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Final report of a four year project at the Scottish Agricultural College, Auchincruive, Ayr KA6 5HW. The work commenced in August 1987 and was supported by a grant of £102,593 from the Home-Grown Cereals Authority (Project No. 0019/5/87).

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**ABSTRACT**

The results of this study, which began in 1987, have shown clearly that in many areas of the United Kingdom a major element of in-crop monitoring is necessary to reliably identify high risk of infection of autumn-sown cereal crops by barley yellow dwarf virus (BYDV).

The importance of local sources of aphids from ryegrass crops, weed grasses in hedgerows, volunteers and weed grasses in cereals has been highlighted. Differences in the incidence of aphid vector species, aphid numbers and strains of BYDV over relatively small geographical areas provides the possibility of regionalised risk assessments.

A scheme called Strategic Monitoring is proposed. This is being developed and refined on the basis of the information gathered from the detailed pre- and post-harvest assessments of BYDV and aphids with post-emergence crop monitoring of aphid colonisation and survival. The former allows advice to be given on the need to apply pre-ploughing treatments such as desiccation, whilst the latter provides an assessment of the threat from local aphids and those arriving by migration. Post-emergence monitoring is designed for use by farmers and advisers and uses a simple prescribed scheme to monitor the development of aphid colonies and their survival in mild autumn weather. Thus insecticide treatments can be targeted on high risk crops and the serious problems which occurred in 1988/89 following unusually mild weather should be avoided.

Strategic Monitoring will be developed over the next three seasons with the financial support of the HGCA.

## OBJECTIVES

To conduct a comparative study of existing methods of forecasting BYDV in autumn-sown cereals. Evaluate and develop new methods of forecasting BYDV thus promoting the timely application of insecticides and reducing unnecessary pesticide usage.

## INTRODUCTION

The trend in recent years towards early drilling of winter barley has greatly increased the risk of serious attacks by barley yellow dwarf virus (BYDV). The disease has been a particular problem in the west of Scotland and Northern Ireland where mild autumns, high aphid numbers and extensive infection of ryegrass has led to the complete destruction of number of crops.

BYDV is exclusively transmitted by aphids, in particular by the bird-cherry aphid (*Rhopalosiphum padi*) and the grain aphid (*Sitobion avenae*). A number of other aphid species including *R. insertum*, *Metopolophium festucae* and *M. dirhodum* can transmit BYDV, but perhaps with a lower degree of efficiency. BYDV exists as five strains, three of which occur in the United Kingdom (Holmes, 1991). The five known strains were characterised by Rochow (1969) in North America and are known by acronyms which relate to the aphids which transmit them. Thus in the UK, RPV is transmitted specifically by *R. padi*, PAV non-specifically by *R. padi* and *S. avenae*, and MAV is transmitted specifically by *Sitobion* (= *Macrosiphum*) *avenae*. The RPV and PAV strains generally are regarded as having a severe effect on cereal growth (i.e. leaf yellowing, stunting), and the MAV strain as having a mild effect (i.e. leaf yellowing, little stunting). However, if infection occurs early in the autumn when the plants are small, all three strains can have a severe effect, causing plant death. Plants which survive but are stunted yield around 50% of healthy plants.

In areas of mixed grass and arable farming, ryegrass constitutes the main source of both aphids and virus. Surveys (Doodson, 1967; Holmes, 1985) have shown that BYDV is very widespread in grass crops and that within individual fields infection levels can be extremely high (Holmes, 1991). In contrast to cereals, ryegrass is tolerant to infection by BYDV, and visual symptoms are rare.

The majority of infection of winter cereals usually occurs in the autumn (September-November). During this period, aphids migrate from grasses and volunteer cereals to their overwintering host on which eggs are laid. In the case of *R. padi* this is the bird-cherry (*Prunus padus*), and in the case of *S. avenae*, rose (*Rosa* spp.). The extent of infection of the autumn-sown cereals depends on numbers of aphids migrating, their species, morphological form and the proportion carrying virus. This initial inflight of winged (alate) aphids gives rise to individual infected plants, but it is their wingless (apterae) offspring which carry the virus to adjacent plants creating damaging patches of infected plants. The extent of the patches depends on how long mild weather permits survival and movement of the aphids.

