA ON CEREAL APHID POPULATIONS

Although the polyphagous predators found in cereals belong to at least 14 major taxonomic groups (37) they can be treated as a single unit for the purpose of field experiments to determine the effects of predators on aphid populations. Such experiments have been carried out in England (9, 38), Belgium (7) and Sweden (4).

In these experiments predator abundance was reduced by varying degrees in large plots of commercially grown cereals. Predator reduction was achieved using pitfall traps and insecticide applied to the soil; the plots were isolated by plastic barriers. In nearly all cases aphid numbers reached the highest levels (e.g. 5x the normal field population) where predator numbers were lowest and in some cases predator reduction induced an economically damaging level of aphids.

In Sweden (in three out of four years) the same predator-aphid relationship was found in the absence of experimental manipulations and using whole fields as the study units (Ekbom and Wiktelius in prep.) (Fig. 1a). No such relationship was found in a comparable study in England (Sunderland, Chambers and Stacey, unpublished) (Fig. 1b). In the Swedish study the incidence of parasites and pathogens was very low. Aphid-specific predators also appeared in low numbers, often late in the season. These natural enemies were strongly in evidence in the English study and may have obscured a relationship between aphids and polyphagous predators. There is circumstantial evidence in support of this explanation in that a significant negative correlation between aphid increase rate and abundance of aphid-specific predators was found in some years in England (Chambers, Sunderland, Stacey and Wyatt, in prep.).

2. THE RELATIVE CONTRIBUTION TO APHID CONTROL OF THE CONSTITUENT GROUPS AND SPECIES OF PREDATORS

At least 390 species of polyphagous predators are recorded as occurring in UK cereals. Most are spiders or beetles of the families Carabidae and Staphylinidae (Table 1). Many are vagrants or are present only at very low population density. Nevertheless, it is estimated that up to c. 100 species may be numerous in a typical field during the summer. Very little is known of the ecology of some of these dominant species (e.g. within the Acari and Diptera) even though they are potentially important in aphid control. For example, predatory Diptera can be very numerous in cereals (25) and some species will feed on cereal aphids (15).

Fig. 1a. Relationship between Rhopalosiphum padi numbers and polyphagous predators in spring barley, 1979-1981, Uppsala, Sweden (Ekbom and Wiktelius, in prep.)

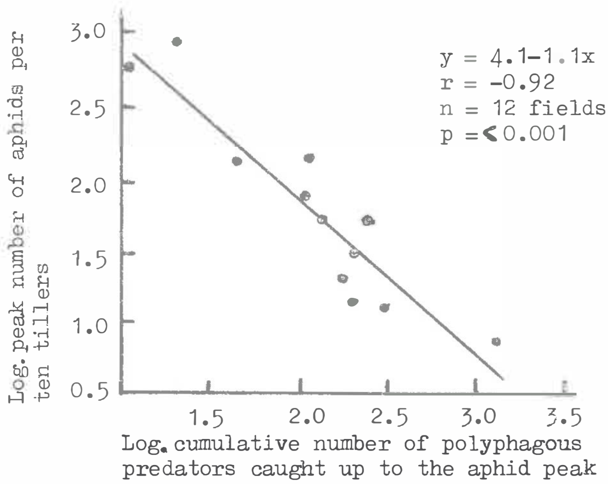
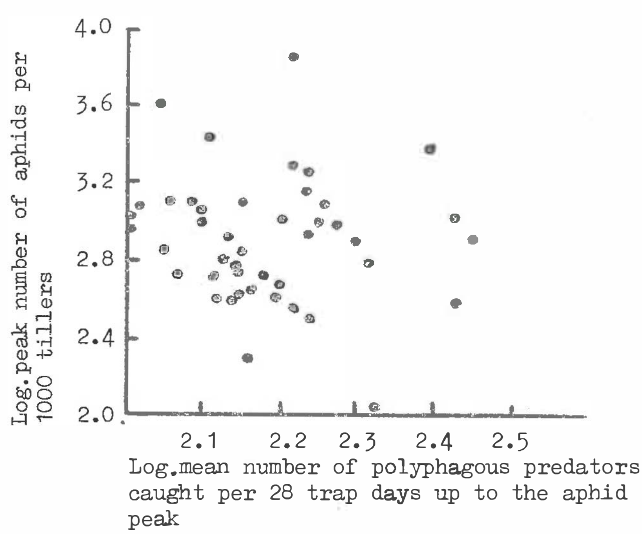


Fig. 1b. Relationship between cereal aphid numbers and polyphagous predators in winter wheat, 1980-1981, Sussex, England



Dermaptera, Carabidae and a few species of Staphylinidae ingest parts of the exoskeleton of their prey when feeding. Analysis of the gut contents of these predators showed that, although a wide range of food is eaten, many species tend to concentrate on a particular food item such as aphids, Collembola, seeds or fungi (34). The common earwig (Forficula auricularia) and the carabids Agonum dorsale and Demetrias atricapillus are strongly aphidophagous and even take aphids at aphid densities of less than one per m^2 in the spring (36). At this stage predator-prey ratios are high and the potential for aphid control optimal. In parts of Europe where aphid-specific predators are numerous it will often be sufficient for polyphagous predators to keep the aphid population below the economic threshold until the arrival of aphid-specific predators later in the season. Recent studies (Chambers, unpublished) have shown that oviposition by Syrphidae in wheat begins at an aphid density of 0.5 per tiller and reaches a peak at between one and two per tiller; thus even if polyphagous predators were to keep aphid populations as low as one per tiller this would not inhibit oviposition by aphiophagous Syrphidae.

Gut dissection is not an appropriate method of dietary study for the majority of polyphagous predators which are fluid-feeders. A serological method called enzyme-linked immunosorbent assay (ELISA) has, however, been shown to be a sensitive and specific technique suitable for this purpose (5). In this assay cereal aphid proteins from the guts of predators are detected by antibodies prepared from aphid extracts. We have used ELISA to examine 6000 predators collected from winter wheat in the South of England. The antiserum used reacts with a range of aphid species, but with no other species. A high proportion of the predators tested had fed on aphids at some time during the study (Table 1).

Table 1. Aphid feeding by polyphagous predators in the UK

	Number of species		
	In UK cereals	Tested by ELISA	Positive in ELISA
Carabidae	86	16	15
Staphylinidae	66	17	11
Cantharidae	10	0	-
Silphidae	3	0	-
Coleoptera larvae	21	15	8
Diptera	25	3	1
Hemiptera	3	2	2
Formicidae	2	1	1
Neuroptera	1	0	-
Dermaptera	1	1	1
Araneae	151	30	20
Acari	10	1	1
Opiliones	8	2	2
Chilopoda	4	2	2
TOTAL	391	90	64

In Table 2 the commonest predator species are ranked in order of abundance. This ranking is based on pitfall trapping and is adequate for most species but underestimates abundance of predatory Diptera and plant-climbing species such as F. auricularia, D. atricapillus and Tachyporus spp. Nearly all the species in Table 2 fed on aphids at some time between April and September and many species took aphids at low aphid density (<1 per 5 tillers) before the start of anthesis. The spiders Pachygnatha degeeri, Oedothorax spp. and Erigone spp. and the staphylinid Philonthus cognatus appeared to be particularly valuable predators during the earliest stages of an aphid infestation (Table 2). However, when account is taken of the differences in digestion rate which affect the period of detection of an aphid meal by ELISA (up to c. 7 days at $13^{o}C$ for most spiders and carabids but c. 1 day for many staphylinids, beetle larvae and mites) it becomes probable that representatives of all the main taxonomic groups have a role to play in early aphid control. Previous studies, using gut dissection, showed that c. 20% of Agonum dorsale contained aphid remains at low aphid density (12, 36) whereas the equivalent figure for ELISA was zero (Table 2). This is only partly explained by the detection period for ELISA being less than that for gut dissection. Laboratory observations show that, for polyphagous predators in general, rate of protein digestion is only weakly related to rate of voiding of solids from the gut and that in addition there is a large amount of variation between individuals of the same species in both these rates. It was also noted that more than 60% of individuals of some species of Staphylinidae adults and larvae digested their aphid meal during feeding (i.e. individuals were negative by ELISA immediately after feeding). This means that values in Table 2 are under-estimates of the true field values.

The work is being extended to take account of the species of aphid eaten and the effect of alternative foods (such as springtails) and also to measure rates of aphid consumption in the field. The latter can be estimated from the equation:

$$\text{Predation rate} = \text{Predator density} \times \text{Lmax.} \times \frac{P}{Dt}$$

where Lmax. is predation rate calculated from experiments in simple laboratory arenas, P is the proportion of predators (from field) positive in ELISA and Dt is the temperature-specific detection period. P/Dt is effectively an index of predator-prey encounter rate in the field.