Spread of BYDV by this means can be controlled effectively by a well-timed application of insecticide in the autumn. As the risk of BYDV varies greatly from year to year, and as the sprays must be applied before any symptoms develop, there is a considerable risk of unnecessary insecticide usage. The Infectivity Indexing method of Plumb (1986) is designed to identify high risk autumns, and control is based on a spray application around late October/ early November should the high risk threshold be exceeded. This system appears to work well in those parts of England and Northern Europe where cereal cropping is intensive and the bird-cherry relatively uncommon. However, it may be less successful where cereal crops are interspersed with grass fields, and where alternative hosts occur widely.

This project was designed to evaluate alternative methods of forecasting the risk of BYDV in western areas. This involves, amongst other things, an epidemiological investigation of the incidence of virus strains, aphid species and number in grasses. The possibility of sampling grass crops for aphid numbers and infectivity instead of relying exclusively on tower trap data, and the use of rapid and sensitive serological techniques to determine aphid infectivity rather than the existing labour intensive and protracted biological tests on susceptible cereal seedlings were also investigated.

## GENERAL MATERIALS AND METHODS

### 1. Aphid sampling methodology

In the initial stages of the study, aphids were collected and taken to the laboratory for identification. Later, they were identified in the field using a hand lens.

#### 1.1 Ryegrass pastures

Five or 10 areas each 1-1.5 $m^2$ in each field were sampled using a sweep net.

#### 1.2 Hedge bottoms and weed grasses in cereal crops

Aphids were collected from individual plants.

#### 1.3 Winter cereals

The methodology varied during the course of the project. Initially, 25 x 1 $m^2$ areas were assessed per field, but for much of the study 10 x 1 m length drills at random across the field were adopted as standard.

#### 1.4 Remote monitoring

Aerial aphid populations at 12.2 m were monitored using a standard Rothamsted tower trap. The species and aphid numbers were determined

on a weekly basis at SOAFD Scientific Services, East Craigs, Edinburgh.

Live aphid trapping was by means of 1.2 m high suction traps (commode traps).

## 2. Biological testing for BYDV transmissibility

Aphids collected live from the field, or caught in the 1.2 m trap, were tested for the presence of BYDV, and the ability to transmit virus using a standard transmission test.

Individual aphids were placed on oat seedlings (2-3 leaves) grown singly in 7.5 cm diameter pots in an insect-proof glasshouse. The seedling was then sealed inside a ventilated plastic cover and the aphid allowed to feed for 48 h. Survival and reproduction of the aphid was monitored at intervals during this period. After 48 h the aphid was removed for identification and the plants sprayed with insecticide. The plants then remained in the insect-proof glasshouse for 3-4 weeks after which time the presence of foliar symptoms of BYDV was determined. If identification of the strain or strains of the virus in the plant was required then an ELISA test was conducted.

## 3. Serological testing for BYDV

The enzyme-linked immunosorbent assay (ELISA) was extensively used for the identification of BYDV in cereals and grasses.

The procedure used basically was that devised by Clark & Adams (1977). The indirect-ELISA was used throughout. The coating antibodies to the PAV, MAV and RPV strains were polyclonal and supplied by Prof. W. Rochow, Cornell University, N.Y., U.S.A. The second stage antibodies were monoclonals (MAC 92, MAC 91, MAFF 2) produced by MAFF CSL Harpenden Laboratory. The presence of the specific strain of BYDV was visualised by enzyme reaction on a phosphate substrate. Absorbance at $A_{405}$ was measured in a Titertek Multiskan Reader. In all tests healthy and known-infected control samples were included.

## 4. Sample preparation for ELISA

The standard preparation procedure for grass and cereal leaf material was to grind 1 g of finely chopped tissue first in liquid nitrogen and then in standard extraction buffer. The macerate was strained through fine muslin to remove leaf fragments and the sap placed without further treatment in the multiwell ELISA plates.

## 5. The incidence and regional distribution of BYDV in cereals

### 5.1 Region

The west of Scotland is divided into a number of regions (counties) as shown in Fig. 1. These conveniently provide areas of contrasting geography and climate. Wigtown and Ayrshire are particularly mild, benefiting from the residual effects of the Gulf Stream. Dumfries is also relatively mild being in the south of the area, but without the warming effect of the Gulf Stream. Renfrew, Stirling and Lanark are increasingly cold in winter, being further from the coast (Renfrew), more northerly (Stirling) and at a higher altitude (Lanark).

### 5.2 Crop Sampling

#### 5.2.1 Autumn 1988/89

During the autumn and winter a limited number of fields (5) were examined in detail weekly. Two of the fields were in Ayrshire, two in Wigtown and one in Stirling. At each visit, 25 x 1 $m^2$ areas at 10 m intervals across the crop were examined for aphids. The species and numbers were determined.

#### 5.2.2 Spring 1989

In the spring of 1989 there was widespread development of foliar symptoms of BYDV in autumn-sown cereals throughout the west of Scotland. A detailed survey of 45 crops was undertaken. All the fields were visited in late April or early May and 16 were re-visited in late May.

At each visit, a circuit of the field was made following tramlines. Ten plants were selected at random and examined for aphid species incidence. When more than one species was present, the more numerous species was denoted as the predominant species.

The presence of BYDV and the strain was determined for each field by testing by ELISA a bulk sample of several leaves from each of five randomly selected patches of yellow plants per field. A similar number of samples of symptomless plants were collected to determine the true extent of infection in fields.

#### 5.2.3 1989/90

Twenty-six winter barley crops in five regions were sampled. Ten x 1 m lengths of drill were examined in each field. Aphid colonies instead of aphid individuals were counted. A colony could consist of an adult and one or more nymphs or several nymphs and no adult. This approach reduced the number of occasions when counting large numbers of aphids was necessary. Also, it gave an epidemiologically meaningful measure of aphid infestation level, because it indicated the number of potential

sites of patches of infected plants. The numbers of colonies in each metre length which were of *R. padi* and *S. avenae* were noted.

5.2.4 Autumn 1989

In the autumn, fields were examined every 2 weeks between September and November. Not all fields were visited on all occasions. The maximum number of visits to any one field was four, and the minimum two.

5.2.5 Winter 1989/90

During the months of January, February and March observation visits were made to some of the fields in Ayrshire and Wigtown.

5.2.6 Spring 1990

All 26 fields were sampled monthly from April to June. Two of the Ayrshire fields were sampled twice in April.

5.2.7 Spring 1990 BYDV survey

In April and May, single yellow leaves were collected from five randomly selected yellow plants from each of the 26 survey fields. In several fields in which patches of yellow plants were present, samples of 10 leaves/patch were also collected and tested by ELISA.

During the May and June visits, the percentage of each crop which comprised yellow plants and the diameters of the patches of such plants were estimated. The incidence of individual yellow plants was also assessed as low (1 in 100 $m^2$) and high (1 in 10 $m^2$).

5.2.8 Autumn 1990 and Winter 1991

Twenty-five winter barley crops were sampled in Dumfries, Wigtown and Stirling. The methodology was the same as in 1989/90.

Between late September/early October and mid-November all fields were visited weekly, then every two weeks until mid-December.

The fields were re-visited in early January.

5.2.9 Spring 1991

The fields were visited once at the beginning of May.

The incidence of plants with symptoms of BYDV infection was assessed in 20 of the survey fields. Samples of affected plants for testing by ELISA were collected from all 25 fields.

## 6. The incidence of BYDV in grass

### 6.1 Poa annua

#### 6.1.1 1989

In July, 10 plants of *P. annua* were collected from each of 14 of the 45 winter barley crops surveyed for BYDV. The samples were tested for BYDV by ELISA.

#### 6.1.2 1990

In May and again in June, approximately 10 plants of *P. annua* were collected from each of nine fields and tested by ELISA.

### 6.2 Weed grasses in hedgerows

In 1990 between May and September, five grass weed species which were common in hedgerows and farm lanes were selected for the determination of BYDV strains and infestation by aphid vectors.

Two farms in Ayrshire were used for the study and on each visit 10 individual plants of each species were examined for aphid infestation *in situ*. For BYDV determination, samples of the five grass weed species were collected from six farms in Dumfries, Wigtown, Renfrew and Stirling on one occasion between May and June and on two occasions in Ayrshire during the same period.

### 6.3 Ryegrass pasture

#### 6.3.1 Aphid assessments

The standard aphid sampling procedure was to sweep ten times with a flat-bottomed net (aperture 30 x 33 cm) in each sampling area (1.0-1.5 $m^2$). In intensively grazed pastures only lusher areas were chosen. In ungrazed and extensively grazed fields, sampled areas were representative of the whole field.