The feasibility of using a potentially more accurate measure (equation below) is being investigated by P. Sopp (Glasshouse Crops Research Institute/Southampton University):

$$\text{Predation rate} = \text{Predator density} \times \frac{a}{b.(Dt\ .\ c)}$$

a = area under curve of aphid biomass in the gut of a mean predator in the field as determined by quantified ELISA

b = unit of time over which 'a' is computed

c = a proportion (of Dt)

Dt . c is related to the decay curve of detectable aphid material in the predator's gut which can be measured by the method of Lövei et al. (18)

Table 2. Abundance of, and aphid-feeding by, some common species of polyphagous predator

Species	Taxonomic group [a]	Abundance [b]	In ELISA: Number tested	Overall % positive	% positive at low aphid density [c]
1. Erigone atra	A	27.3	584	12	13
2. Erigone dentipalpis	A	20.9	482	7	10
3. Bembidion lampros	C	13.6	242	2	1
4. Pterostichus melanarius	C	13.4	261	10	6
5. Oedothorax fuscus	A	8.4	96*	5*	-
6. Oedothorax retusus	A	7.4	106*	2*	-
7. Agonum dorsale	C	7.0	75	8	0
8. Milleriana innerans	A	6.6	163	10	5
9. Loricera pilicornis	C	4.6	121	3	0
10. Nebria brevicollis	C	4.2	69	1	0
11. Pergamasus spp.	Ac	3.9	392	11	3
12. Meioneta rurestris	A	3.8	64	13	4
13. Pachygnatha degeeri	A	3.1	162	39	53
14. Pardosa pullata	A	2.9	45	20	(29)
15. Philonthus cognatus	S	2.8	171	9	9
16. Loricera pilicornis L.	CL	2.7	258	2	0
17. Linyphiidae immatures	A	2.6	304	13	0
18. Tachyporus hypnorum	S	2.6	80	4	0
19. Oedothorax apicatus	A	2.4	28*	4*	-
20. Philonthus spp. L.	SL	2.1	99	4	0
21. Tachyporus spp. L.	SL	2.0	82	1	-
22. Notiophilus biguttatus	C	1.9	96	7	0
23. Pardosa palustris	A	1.9	11	27	-
24. Notiophilus biguttatus L.	CL	1.9	70	4	4
25. Lepthyphantes tenuis	A	1.8	91	38	-
26. Bathyphantes gracilis	A	1.6	224	15	7
27. Amara aenea	C	1.6	15	13	-
28. Lycosidae immatures	A	1.5	58	14	(13)
29. Pardosa amentata	A	1.4	22	50	-
30. Amara spp. L.	CL	1.2	7	(0)	-

KEY:

a. A - Araneae; C - Carabidae; S - Staphylinidae; L. - larva, CL - carabid larva; SL - staphylinid larva; Ac - Acari

b. Mean number of pitfalls per 28 trap days; based on trapping in 27 cereal sites in the Sussex study area, April-September for a five year period.

c. For aphid densities of up to 100 per m^2 (= up to c. 1 aphid per 5 shoots) during the period up to start of anthesis (Zadoks 61); based on 2 years' data.

* For males only; of 202 Oedothorax spp. females tested, 22% were positive overall and 26% positive at low aphid density.

- sample size < 5   ( ) sample size 5-10

Other methods of quantification are applicable for particular groups of predators. For example, Nyffeler (22) was able to estimate spider predation in the field layer of cereals by taking account of the time to eat a prey item and the proportion of spiders feeding at any given time. Fraser (11) calculated rates of predation of aphids by linyphiid spiders in winter wheat using a knowledge of prey availability, web-cover and capture efficiency. Linyphiids are the commonest spiders in arable crops and densities in excess of 100 per m^2 (a million per ha) have been recorded in cereals. They make non-sticky, horizontal hammock webs on the ground and strung between cereal stalks at various heights. More than half the surface area of fields can be covered by their webs. Fraser calculated that they reduced peak aphid numbers by 37% in one field and he considered them capable of averting minor aphid outbreaks. Colonisation of cereals by spiders (by walking and aerial dispersal on gossamer) is intense in the autumn and continues throughout the winter. It is therefore to be expected that autumn applications of pyrethroids (to which spiders are particularly susceptible (e.g. 1) for the control of BYDV will reduce spider populations and hence the likelihood of natural control of aphids in the following spring. Linyphiids remain active at low temperatures but the extent to which they feed on aphids during the cold months of the year, and thus reduce the spread of BYDV, has not yet been determined.

From casual daytime inspection of the crop, farmers may get the impression that few predators are present. This is, however, very misleading because many are small and cryptic, often hiding during the daytime under weeds and stones and even digging into the soil as far as 25 cm (21). Many emerge at night to climb the plant in search of aphids and other food (17, 41). Holmes (14) observed that larvae of Tachyporus made frequent visits to ears of winter wheat where they took a mean of six Sitobion avenae per colony. Aphids may also leave the plant and come into contact with predators on the ground. Metopolophium dirhodum is easily dislodged from the plant (8); this could result from disturbance by predators or the abrasion of leaf against leaf during windy weather. S. avenae is less easily dislodged, especially when on the ear, but it does frequently move from plant to plant via the ground (6, 23, 42) apparently in search of prime feeding sites (14). Holmes (14) found that it would 'jump off' the plant in response to the presence of a coccinellid but totally ignore the close proximity of a syrphid larva or Tachyporus larva. As a result of these various causes the percentage of the tiller population on the ground can be very high; Griffiths (12) estimated an instantaneous value of 4% and Fraser (11) recorded up to 90% for a 24 hour period. Predator activity on the ground can be considerable. The mean catch per pitfall trap (area 42 cm^2) per day in cereals on the Sussex Study area, over a period of six years, was 7.3 which is equivalent to 1737 predators temporarily present in each m^2 in a day. From the above it appears likely that the opportunities for aphid predation on the ground are great. The probability of predator-aphid encounters is enhanced in the case of many aphidophagous carabids and staphylinids because of their ability to aggregate in aphid-rich patches in cereals (2). The mechanism(s) underlying this ability is not yet known.

3. INCREASING THE ABUNDANCE AND EFFECTIVENESS OF PREDATORS

The abundance of polyphagous predators in cereals could be affected by conditions in overwintering sites outside fields and by a wide range of farming practices within fields. Examples of the latter include timing, method of application and formulation of pesticides, type of fertiliser used and degree of weediness or use of undersowing.

Many of the species of Carabidae and Staphylinidae that are found in cereals in the summer months overwinter in greater numbers beneath field boundaries than in other habitats such as woodland, grassland, stubbles or winter cereals (30). Most overwinter as adults and migrate to crops in the spring. It is possible that management procedures will be devised to foster predators in these boundaries without at the same time exacerbating pest or weed problems.

There is now considerable interest in screening the present generation of pesticides for their effect on polyphagous predators. The aim is to find active ingredients which are effective against their target but which cause minimal mortality of predators. Evaluation of foliar fungicides holds out promise that this may be achieved. These exhibit a wide range of insecticidal action but some appear to cause little predator mortality (31). It may also be possible to increase the abundance of some predators by using organic rather than inorganic fertilisers. Use of sewage cake, for example, results in incrased levels of predatory staphylinids (29).

Polyphagous predators do not appear to thrive on sites where there is only bare soil below the cereal crop. It has been found that weediness (26, 32, 39) and undersowing with ryegrass (29) or clover (13) or grass/legume mixtures (40) enhances populations of predators such as staphylinid adults and carabid and staphylinid larvae. There are often associated reductions of cereal aphids of up to 50%. The presence of grass-weeds would be unacceptable to most farmers but some species of dicotyledons at low density would not be detrimental. Whether predators are increased and aphids significantly reduced in the latter case, is being jointly investigated by the GCRI and the Weed Research Organisation. Similarly, the use of undersown legumes in pest control requires full agronomic evaluation.

Two variables likely to influence the effectiveness of predators in keeping aphid populations below the economic threshold are (i) the extent of aphid settling after immigration and (ii) the subsequent rate of increase of settled aphids. It is known from laboratory and glasshouse observations (e.g. 19, 20) that a wide range of degree of antixenosis and antibiosis is exhibited amongst cereal varieties recommended for commercial use. Van Emden and Wearing (10) showed that, in theory, a combination of varietal rseistance and predators could keep aphid populations below the economic threshold when either, by itself, is insufficient. Predation should also reduce the rate of breakdown (by natural selection) of resistance. Significant differences between cultivars in aphid population development have been recorded in the field for M. dirhodum (16) and S. avenae (27, 33). Chambers et al. (3) monitored aphid populations in winter wheat and found that the increase rate of S. avenae was 30% lower in a field of cv. Rapier as compared with a field of cv. Huntsman during a three week period in June. It is important to know (for the development of integrated control programmes and in forecasting the need for aphicide applications) the relative contribution of natural enemies and varietal resistance in aphid control, and the extent to which synergism occurs between the two. Experiments to measure this, using split-field trials and field cages, are in progress at the GCRI.