Length of grass at time of sampling was defined as follows:-

1. Generally short - either due to grazing or cutting (< 4 cm high).

2. Obviously grazed but with lusher areas associated with dunging.

3. Essentially even, long grass throughout the field (> 4 cm high).

In 1988, samples were collected between June and August from a total of 19 fields in four regions. An additional nine were sampled in Ayrshire during late summer and autumn. Six areas were sampled in each field.

In 1990, 13 fields in Ayrshire were sampled between April and September.

For ease of presentation, the area sampled was adjusted to the equivalent of 100 $m^2$ of ryegrass crops because the sampling methodology changed during the course of the project.

6.3.2 BYDV survey

Seventeen fields were sampled monthly between March 1988 and February 1989. On each occasion, a 1 $m^2$ quadrant was placed at five widely spaced intervals on a diagonal across the field. Grass leaves were cut from 10 small areas within the quadrant and bulked together. Thus five composite samples were collected from each field. The approximate location of each sample area was noted and subsequent monthly samples collected from the same field locations.

## RESULTS

### Monitoring aphid numbers and BYDV in winter barley crops 1988-1991

#### 1. 1988-1989

1.1 Aphid numbers, autumn 1988

The greatest numbers of *R. padi* and *S. avenae* were recorded in Wigtownshire (Table 1), but even there, the populations were less than one aphid/$m^2$. Few aphids were found in crops in the other two areas. By the end of November there appeared to be a natural decline in aphid numbers.

1.2 Aphid numbers, 25 January, 1989

Although the indications were that aphid numbers were declining in November 1988, they were still present in fields on 25 January (Table 2). This would be regarded as unusual and was a reflection of the atypically mild weather conditions which persisted until the spring (Fig. 2).

1.3 Aphid numbers and BYDV, spring 1989

*S. avenae* was found in 33 of the 45 survey fields (Table 3) and was

particularly common in Dumfries, Stirling and Renfrew. *R. padi* and *M. dirhodum* occurred only infrequently except in Wigtown where *R. padi* was common. No aphids were found in the Lanarkshire crops which were surveyed.

In 29 of the fields *S. avenae* was the predominant aphid species. Although on average 38.2% of plants were infested with this aphid, the mean infection level in these fields was only 6.1%. The rose-grain aphid (*M. dirhodum*) was found in eight of the survey fields but predominated in only one where there were 50% of the plants infested and the infection level was 50%. Interestingly *R. padi* predominated in only four fields (Wigtown and Ayrshire), and whilst the infestation levels average 38%, the mean infection level was 51%. The percent infestation level was probably lower when surveyed than it had been because crops which obviously had been heavily infested were treated with insecticide before the survey was conducted.

### 1.4 Regional levels of aphid infestation and BYDV infection

There was a marked regional variation in the extent of aphid infestation (Fig. 3). Infection levels followed a similar pattern and in Dumfries an average of 10.2% of plants were affected. Aphid data for Wigtown is not available as extensive insecticide spraying took place shortly before the first survey visit. However, the mean infection level of 50% indicates that infestation was very extensive. Overall, as one moved north and inland then the level of infestation and extent of infection declined.

### 1.5 Sowing dates, aphid infestation and infection level

As most of the infection arose from aphid infestation which developed in January and February, the sowing date did not have a marked effect on infection level (Fig. 4), although very little BYDV was found in the few crops sown in late October.

### 1.6 Strains of BYDV

The predominant strain of BYDV was MAV (Fig. 5). The PAV strain occurred at low levels in most areas, whilst the PAV and RPV strains were predominant in the Wigtown area. A proportion of symptomless leaves also contained virus.

### 1.7 Infectivity of aphids from survey fields

Biological testing of aphids collected from crops in spring showed that 21.6% of *S. avenae* were carrying BYDV (Table 4), the majority of which was the MAV strain. A similar proportion of *M. dirhodum* (27.8%) transmitted virus and again was mostly MAV. A higher proportion of *R. padi* were infective. This was mainly the RPV strain, although a surprising proportion also appeared to be

carrying the MAV strain as well. This is probably the result of transcapsidation, a phenomenon whereby the genetic material of MAV becomes coated in RPV protein in jointly infected cells. Thus the aphid, which recognises the protein coat of the virus particles transmits the MAV code material. When introduced into a new plant, the protein coat comes off and MAV particles are replicated.

The aphid infestation data were analysed to test whether there were associations between aphid infestation levels and four factors: region, previous cropping type, sowing date and predominant aphid species. Due to between-crop variation, no significant associations were detected.