4. OTHER PESTS AND OTHER CROPS

The predators discussed here belong to a wide range of taxonomic groups employing various predation strategies (e.g. active hunting on ground and plant or the "sit-and-wait" strategy of web-building spiders) and they have been recorded feeding on many different types of pest. The same species of predator, which in cereals attack such pests as aphids, frit fly, wheat bulb fly, wheat blossom midges, wireworms and slugs, also occur commonly in many other crops, such as permanent pasture, brassicas, legumes, root crops, lettuces, strawberries, hops and orchards (24) where they are known to attack pests (35). It can therefore be expected that much of the detailed information about individual species of predator together with the more general principles and methods being developed for aphids in cereals will also be applicable to other pests and other crops.

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INVESTIGATIONS ON THE INFLUENCE OF FUNGICIDES ON THE POPULATION DYNAMICS OF CEREAL APHIDS

S. KELLER and F. BIGLER
Swiss Federal Research Station for Agronomy
Reckenholzstrasse 191, 8046 Zurich, Switzerland

Summary

In the years 1982 and 1984 we studied the effects of two fungicides on the population dynamcis of cereal aphids on two varieties of winter wheat, Arina and Zenta. In both years the aphid densities were relatively low, but they were markedly higher on the variety Arina, suggesting its higher sensibility to aphid attack.

We could observe neither a distinct influence of the fungicides on the aphid density, nor on their distribution on the plants, nor on the frequency of syrphids, parasitised and diseased aphids. The latter were not present when the fungicides were sprayed which could have been the reason for the absence of an effect on these fungi.

I. INTRODUCTION

Fungicides may influence the population dynamics of cereal aphids in the following ways: (1) The plants are retained in a healthier state, they are more attracitve for aphids and allow them to reproduce more and to stay longer. (2) The fungal antagonists of the aphids (mainly *Erynia neoaphidis* Rem. & Henn., *Conidiobolus obscurus* (Hall & Dunn) Rem. & Kell. and *Entomophthora planchoniana* Cornu) are suppressed. Both effects would favour the development of aphids. With the field trials described below we tried to determine whether such side-effects exist under practical conditions.

II. MATERIAL AND METHODS

The trials were carried out in the years 1982 and 1984 in two fields each of winter wheat of the varieties Arina and Zenta. We tested the two fungicides Tilt-2-Captafol (12.5 % Propiconazol + 60 % Captafol) and Frumidor (14 % Methyl-Thiophanat + 60 % Maneb). Each treatment had 4 replicates. The plots measured 6 x 6 m (1982) and 10 x 10 m (1984). The variety Arina was sprayed in 1982 at growth stage 55 (decimal code), all other sprayings were carried out at growth stage 57 at the recommended dosages.

We counted at weekly intervals the number of aphids and the number of antagonists (Coccinellidae, Chrysopidae, Syrphidae, parasitised and diseased aphids) on 50 tillers/plot. We further noted the species of the aphids and their location on the plants.

III. RESULTS

a. 1982. On the variety Arina, the densities in the 3 treatments at the time when the fungicides were applied were between 3.6 and 5.0 aphids/tiller. After the application the densities decreased in all treatments. This was discovered to be due to the application of Pirimicarb in neighbouring plots. In the untreated plots the density increased again and amounted to 4.3 aphids at growth stage 85. In the plots treated with fungicides, however, the densities remained more or less constant between 1 and 2.5 aphids/tiller.

The fungicides had no distinct influence on the distribution of the aphids on the plants. The proportion of the aphids on the ear increased in all treatments in a comparable manner. At growth stage 85 between 70 and 90 % of the aphids were on the ear.

Of all antagonists syrphids, parasitoids and Entomophthorales were the most frequent. In plots treated with Tilt-2-Captafol the mean number of syrphid larvae was highest with 1.44 per 100 living aphids compared with 0.82 and 0.84 in the other treatments. The number of parasitised and diseased aphids was comparable in all treatments.

On the variety Zenta the densities at the time of the fungicide application amounted to between 1 and 1.4 aphids/tiller.They doubled within the following 4 weeks and reached the maximum density between growth stages 69 and 75. Subsequently they decreased gradually. There was no substantial differences between the treatments. This was also true for the distribution of the aphids on the plants. However, in contrast to the aphids population on the variety Arina, the increase of the proportion colonising the ear was less marked.

Syrphid larvae again were most frequent in plots treated with Tilt-2-Captafol. They reached an average of 1.72 per 100 living aphids, about twice the number of those in the other treatments. Parasitised aphids were found in similar numbers in all treatments whereas the number of diseased aphids was slightly higher in the untreated plots than in the plots treated with fungicides.

b. 1984. On the variety Arina the densities at the time of fungicide application amounted between 1.6 and 2.0 aphids/tiller. In the untreated plots the density reached its maximum one week later at growth stage 65 with 6.2 aphids/tiller. Subsequently it decreased, most rapidly between growth stage 71 and 73. In plots treated with Frumidor the aphids developed in a similar way. They reached their maximum density at growth stages 65-71 with 5.6 aphids/tiller. Plots treated with Tilt-2-Captafol had the lowest aphid density, which was maximum at growth stage 71 with 3.8 aphids tiller.

The fungicide treatments had no marked influence on the distribution of the aphids on the plants. Plots treated wiht Tilt-2-Captafol had less syrphid pupae but more parasitised and diseased aphids than the two other treatments, which had similar numbers.

On the variety Zenta the density at the time of the fungicide application was 0.5 aphids/tiller. Two weeks later at growth stage 71 all treatments reached their maximum densities: 4.0 in plots treated with Tilt-2-Captafol, 3.1 in those treated with Frumidor and 2.4 in the untreated ones. After growth stage 73 the densities in all treatments remained between 0.5 and 0.9 aphids/tiller.

There was no distinct influence of the fungicides on the distribution of the aphids on the plants. Untreated plots had the lowest and plots treated with Frumidor the highest number of syrphid pupae and diseased aphids. Parasitised aphids were most frequent in plots treated with Tilt-2-Captafol. The differences were usually only small and never exceeded a factor of 2.

Aphids species and their localisation were similar in both years. Aphids colonising the ear were almost exclusively Sitobion avenae F. This species was found in small proportions also on the leaves, especially at early growth stages of the plants. Metopolophium dirhodum Walk. colonised almost exclusively the leaves, Rhopalosiphum padi L. was very rare throughout the observation period.

IV. DISCUSSION

In the 4 series of trials described we could not find any unequivocal and constant effect of fungicides on the population dynamcis of cereal aphids. There was neither an influence on the aphid density, nor on the distribution of the aphids on the plants nor on the occurence of aphid antagonists.

On the other hand we observed different small effects which, however, never acted in the same way in more than 2 out of the 4 trials. We may therefore conclude that these small effects occurred accidentally or under particular circumstances. In both years however we observed distinctly higher aphid populations on plants of the variety Arina than on those of the variety Zenta, suggesting a certain resistance of the latter to aphid attack.

Under the conditions of the trials we may therefore exclude any effect of the tested fungicides on cereal aphids and some of their antagonists. But the absence of such an effect can hardly be an attribute of these fungicides since their toxicity or the toxicity of their components for Entomophthorales has already been demonstrated (e.g. DELORME & FRITZ, 1981; FRITZ, 1977; LOAN, 1982; WILDING & BROBYN, 1980). This absence of side effects might be based more on the timing of the fungicide application particularly in relation to the effect on the Entomophthorales. If the fungicide is applied when the fungi are active then undesired side effects cannot be excluded.

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THE BOXWORTH PROJECT : CEREAL PEST/PREDATOR INTERACTIONS

A.J. BURN
Dept. Applied Biology, University of Cambridge, U.K.

Summary

A large-scale project into the effects of intensive pesticide use on winter wheat is being carried out at Boxworth, Cambs., under the direction of M.A.F.F.. This paper summarises the aims of the project, and the areas of research covered by the cereal pest/predator study.

In 1981 the Agricultural Development and Advisory Service began a project to compare the effects of high pesticide input ("insurance"), minimal pesticide input ("supervised"), and an "integrated control" approach to intensive winter wheat production. The study has three broad objectives: to determine the long-term ecological effects of the three treatments on animal and plant species associated with the cereal ecosystem; to determine their effects on crop yield and provide an economic appraisal; to identify the farm management problems that may arise from operating the "supervised" and "integrated" systems. The design of the experiment, which will run for seven years, is based upon the need to be representative of modern farming techniques and its importance lies in its large scale (each treatment area is from 21 to 54 ha) and long-term nature. During the first two years of the project all treatment areas received low pesticide input, to provide baseline data against which any changes can be compared once treatments begin.

The ecological aspect of this study covers several disciplines; work on the cereal pest/predator interactions will concentrate on the effects of different pesticide inputs on the predators of two groups of pests - the cereal aphids and slugs. These pests and the principal groups of predators are being monitored using a range of techniques including baited slug tiles, pitfall traps, D-vac, and aphid dissection for levels of parasitism. The study has focussed on two groups of polyphagous predators: those carabids which overwinter in field boundaries, and the Linyphiid spiders. Preliminary work using plastic exclusion barriers suggested the importance of these groups at the Boxworth site as aphid predators, their role is being further investigated using gut dissections and ELISA tests for fluid feeders, and any changes in the immigration of carabids into fields from overwintering sites are being monitored. Gut dissections have shown that Collembola form an important part of the diet of certain predators during spring; changes in their abundance (measured using D-vac and heat extraction from soil cores), their role as alternative prey, and consequent indirect effects on predator immigration rates and population sizes will form a major part of this study.

SUBGROUP " HOST PLANT INTERACTION "

SOUS GROUPE " INTERACTION AVEC LA PLANTE-HOTE "

STUDIES ON THE EFFECT OF PARTIAL HOST PLANT RESISTANCE ON THE POPULATION DYNAMICS OF THE CEREAL APHIDS

A co-operative research project of the Sub-Group 'Host Plant Interactions'

Th. BASEDOW

Institute of Phytopathology and Applied Zoology,
University of Giessen, FRG

Summary

The Sub-Group 'Host Plant Interactions' held its first meeting in 1981. The decisions drawn at this meeting were the following. 1. Screening for host plant resistance could not be performed collaboratively, but the methods and the results are to be extensively discussed during the future meetings. 2. A collaborative research project was adopted by a couple of members. It is running since 1981/82 in Denmark, Northern Germany (2 locations) and in the U.K. It shall be tested, whether wheat varieties known to be partial resistant to the cereal aphids would be able to keep the aphids below the economic threshold under varying aphid situations, together with the aid of the natural antagonists. To investigate this question collaboratively at several locations will help to get results very much earlier then doing the study on one location only. The first results are shown, but it is far too early to draw conclusions now already. Reliable results will be available not prior than 1985.

1. INTRODUCTION

The Sub-Group mentioned above held its first meeting at Southampton, U.K., in March, 1981. The possible working program has been discussed then.

It was clear to the participants, that screening for host plant resistance is of major importance, when dealing with host plant interactions. But it was also clear, that it would be difficult to achieve co-operative work in this respect, due to different factors: in all countries different assortments of varieties are in trade; the work is very laborious, and the methods of screening are varying to a great extent.

So the Sub-Group members came to the decision, to carry on screening for host plant resistance at the national level, but to discuss the methods and the results at every meeting.

At the Southampton meeting, BASEDOW gave a report on some relevant results concerning field screening. In Northern Germany, oat varieties showed the same degree of susceptibility to the attack by Rhopalosiphum padi whether tested on large fields or on small plots (Table I; BASEDOW et al. 1983).

The second meeting of the Sub-Group took place at Wageningen, The Netherlands, in March, 1984. Some of the members presented their results on screening for cereal aphid resistance, there, for discussion. These reports are partly printed in this Bulletin (see the following paper).

Additional to the above mentioned decision concerning the screening program, a couple of Sub-Group-members decided in 1981 to run a co-operative research project on the effect of partial host plant resistance on the population dynamics of the cereal aphids. In other words, it was to be tested, whether wheat varieties known to be partial resistant to the cereal aphids would be able to keep aphids below the economic threshold under varying aphid situations, together with the aid of the natural enemies.

For one research worker alone, this program would make a lot of work and take him a lot of time, waiting for a number of different aphid situations. So it was of great advantage to have the Working Group, which made it possible to run the program at various locations at the same time. So we are looking forward in getting reliable results within a few years.

Table I. The attack of 3 oat varieties by the birdcherry-oat-aphid on large fields an on small plots in Northern Germany.

Spring Oat Variety	Rhopalosiphum padi per 100 tillers		
	Large fields 1976	small plots 1978	
	Kiel	Kiel	Oldenburg
Leanda	9650*	313*	241
Selma	2260	72	10
Marino	1697	50	-

* significant difference to the other varieties (P = 0.05)

The experiment was started in autumn, 1981, at Lynby, Denmark (J. REITZEL), Harpenden, Herts., U.K. (W. POWELL), Kiel, FRG (Th. BASEDOW) and at Oldenburg, FRG (G. LAUENSTEIN). The following is a report on the experimental design, the methods used, and on the first results.

2. METHODS

For the experiment there were chosen two winter wheat varieties of different susceptibility to cereal aphid attack (LOWE 1980, 1982). 'Maris Huntsman' (susceptible) and 'Bounty' (partial resistant). They were sown in plots of 10 x 10 m in 5 replicates at the same date and did not receive any insecticidal treatment. The following data are measured at weekly intervals from the beginning of May up to harvest:

1. Number of aphids per tiller (50 tillers per plot)
2. Mummified aphids per tiller
   a. by hymenopterous parasites
   b. by Entomophthoraceae
3. Aphid specific predators per tiller (Coccinellidae, Syrphidae)
4. Polyphagous predators in pitfall traps (2 per plot) (Carabidae, Staphylinidae, and spiders.

3. FIRST RESULTS

The analysis of only a part of the first field experiments has been started up to now.

Table II shows a part of the results of two experiments performed near Kiel, 1982 and 1983. The aphid specific predators were almost absent in both years.

Surprisingly, only in 1982, when the aphid attack remained at a low level, there was found a highly significant difference between the two varieties.

In 1983, however, when the infestation by cereal aphids reached a high level, in both varieties the aphids reached almost the equal number per tiller.

The percentage of parasitized and diseased aphids proved to be slightly higher in the variety 'Bounty'.

The figures for the activity of the polyphagous predators are not yet available for both years.

Table II. Differences in the cereal aphid attack in two winter wheat varieties at Muxall/Kiel (FRG), 1982 and 1983.

Year	Maximum number of aphids per tiller			
	'Maris Huntsman'		'Bounty'	
	healthy	paras./diseased	healthy	paras./diseased
1982	4.4	0.3 (23.0%)	0.4**	0.09 (28.1%)
1983	17.3	3.9 (18.4%)	16.5	2.6 (23.4%)

* difference between the varieties at P = 0.05.

4. DISCUSSION

It is too early and was not intended to draw conclusions from only two experiments.

In the beginning of 1985 hopefully the results of 10 experiments will be available for further analysis, which then should be of some importance concerning the value of partial resistance for the integrated control of cereal aphids.

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BREEDING FOR RESISTANCE AGAINST RHOPALOSIPHUM PADI (L.) IN SPRING CEREALS IN SWEDEN

J. WEIBULL

Department of Plant and Forest Protection,
The Swedish University of Agricultural Sciences,
Uppsala, Sweden

Rhopalosiphum padi (L.) is one of the most important insect pests in spring sown cereals in Sweden. In 1978 annual losses (without the use of insecticides) were estimated to 200m SwCr (18m Ł). Apart from causing direct damage to crops the aphid is also an important vector for BYDV, barley yellow dwarf virus.

A project was therefore initiated in 1982 to examine the possibilities of breeding for resistance in spring cereals (oats and barley). The work can be divided in two main parts: the screening of large collections of varieties and development of new screening techniques, and the study and characterization of resistance factors. Environmental influence (i.e. water and nutrient stress, variable light intensity and temperature) on level of resistance will also be considered.

During the last two years we have been screening collections of oats and barley, cultivars as well as wild species. The range of variation is therefore well established for several measures, such as teneral weight, developmental time and reproduction. The results obtained so far suggest that there is greater genotypic variation in Hordeum than in Avena.

To understand the host resistance mechanisms, different aspects of the aphid-plant relationship need to be considered. Therefore, investigations concerning probing behaviour on different hosts, nutritional requirements of the aphid (by means of artificial diets) and intervarietal variation in amino acid and carbohydrate composition, are performed. The latter is achieved by the use of a high frequency microcautery (UNWIN, 1978; MENTIK et al., 1984) to obtain phloem sap samples, in combination with the HPLC technique.