## 2. 1989-1990

### 2.1 Aphid numbers, autumn 1989

There are two important features of the cumulative total number of colonies in each field during the autumn visits (Table 5). First, there was heterogeneity in aphid species incidence within regions, and second, the regional aphid colony totals reflect large aphid colonies in a minority of fields. For example, in Wigtownshire and Ayrshire, one and two fields respectively, which followed untreated ploughed-in leys contributed most of the *R. padi* colonies (on some assessment dates > 10 colonies were recorded per metre length).

There was a significant difference between regions in the ratios of *R. padi* totals to *S. avenae* colony totals during the autumn of 1989 ($X^2$ (4) = 116.9, P < 0.001). Sixty-two percent of the Chi-squared value was contributed by the Renfrew colony totals, because *S. avenae* was more numerous than *R. padi* in this region although overall, *R. padi* colonies were twice as numerous as *S. avenae* colonies. Also, the Wigtown and Ayrshire *R. padi* totals were large relative to the other regional aphid colony totals.

When the aphid colony totals for the crops drilled into an unploughed grass ley were excluded, the differences between regional totals of *R. padi* and *S. avenae* were not significant ($X^2$ (1) = 1.24, N.S.). This indicates that the differences between regions in the incidence of aphid species was due to the previous cropping type of grass in Wigtown and Ayrshire.

### 2.2 Aphid numbers winter 1989/1990

With the exception of one field in Ayrshire, in which two colonies of *S. avenae* were found, no aphids were observed during the winter visits.

### 2.3 Aphid numbers spring 1990

The cumulative total number of aphid colonies in each field during the spring visits is shown in Table 6, together with the regional

colony totals for *R. padi* and *S. avenae*. There was a significant difference between the five regions in the ratios of *R. padi* colony totals to *S. avenae* colony totals ($X^2$ (2) = 168.7, P < 0.001). Two regions had higher numbers of aphids: Wigtown and Renfrew. The two Wigtown fields which followed un-treated ploughed-in grass leys had a resurgence of *R. padi* infestation during the spring despite each receiving an autumn application of insecticide. In Renfrew, three fields had *S. avenae* infestations exceeding 10 colonies per 10 m drill lengths in June. No *R. padi* were found in Dumfries and no *S. avenae* in Stirling.

The relationship between the autumn and spring aphid colony totals differed between regions. In Dumfries, Wigtown, Ayrshire and Stirling, the spring regional colony totals were smaller than the autumn totals compared with Renfrew where the spring total was larger. Relationships between the autumn and spring aphid colony totals were tested separately for *R. padi* and *S. avenae* by linear regression.

For *R. padi* the test was non-significant (r = 0.474, d.f. 3, N.S.) compared to the test for *S. avenae* which was significant (r = 0.913, d.f. 3, P = 0.031).

There were some clear differences between regions in the incidence of aphids. *R. padi* totals in Wigtown were high in both the autumn and spring, whilst the Ayrshire *R. padi* total was high in the autumn and low in the spring. In summary, the autumn totals were greater than the spring totals and most regional aphid totals were low in both autumn 1989 and spring 1990.

## 2.4 Spring BYDV survey 1990

Individual plants with yellow leaves were found in all 26 winter barley crops during late April/early May. In 16 fields, scattered individual yellow plants were assessed as in excess of 1 per 10 $m^2$. However, in only three crops did the area affected exceed 0.1%. In 13 of the 16 fields patches of yellow plants (0.5-1.0 m diameter) were observed.

The incidence of BYDV in the leaves tested is given in Table 7. Overall, 39% of leaves tested were infected with the MAV strain, 24% with PAV and 11% RPV.

The MAV strain was predominant in Dumfries, Wigtown and Renfrew, but the PAV strain was equally common in Ayrshire and predominated in Stirling. With the exception of RPV in Stirling; the three strains of BYDV were found in cereal leaves in all areas.

In a number of the survey fields an additional sample of 10 yellow leaves was collected from patches of yellow plants. Tests on these showed that the predominant strain was PAV (Table 8), this contrasted to individual plants (c.f. Table 7) in which the predominant strain was MAV. This difference was statistically significant overall ($X^2$ (2) = 43.2, P < 0.001).