All the information on possible resistance factors will later be tested and weighed together in a R. padi population dynamic model (WIKTELIUS & PETTERSSON, to be published) to estimate the influence on expected population peaks.

The project is supported by the Swedish Council for Forestry and Agricultural Research and the Plant Breeding Board.

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SOUS GROUPE " TECHNIQUES CULTURALES "

SUBGROUP " CROP MANIPULATION "

SUB-GROUP "SOIL FAUNA AND CEREAL PESTS" (NOW SUB-GROUP ON "CROP MANIPULATION")

R. BARDNER, SUB-GROUP CONVENOR

Background to formation of sub-group

At the meeting of the Working Group for the Integrated Control of Soil Pests at Gottingen in September 1976, the possibility of liaison with the Working Group on Integrated Control in Cereals was discussed. At that time there was no IOBC/WPRS group concerned with the soil fauna of cereal fields, other than carabids, and no group concerned with cereal pests other than aphids, yet methods of cereal growing were (and are) in a state of rapid change and many of the effects of these changes on integrated control were not being investigated. Many cereal pests spend at least part of their life in the soil and even those which are predominantly foliage pests are attacked by many predators that are predominantly soil dwellers. The possibilities of collaborative work in these areas was discussed at the Cereal Working Group meeting at Versailles in January 1977, and R. Bardner was asked to co-ordinate and animate the work of the sub-group.

The first meeting of the sub-group on soil fauna and cereal pests was held at Rothamsted, Harpenden, in March 1979 with twenty-five participants from Belgium France, West Germany, the Republic of Ireland, Spain and the United Kingdom. Interest was expressed in:

(i) Effects of pesticides on beneficial insects
(ii) Effects of beneficial insects on cereal pests
(iii) Development of integrated control measures in cereals
(iv) Methodology, especially standardized methods of estimating populations of pests and beneficial organisms.

Most of the participants were interested in the side effects of broad spectrum fungicides and insecticides on beneficial organisms and a joint experiment to be performed in several countries was agreed as a major project for the sub-group. The experiment, starting in autumn 1979, concerned the effects of benomyl, dimethoate and pirimicarb on autumn-planted wheat, and results are outlined below. It was also intended that information would be exchanged about other relevant work and bibliographies would be circulated.

The second meeting of the sub-group was at Rennes in November 1981, with 14 participants. The joint experiment (or variations of it) had been done by De Clercq (Belgium), Feeny (Ireland), Vickerman (UK), Castanera (Spain) and Rothamsted workers (UK). Some planned to do another season's work in 1982 and others hoped to commence the experiment in that year. Other relevant work had been done at GCRI (UK), and by Gregoire-Wibo in Belgium and Basidow in Germany.

For the future it was decided to concentrate more on the opportunities for farm practise to increase the efficiency of beneficial insects rather than on the adverse effects that were currently being investigated in the joint experiment. Relevant interests were:- Effects of semi-resistant varieties, undersowing, alternative food sources for polyphagous predators, movement of predators (GCRI, UK), organic matter (De Clercq), crop rotation and minimal cultivation (Castanera), undersowing, crop rotation and insecticide timing (Feeny), crop rotation, under-sowing, organic matter and predator movement (Bardner and Powell), rotation (Mouchard and Devrient, France). All of these topics can be covered by the term "Cultural Control". It was agreed that members of the group would work on topics of their choice in this general area and present their results at the next meeting when opportunities for another collaborative experiment would be discussed.

In September 1983 all the sub-group conveners of the Working Group on the Integrated Control of Cereal Pests met in Paris to consider reorganisation and closer integration with other IOBC/OILB activities. It was agreed to re-define all four subgroups, retaining the present conveners. The sub group on soil fauna and soil pests would become the sub group on crop manipulation and will include work on the effects of all cultural manipulations (including pesticides) and their effects on cereal fauna, with special reference to the soil. Cultural practises that could enhance the biological control of aphids will be a priority though effects on other pests will also be considered.

The Joint Experiment

Background There has been a much greater use of insecticide and fungicide sprays in cereals in recent years. For example, in the UK in 1977 an area equivalent to 47% of the wheat crop in England and Wales was treated with organphosphorous sprays, nearly all of which were applied to control aphids. An area equivalent to 36% of the crop was also treated with fungicide sprays. Only about half the insecticide sprays were of the selective aphicide pirimicarb, the rest being broad spectrum materials which can have complex effects on cereal pests and which are also often lethal to predators. Over 60% of the fungicide sprays were of the carbendazim type, a group which has been reported to have toxic effects on some arthropods and on earthworms. It was thought that a collaborative experiment in several countries would be of interest in view of the wide-spread use of these materials. It was realised that although common treatments, layout and measurements might be agreed, circumstances would inevitably result in individual variations of all of these.

Object of experiment To compare the effects of benomyl, dimethoate and pirimicarb at normal rates of application on the ceral fauna of winter wheat at various sites in Europe, with special attention to the effects on cereal pests and their parasites and predators.

Treatments

(1) Untreated
(2) Benomyl at 0.28 kg a.i. ha^{-1} applied at Zadoks growth stage 30-31. (usually April in UK)
(3) Dimethoate, at 0.35 litres a.i. ha^{-1} applied at beginning of flowering (growth stage 60)
(4) Pirimicarb, at 0.14 kg a.i. ha^{-1} applied at beginning of flowering.

Design 3-4 blocks of 4 plots = 12 or 16 plots. Each plot square in shape with area about 0.04 ha. Wheat should be autumn-sown, using seed cultivars, seed rate, fertilizer treatment and herbicides typical of locality.

Measurements

(1) Surface predators (carabids, spiders etc) using pitfall traps, (spring until harvest).
(2) Surface fauna. Soil washing and/or Tullgren funnels before and after application of treatments and immediately after harvest.
(3) Weekly counts of aphid infestations.
(4) Stem borers - after benomyl application.
(5) Inflorescence pests (Thrips, Cecidomyids).

(6) Coccinelids and other beneficial insects on foliage (by sweeping or suction sampler)
(7) Surface predation after harvest (if land remains uncultivated until spring.

A further refinement in several experiments was to surround each plot with a vertical polythene barrier, the bottom of which was buried in the soil. This was intended to decrease the movement of soil surface arthropods between plots.

Other relevant work by sub-group members :

Effects of organic matter on epigeal arthropods

R. de Clercq and R. Pietraszko, Rijksstation voor Nematologie en Entomology, Burg. van Gansberghelaann 96, Merelbeke, B-9220, BELGIUM

The effects of a single application of organic manure were examined applied either one or two years before growing winter wheat after potatoes. Total numbers of carabids + staphylinids + spiders were:- Untreated 5,529, Manured two years previously 6,619, manured one year previously 5,924.

Earlier work included a study of the carabid fauna of winter wheat fields in collaboration with workers in Germany, the Netherlands and Sweden, a study of the arachno-fauna of winter wheat, the staphylinid fauna of winter wheat and experiments on the influence of soil fauna on the aphid populations of winter wheat.

Effects of herbicide treatment on the insect fauna of winter wheat

W. Powell, Rothamsted Experimental Station, Harpenden, Herts, U.K.

Experiments compared weedy and weed-free plots in 1980 and 1981. There were no polythene barriers, allowing the fauna to select their preferred conditions. Cereal aphid numbers were low in both seasons and there was little difference between treatments. Numbers of spiders caught in pitfall traps was similar in all treatments whilst numbers of carabids and staphylinids showed treatment differences varying with species. Staphylinids were either unaffected or were caught in greater numbers in the weedy plots. Amongst the carabids, *Loricera pilicornis*, *Agonum dorsale* and *Amara* spp. were caught in greater numbers in the weedy plots, whereas *Pterostichus melanarius* and *P. madidus* were caught preferentially in the clean plots.

Effects of Organic Matter on soil fauna and epigeal predators

W. Powell, R. Bardner, J.E. Bater, J.R. Lofty, Rothamsted Experimental Station, Harpenden, Herts, U.K.

Experiments were begun at Rothamsted in 1983 attempting to increase polyphagous predators in winter wheat by increasing alternative prey using organic matter applications. The plots used had received applications or inorganic nitrogen, farmyard manure or sewage cake for six consecutive seasons and were balanced for approximately equal amounts of nitrogen. Pitfall traps showed that more carabids, especially *Agonum dorsale* were caught on the sewage cake plots in May and much greater numbers of staphylinids were also caught on these olots in June or July. Preliminary examination of the microfauna from soil cores shows that there were more animals in the plots treated with either form of organic matter than on the inorganic plot.

Influence of crops and tillage practices on Carabid populations

C. Gregoire-Wibo with P. Stassart and M. Frankinet, Laboratoire D'ecologie, Universite Catholique de Louvain, Place Croix du Sud 5, B-1348 Louvain - La -Neuve, BELGIUM.

An experiment on the long term effects of minimal cultivation was sampled in 1982. There were three tillage practices (normal ploughing to 30 cm, shallow ploughing to 15 cm and direct drilling). The crops were winter wheat, winter barley, maize and sugar beet. Pitfall traps were used from April until harvest. Results show important differences related to crop and tillage. Several species enhanced their abundance after minimal cultivation.

Other related work includes studies of carabid ecology and laboratory studies on the toxicity of insecticides to carabids.

Agonum dorsale and the effects of insecticides on its abundance in Northern Germany

T. Basedow, Biologische Bundesanstalt fur Land und Forstwirtschaft, Schlosskoppelweg 8, 2305 Heikendorf-Kitzeberg, W. Germany.

Populations of *Agonum dorsale* were decreased by 86.5% when parathion was sprayed for aphid control, and by 60.7% when oxydemeton-methyl was sprayed. In 1972-74, when only 33% of the wheat oat fields near Kiel were sprayed with either of these two insecticides there were 15.7 *A. dorsale* per $10m^2$, but when 90% of the area was sprayed (1979-80) populations declined to 4.3 per $10m^2$.

ON THE INFLUENCE OF PESTICIDES ON THE EPIGEAL ARTHROPOD FAUNA IN WINTER WHEAT

R. DE CLERCQ and R. PIETRASZKO
Rijksstation voor Nematologie en Entomology, Burg. van Gansberghelaan 96
Merelbeke, B-9220, Belgium

Summary

During 1980, 1981 and 1982 the influence of the insecticides parathion, dimethoate and pirimicarb, and of the fungicide benomyl has been investigated on the epigeal predator fauna (Carabidae, Staphylinidae and Araneae) in winter wheat. Our experiments were carried out in 3 replicates on square barriered plots of 25 m^2. The predator fauna was examined by means of pitfall traps. From these experiments it can be concluded that the insecticides parathion and dimethoate are very toxic for the dominant Carabidae and Staphylinidae spp., but only little for the spiders, whereas pirimicarb and the fungicide benomyl had no influence on this fauna.

1. INTRODUCTION

During a study on the occurrence of the epigeal arthropod fauna on winter wheat fields in two regions in Belgium, we found that this fauna was composed for 45% of Araneae, for 27% of Carabidae, for 21% of Staphylinidae and for 7% Acari (3,4). It has been proved in our investigations that this arthropod fauna or at least some components of it, must act as aphid predators in one way or another (2). SUNDERLAND et al. obtained analogous results in their experiments (5). In recent years there has been a growing use of insecticides and fungicides in cereals in Belgium.

This paper described experiments carried out in order to investigate the possible influence of pirimicarb, parathion, dimethoate and benomyl on the epigeal arthropod fauna in winter wheat.

2. Methods

The experiments were carried out in 1980, 1981 and 1982 in 3 replicates on suqare plots of 25 m^2. Winter wheat was sown in November, using seed cultivar, seed rate, fertilizer treatment and herbicides typical of locality. All the plots were barriered half June with 50 cm high corrugated plastic sheets which were buried 20 cm into the soil in order to prevent migration of the animals between the different plots.

The following objects were compared:

- untreated
- benomyl at 300 g a.i./ha crop treatment
- pirimicarb at 200 g a.i./ha crop treatment
- pirimicarb at 200 g a.i./ha ground treatment
- parathion at 250 g a.i./ha crop treatment
- parathion at 250 g a.i./ha ground treatment
- dimethoate at 400 ml a.i./ha crop treatment

Application took place at the beginning of flowering of the cereals. Four days after the application of the pesticides 8 plastic beakers with a diameter of 10 cm were buried within each plot with their open end level to the soil; four of them were divided on equal distances in the middle of each plot, and one was placed close to each sheet in the middle of it. The beakers filled with a formol solution 1% to which a spreading agent was added, were weekly emptied, beginning a week after the application of the pesticides until the end of July.

3. Results

The total number of predators caught during the 3 years within the different plots is given in table 1. The Araneae were the most abundant group and consisted mainly of : Erigone atra (Blackwall), E. dentipalpis (Wider), E. vagans Audouin, Oedothorax apicatus (Blackwall), O. fuscus (Blackwall), Bathyphantes gracilis (Blackwall), Leptyphantes tenuis (Blackwall), Meioneta rurestris (C.L. Koch). These results demonstrate that all the treatments caused a reduction of the number of spiders by 7% to 18% during the observed post-treatment period. No significant differences in toxicity between the pesticides used were found.

Table 1 Influence of 4 pesticides on the predators in 1980, 1981 and 1982
Total catches in 3 x 8 pitfalls from half June to the end of July

Treatment	Carabidae		Staphylinidae		Araneae	
	Total	%	Total	%	Total	%
Untreated	1741	100	4310	100	18018	100
Pirimicarb (ground treatment)	1549	89	4172	97	15633	87
Pirimicarb (crop treatment)	1756	101	4441	103	16586	92
Parathion (ground treatment)	1242	71	1399	33	14786	82
Parathion (crop treatment)	1247	72	1606	37	15682	87
Dimethoate	1261	72	2981	69	16109	89
Benomyl	1742	100	3959	92	16796	93

The most numerous occurring staphylinids were : Aloconata gregaria (Er.), Oxypoda exoleta Er., Tachyporus hypnorum (L.), Oxytelus rugosus (Grav.), O. sculpturatus Grav., Latrobium fulvipenne Grav., Xantholinus semirufus (Rtt.), Philonthus fuscipennis (Mannh.), Atheta fungi (Grav.) and Amischa analis (Grav.). The results indicate that parathion (both ground- and crop treatments) and dimethoate (crop treatment) are very noxious to the rove beetles, reducing their number respectively by 67%, 63% and 41%; pirimicarb and benomyl had only little effect on the staphylinid population.

The Carabidae were less abundant than the former predators. The dominant and subdominant species were : Bembidion lampros Herbst, B. ustulatum L., B. obtusum Strm., Platynus dorsalis Pont., Pterostichus melanarius (Illiger), Trechus 4-striatus Schrk., Asaphidion flavipes L., Lorocera pilicornis F., Clivina fossor L. and Notiophilus biguttatus F.. Only parathion (both ground and crop treatments) and dimethoate caused a mortality, respectively 29%, 28% and 28%.

The relative numbers of animals caught in 1980, 1981 and 1982 are given in table 2. It can be concluded from this table that the yearly obtained results are very analogous, the only slight differences being caused by the variability of micro-climate and vegetation density.

4. Conclusion

These experiments have shown that parathion and dimethoate are toxic for carabids and staphylinids, but less for spiders. Our results are analogous to those obtained by BASEDOW et al. (1) and VICKERMAN and SUNDERLAND (6). The selective insecticide pirimicarb and the fungicide benomyl did not decrease the arthropod fauna.

Because of their detrimental effect on the beneficial insects, a widespread use of broader spectrum insecticides - such as parathion and dimethoate - for cereal aphid control ought to be avoided.

Damage to the epigeal fauna can only be minimized when using selective pesticides, such as pirimicarb, for the control of aphids in cereals, but even this insecticide should only be applied when the aphid infestation exceeds the economic threshold level.

Table 2 Influence of 4 pesticides on the predators in 1980, 1981 and 1982

Treatment	Carabidae			Staphylinidae			Araneae		
	1980	1981	1982	1980	1981	1982	1980	1981	1982
Untreated	100	100	100	100	100	100	100	100	100
Pirimicarb (ground treatment)	83	87	103	107	85	94	87	75	103
Pirimicarb (crop treatment)	94	108	93	120	92	93	93	85	107
Parathion (ground treatment)	57	76	82	24	41	35	76	72	90
Parathion (crop treatment)	59	71	95	29	48	38	79	81	101
Dimethoate	56	78	86	84	49	68	94	85	93
Benomyl	118	90	100	90	82	102	87	87	105

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STUDY OF THE SOIL FAUNA IN WINTER WHEAT FIELDS AND EXPERIMENTS ON THE INFLUENCE OF THIS FAUNA ON THE APHID POPULATION

R. DE CLERCQ
Rijksstation voor Nematologie en Entomologie,
Burg. Van Gansberghelaan 96, Merelbeke, B-9220, Belgium

1. Study of the Carabidae fauna in winter wheat fields

This study was carried out in 1974 in co-operation with colleagues from Germany, the Netherlands and Sweden. The occurrence of Carabidae was investigated by pitfall trapping on two loamy soils at Waasten and on two heavy clay soils at Kieldrecht from at least 5 ha, during the period end May to beginning of August. Our results of this study together with those of the German, Dutch and Swedish colleagues have been jointly published in Entomophaga (1976, 21, 59-72).