## 3. 1990/1991

### 3.1 Aphid numbers, autumn 1990

Both *S. avenae* and *Rhopalosiphum* spp. (species not differentiated) occurred in three regions monitored (Table 9). Overall, colonies of *Rhopalosiphum* spp. were most common and predominated in Dumfries and Wigtown. In Stirling they occurred with similar frequency.

Most *Rhopalosiphum* spp. recorded were alate *R. insertum* which migrated into crops in all three regions but did not reproduce. During November, a greater proportion of the colonies were apterous *R. padi*, particularly in Dumfries. Most *S. avenae* colonies were apterous.

### 3.2 Aphid numbers winter 1990/91 and spring 1991

No aphids were observed in early January, or in the 25 crops of winter barley examined at the beginning of May 1991.

### 3.3 BYDV survey, spring 1991

No significant patches of yellow plants were found in any field, although scattered plants with symptoms did occur. In no field did the area of crop affected exceed 0.1%.

The most frequently detected strain was MAV (Table 10) followed closely by PAV. Relatively little RPV was found.

Regional differences in strain incidence were non-significant ($X^2$ (2) = 1.7, N.S.).

## The incidence of BYDV in *Poa annua*

## 1. 1989

With the exception of Renfrew, all three strains of BYDV were found in *P. annua* in all regions (Table 11). Overall, the MAV strain was most frequently found (58% of plants). However, in Wigtown and Ayrshire, the RPV and PAV strains were most commonly found. These two strains were also common in Dumfries. Relatively little RPV or PAV was found in Renfrew or Stirling.

## 2. 1990

There were marked regional differences in the incidence of BYDV in *Poa annua* (Table 12). All three strains of the virus were present in all areas except Stirling. There were significant regional differences in the BYDV strain ratios indicating that, as with yellow barley leaves, BYDV strain incidence varied between regions.

Although the detection of BYDV in individual fields differed between the two sampling occasions (May and June), taken on a regional basis, there was no significant difference between virus and strain incidence in May and June ($X^2$ (2) = 1.3, N.S.).

A relationship between regional percentage BYDV infection of single yellow winter barley leaves and *P. annua* was tested for by linear regression after arcsine transformations (data for each strain were pooled to give 15 pairs of observations). The non-significant result ($r = 0.39$, d.f. 13 N.S.) is reflected in the scatterplot of the regional percentage BYDV infection of the single yellow leaves and *Poa annua* (Fig. 6). Although the relationship is not linear as the test above showed, greater percentages of infection in yellow barley leaves are reflected in greater infection in *Poa annua*. The highest levels of infection of both barley leaves and *P. annua* were associated with the MAV strain. Mann-Whitney tests on the percentage infection of single yellow barley leaves and *P. annua* pooled for each strain, gave a significant result between the RPV and MAV strains ($W = 72.5$, $P = 0.016$), but the medians of the percentage infection for the RPV and PAV strains ($W = 81$, N.S.), and the PAV and MAV strains ($W = 90.5$, N.S.) were not different. Another feature of Fig. 6 is that all Dumfries and Wigtown points are grouped on the left (low infections in *P. annua*) whilst all the Ayrshire and Renfrew points are grouped on the right (high BYDV infections in *P. annua*). A Mann-Whitney test showed that the medians of the percentage BYDV infections of these two groups differed significantly ($W = 103$, $P = 0.007$).

An analysis of the 'all regions' totals for infection of cereal leaves and *P. annua* showed that in the area as a whole, BYDV incidence was similar in barley leaves and *P. annua* in the spring of 1989 ($X^2$ (2) = 1.14, N.S.).

**Aphids on and BYDV infection of wild grasses in hedgerows and farm lanes**

**1. Aphid infestations of wild grasses**

Table 13 shows the total number of plants of each weed species (maximum 100) with at least one colony of any BYDV aphid vector species on either the leaves/stems or inflorescences in the summer of 1990.

On *D. glomerata* and *H. lanatus*, there were significantly more aphids on the inflorescences than on the leaves ($P < 0.001$). On the other three grass species, infestation levels were similar on the leaves and inflorescences.

The commonest aphid was *Sitobion* (*fragariae* and *avenae*) which infested 16% of inflorescences of *D. glomerata* and 12% of inflorescences of *H. lanatus*. *Sitobion* spp. were not found on the leaves of these two species.