This study has been continued on the same 4 fields in 1975, 1976, 1977 and 1978 in order to examine the possible influence of other crops (sugar beet, flax and barley) on the soil fauna. Although the data of this further studies have not yet been processed in detail we already can conclude that the same species as in winter wheat also occur in the other crops on the same field but with different ratio's as far as the number of each species is concerned.

2. Study of the Arachno-fauna on fields of winter wheat

Simultaneously with the Carabidae also the Araneae and the Staphylinidae have been carefully collected from the pitfall traps in the 4 winter wheat fields in 1974, counted and determined further up to the species.

Fifty-five species of Araneae were captured at at Kieldrecht and 46 at Waasten. These species mainly belong to the family of the Linyphiidae. This family was quantitatively very important representing 96% to 99% of the total spider population. The remaining species belonged to the family of the Tetragnathidae, Lycosidae, Agelenidae, Clubionidae, Theridiidae, Thomisidae, Zoridae and Gnaphosidae.

A rather limited number of species, namely Oedothorax apicatus (Blackwall), O. fuscus (Blackwall), Erigone atra (Blackwall), E. dentipalpis (Wider), E. vagans Audouin, Leptyphantes tenuis (Blackwall), Bathyphantes gracilis (Blackwall) and Meioneta rurestris (C.L. Koch) represented 94% to 98% of the total population of the Linyphiidae.

Four species have been captured which are new for the Belgian fauna, namely Jacksonella falconeri (Jackson), Troxochrus cirrifrons (O.P.-Cambridge), Milleriana inerrans (O.P.-Cambridge) and Syedra gracilis (Menge).

3. Study of the Staphylinidae-fauna on fields of winter wheat

Twenty three different species were captured at Kieldrecht and 20 at Waasten.

The number of captured rove-beetles on the heavy clay-soils at Kieldrecht was larger than that on the loamy soil at Waasten, namely 1303 and 957 at Kieldrecht versus 515 and 770 at Waasten. Atheta fungi (Grav.) was most numerous at Kieldrecht with 58 and 50% and the species Oxytelus sculpturatus Grav. at Waasten with 32 and 47%.

Concerning the number of captured beetles, the secondly most important species on both fields was Tachyporus hyonorum (L.). The following species were found on both fields in a rather limited number : Latrobium geminum Kr., Oxytelus inustus Grav., Tachyporus solutus Fr., Philonthus fuscipennis (Mannh.) and Micropeplus porcatus (F.).

4. Experiments on the influence of the soil fauna on the aphid populatin in winter wheat

The influence of the soil fauna on the aphid population in winter wheat was investigated by reducing this fauna on small square plots of 25 m^2 that were fenced with corrugated plastic sheets. Therefore 10 pitfall traps were put within each plot in order to catch as many Carabidae, Staphylinidae and Araneae as possible. This experiment was carried out in four replicates, in 1977 and 1978.

The number of aphids per 50 tillers for each plot was counted at different dates.

The results obtained are given in the following table; they clearly show that the aphid population on the plots with reduced soil fauna was almost doubled, when compared with that on the control plots.

Number of aphids per tiller on winter wheat
(averages of 4 counts of 50 tillers)

Date of counts		Plots with normal fauna	Plots with reduced fauna
1977	4 July	16,83	36,01
	11 July	2,06	15,72
1978	4 July	10,27	16,22
	11 July	11,04	22,71
	17 July	10,66	18,93
	24 July	7,37	15,64

The number of Carabidae, Staphylinidae and Araneae captured during this experiment in the 40 pitfall traps from the 4 small isolated field plots are given in the following table

Total number of captured	Pitfall traps emptied on						
	1977			1978			
	4.7	11.7	19.7	15.6	30.6	18.7	31.7
Carabidae	694	181	124	571	468	345	314
Staphylinidae	443	157	157	1469	828	286	471
Araneae	537	1333	2259	1150	1620	1128	1207
Total	1724	1681	2540	3190	2916	1759	1992

EFFECTS OF POLYETHYLENE BARRIERS ON THE NUMBERS OF EPIGEAL PREDATORS CAUGHT IN PITFALL TRAPS IN PLOTS OF WINTER WHEAT WITH AND WITHOUT SOIL-SURFACE TREATMENTS OF FONOFOS

W. POWELL and R. BARDNER
Rothamsted Experimental Station, Harpenden, Herts, AL5 2JQ

Re-invasion of plots treated with insecticides hinders the measurement of treatment effects, particularly on highly mobile epigeal predators. This was investigated by pitfall trapping in plots with and without barriers in the presence or absence of the insecticide fonofos applied at 4.5 kg a.i.ha^{-1} to the soil surface in the spring. Plot size was similar to that used in the joint IOBC/OILB experiment.

Barriers had no effect on the numbers of staphylinids caught, probably because most are active fliers. In the case of spiders, barriers did not affect numbers caught in untreated plots but the reduction in numbers due to fonofos was greater when barriers were used. Similar results were obtained for spring-breeding carabids, e.g. Agonum dorsale, Bembidion lampros. Catches of B. lampros actually increased in open, fonofos-treated plots, presumably due to re-invasion and increased activity in the presence of sub-lethal pesticide levels. In 1980 barriers hindered emigration from an overcrowded population of Pterostichus melanarius resulting in abnormally high catches in untreated, barriered plots. In both years the highest yields were obtained from the plots treated with fonofos, but as none of the cereal pests were present in large numbers there is no obvious explanation.

Barriers are useful in helping to detect the effects of pesticides on epigeal predators but in some circumstances they can give erroneous results by interfering with natural immigration and emigration by predator species (see tables 3 & 4).

Other associated work (J. Ashby) includes a comparison of the epigeal fauna of bare (fallow) soil with a winter wheat crop using both surface and subterranean pitfall traps throughout the year.

Table 1 Polyphagous predators caught in pitfall traps in winter wheat after pirimicarb and dimethoate treatments (1981)

	Days after treatment	Untreated	Pirimicarb	Dimethoate
Carabidae	1-3	45	34	1***
	8-10	59	74	26**
Staphylinidae	1-3	29	23	9*
	8-10	24	24	6*
Araneae	1-3	34	32	9**
	8-10	104	81	49**

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Table 2 Aphid parasitoids caught in suction-net samples in winter wheat after pirimicarb and dimethoate treatments

Year	Days after treatment	Untreated	Pirimicarb	Dimethoate
1980	1	39	20**	12**
	13	57	24**	16 **
1981	3	14	8	2*

* $p < 0.05$
** $p < 0.01$

Table 3 Mean numbers of epigeal predators caught per plot between mid-April and mid-August, 1980 in untreated plots, untreated plots surrounded by barriers, fonofos-treated plots, and fonofos-treated plots surrounded by barriers (3 replicates per treatment)

	Untreated	Untreated + barriers	Fonofos-treated	Fonofos-treated+ barriers
Total Carabidae	884.0±97.4	1337.3±165.0	462.3±22.9	336.7±51.9
Bembidion lampros	49.3±3.3	37.3±7.5	87.3±17.9	22.3±3.3
Pterostichus madidus	112.7±9.4	160.0±22.2	55.3±5.2	57.0±12.2
P. melanarius	611.7±96.5	1023.7±127.5	280.3±7.1	238.0±45.2
Trechus quadristriatus	80.3±13.0	85.3±12.5	10.3±3.1	5.0±2.2
Total Staphylinidae	213.0±14.6	226.3±37.5	132.6±17.7	107.0±8.27
Aleocharinae	98.7±6.7	122.0±24.2	89.7±9.7	75.0±7.4
Oxytelus spp.	36.0±4.5	28.0±5.4	13.0±5.0	5.3±1.7
Philonthus cognatus	13.0±2.6	25.0±2.4	3.0±0.0	3.7±0.5
Tachyporus hypnorum	32.7±2.2	24.3±3.3	14.7±2.4	11.7±1.8
Total *Tachyporus* spp.	47.7±2.2	38.0±3.3	25.0±2.9	20.3±2.2
Carabid + Staph. Larvae	56.7±6.5	82.7±9.0	18.7±1.5	11.7±3.1
Araneae	695.7±50.7	572.3±23.8	367.7±59.5	156.0±11.0

Table 4 Mean numbers (±S.E.) of epigeal predators caught per plot between the beginning of May and mid-August 1981, in untreated plots, untreated plots surrounded by barriers, fonofos-treated plots and fonofos-treated surrounded by barriers (3 replicates per treatment).

	Untreated	Untreated + barriers	Fonofos-treated	Fonofos-treated+ barriers
Total Carabidae	171.7±10.4	156.0±17.6	40.7±3.5	21.0±1.4
Agonum dorsale	6.7±1.0	3.3±1.1	5.7±0.3	0.3±0.3
Loricera pilicornis	30.3±5.5	30.0±5.4	3.3±0.3	0.3±0.3
Pterostichus madidus	17.3±3.1	8.3±2.4	4.0±1.2	0.3±0.3
P. melanarius	102.7±18.4	108.0±13.9	19.7±1.2	17.3±1.0
Total Staphylinidae	260.3±30.4	274.3±32.0	104.3±9.0	98.3±13.7
Aleocharinae	130.0±15.4	132.0±15.9	65.3±6.5	62.3±8.3
Oxytelus spp.	37.0±6.0	33.7±2.7	4.0±2.2	3.3±0.5
Philonthus cognatus	36.7±6.4	44.0±9.4	0.7±0.5	1.3±1.1
Tachyporus hypnorum	16.3±4.0	19.3±2.2	12.7±0.5	14.0±4.1
Total _Tachyporus_ spp.	31.3±4.0	36.7±1.2	33.7±0.7	30.0±4.0
Carabid + Staph. Larvae	179.3±12.5	181.3±19.2	24.7±6.0	17.7±1.4
Araneae	278.7±13.4	256.3±14.7	122.7±5.7	77.0±2.8

CONTRIBUTION TO THE JOINT IOBC/OILB EXPERIMENT ON SOIL FAUNA ON CEREAL PESTS

W. POWELL and R. BARDNER
Rothamsted Experimental Station, Harpenden, Herts, AL5 2JQ, U.K.

Experiments were done in 1980 and 1981, using the suggested treatments and lay-out, with three replicates per treatment. The plot size was 19 x 13.5 m and plots were separated by 3.4 m discards. Benomyl at 0.5 Kg/ha was applied at Zadoks growth stage 31-32, pirimicarb at 0.14 kg/ha was applied at growth stage 61-65, as was dimethoate at 0.35l/ha. In 1980 there were no polythene barriers round the plots, in 1981 barriers were erected in early May. The barriers extended 15 cm below the soil surface and 45 cm above it. In each plot there were six pitfall traps 7 cm in diameter containing 50% methanol. Each trap was operated for 48 hours each week between mid April and harvest. Additionally, foliage was also sampled with a suction apparatus ("Devac") on nine occasions, and aphid counts were made in the first year. Aphids were too scarce to be counted in 1981 and in 1982 they did not exceed the economic threshold of five per ear.

Benomyl did not affect the numbers of predators or parasites in either year. In 1980 neither insecticide affected the numbers of epigeal predators caught in pitfall traps presumably because of re-invasion from the surrounding area. In 1981, when the plots were surrounded by barriers, fewer spiders and adult and larval carabids and staphylinids were caught in pitfall traps in the dimethoate plots compared untreated plots in the first two weeks following application. Pirimicarb had no effect.

Absence of barriers had less effect on the suction trap catches of predators, presumably because they involved less active, vegetation-climbing species. In 1980, dimethoate decreased the numbers of adult carabids and staphylinids caught by suction one day after application and effects were still noticable 13 days after treatment. Similar effects occurred in 1981. Suction catches showed that in both years the numbers of parasitic hymenoptera were decreased by both pirimicarb and dimethoate, and some of these effects were still evident three weeks after treatment. The "aphid specific" predators (Coccinellidae, Syrphidae and Chrysopidae) were scarce in the experiment in both years.

The commonest carabids were Pterostichus melanarius, P. madidus, Trechus quadristriatus, Harpalus rufipes, Loricera pilicornis, Nebria brevicollis and Agonum dorsale. Amongst the staphylinidae the most frequent were Aleocharinae, Tachyporus spp., Oxytelus spp., Philonthus cognatus and Xantholinus spp.

A summary of this data is presented in the accomanying tables (1 & 2). Full details are now in press (Powell, W., Dean, G.J. and Bardner, R. "Effects of pirimicarb, dimethoate and benomyl on natural enemies of cereal aphids in winter wheat" Annals of applied Biology 1985).

STUDY OF THE SOIL FAUNA IN WINTER WHEAT IN CENTRAL SPAIN IN 1980-83

P. CASTANERA and P. DEL ESTAL
INIA, CRIDA-06, Departamento de Proteccion Vegetal, Apartado 8.111, Madrid-35, Spain

In connection with the joint project, the polyphagous soil fauna in a winter wheat crop in Central Spain was studied.

Winter wheat, cv. Pane 247, was sown after Triticum turgidum or Hordeum vulgare on a 0.6 ha. field at "El Encin" (Alcala de Henares, Madrid) usual farmer practices were followed in all plots.

A randomised block design was used with three replicates (Plot size: 20 x 10 m) in 1980 and 1981 and four replicates in 1982.

Treatments:

- Untreated
- Benomyl, at 0.28 kg.a.i./ha. at Growth Stage (G.S.) 30-31 (applied only in 1980 and 1981).
- Pirimicarb, at 0.14 kg.a.i./ha. at flowering (G.S. 60-65 Zadoks' scale).
- Dimethoate, at 0.35 litres a.i./ha. at flowering (G.S. 60-65 Zadoks' scale)

Four pitfall traps were set up 7 m apart in each plot around the beginning of March each year. The most abundant arthropods caught during the weekly sampling were Arachnids and Carabids, but no effect due to fungicide and insecticide application was observed on them in the sprayed plots, which were not isolated by polyethylene barriers. Therefore, it seems very likely that despite the 3.5 m separation among plots, redistribution of the population did occur.

The arachnids and carabids collected in pitfall traps were counted and determined to species in most cases.

A total of 1662 arachnids were caught in 1980 from March-Aggust, 43 species were found. These species belong to 15 families, three of which: Thomisidae, Drassidae and Lycosidae account for > 90% of the total spider collected. Seven species, Thanatus lineatipes, Xysticus kochi (Thomisidae), Pardosa monticola (Lycosidae). Zelotes carmeli, Zelotes circumspectus, Gnaphosa trigina and Zelotes caucasius (Drassidae) represent > 80% of the total number of species.

The ~~remaining~~ species belong to the family of the Agelenidae, Amaurobidae, Agropidae, Clubionidae, Dictynidae, Dysderidae, Eresidae, Erigonidae, Oxyopidae, Salticidae, Theridiidae and Zoodariidae.

A total number of 2430 carabids were collected from March-August 1980-82. The 30 species determined belong to 21 genus. The species number and their relative abundance differed greatly between years, though Ditomus capito Serv., Harpalus distinguendus Duft., Harpalus anxius, Poecillus cremulatus Dej., Bradytus apricarius Payk, Harpalus rufipes de Geer, Acinopus picipes Oliv. and Trechus quadristriatus Schrank. were the most abundant species representing > 80% of the total number of captures during 1980-82, some of this species have been reported at cereal aphids predators, e.g. H. rufipes and T. quadristiatus.

Staphylinids were very scarce in this period.

In 1983, four pitfall traps were set up 7 m apart in each plot (plot size: 22 x 40 m) using a randomised block design with replicates for each of the following treatments:

T_1 - Disc harrow - cultivator - sowing - roller.
T_2 - Chisel - cultivator - sowing.
T_3 - Direct drilling (Paraquat 0,8 l.a.i./ha - sowing)

Seven species represent > 85% of the 986 carabids caught in the pitfall traps in all treatments (Table 1).

The species complex was rather similar in all treatments. Agonum dorsale Pont. was caught in the pitfall traps for the first time in this area. The number of species captured in the direct drilling plots were 87.9% and 55.1% higher than in the treatment T_2 and T_1 respectively. This could be due to the fact that those plots in which ploughing is used larvae and adult carabids are exposed to birds which may kill a great deal of them. The organic matter content of the soil was analysed and n no significant increase was found between treatments (1.6 for T_1 and T_2, and 1.8 for T_3).

Table 1 Species caught in pitfall traps (March-August) in 1983 representing > 80% of total captures.

SPECIES	T_1	T_2	T_3
Claenius chrysocephalus	18	13	40
Ditomus capito	53	63	80
Poecilus crenulatus	29	16	25
Harpalus distinguendus	21	16	108
Harpalus anxius	96	68	103
Harpalus rufipes	17	30	26
Trechus quadristiatus	15	8	13
Other species (21 spp.)	43	27	58
TOTAL	292	241	453