*Rhopalosiphum* spp. (*padi* and *insertum*) occurred at low levels (less

than 3%) on the leaves of all grass weed species except *A. pratensis*. Few aphids were found on the inflorescences. Leaves of *A. pratensis*, *D. glomerata* and *P. annua* had low level colonisation by *Metopolophium* spp.

2. **BYDV infection of wild grasses**

All five grass weed species were infected to varying extents by the three strains of BYDV (Table 14). All the plants of *D. glomerata* were infected, usually with two or three strains of the virus.

The MAV strain was most frequently detected (52% of samples), compared to 37% and 27% for RPV and PAV respectively.

## Transmission of BYDV by field-collected aphids

1. **Aphid species**

1.1 Sitobion avenae

Overall, 19% of the 1126 *Sitobion avenae* tested between 1988 and 1990 transmitted BYDV (Table 15). The predominant strain was MAV although both RPV and PAV were transmitted, albeit at relatively low levels. The frequency of transmission from winter barley and grass weeds in winter barley crops was similar at 22% and 23% respectively. Transmission by aphids collected from ryegrass pastures and grass weeds in hedge bottoms was lower at 15% and 10% respectively. The majority of aphids transmitted only one strain of the virus, although as reported earlier, the source plants often contain two or even three strains of BYDV. The incidence of transmission of two strains was low, and none transmitted mixtures of all three strains.

1.2 Rhopalosiphum padi

A much bigger proportion (34%) of *R. padi* transmitted BYDV to oat test plants (Table 16). Although RPV was most frequently transmitted, PAV was regularly detected, and surprisingly, so was the MAV strain. The importance of the source plants differed markedly from *S. avenae*. Thirty-seven percent of aphids from ryegrass pastures transmitted virus followed closely by winter barley (32%) and grass weeds in winter barley crops (29%). Weed grasses in hedgerows were also a good source of virus with 20% of aphids transmitting BYDV. The incidence of two-way strain transmission was higher than with *S. avenae*, and a number infected the test plants with all three strains.

1.3 Metopolophium dirhodum

*M. dirhodum* proved to be a good vector of BYDV (Table 17), but aphid numbers were relatively low. Overall, 22% transmitted virus. Again,

the importance of the various host plants differed from *S. avenae* and *R. padi*. Winter barley appeared to be the best source plant (27%), followed by grass weeds in hedgerows (22%). Both grass weeds in winter barley and ryegrass pastures were poor sources of virus. MAV was the principal strain transmitted with little PAV or RPV being found. There were virtually no double or triple transmissions.

### 1.4 Rhopalosiphum insertum

*R. insertum* was a more efficient vector than expected with 17% transmitting BYDV overall (Table 18). The rate of transmission was similar from all source plants (17-18%). The three strains were transmitted with roughly equal frequency, and the only mixture of strains detected in oats was RPV and MAV.

### 1.5 Metopolophium festucae

The only host on which a significant number of aphids were found was ryegrass pasture (Table 19). The transmission rate was low (9%) and the MAV was mainly found although both the RPV and PAV strains were transmitted by a few aphids.

## 2. Seasonal influence on the transmission of BYDV from source plants

In all habitats except ryegrass pastures, *S. avenae* was the most numerous aphid. Also it remained at a higher population level for a greater proportion of the year (Tables 20-23). In ryegrass, *R. padi* was most numerous although it was highly seasonal (Table 22). Few *S. avenae* or *M. dirhodum* were found in ryegrass. Transmission rates by all aphid species from the different habits show marked seasonal fluctuations, although this must be interpreted with caution because of variable numbers of aphids collected.

## 3. Aphid numbers in ryegrass pastures

During 1988, perennial ryegrass pastures were sampled for aphids on 98 occasions, a total of 26 fields were visited and on eight occasions no aphids were found. Comparable figures for 1990 were 66, 22 and 18.

### 3.1 Seasonal incidence of aphids

Analysis of variance showed that for all aphid species, number varied significantly between months (Table 24). *M. dirhodum* was least common, however it was observed in both years at low density mainly in the June to August period. *Rhopalosiphum* spp. (including *R. padi*) and *R. insertum* were found in appreciable numbers between July and September, peaking in August. Both *M. festucae* and *S. avenae* were found mainly between June and August.

### 3.2 Influence of grass length on aphid abundance

Aphid numbers generally were unaffected by the length of the grass (Table 25). The exception was *S. avenae* which occurred at significantly higher numbers in long grass than in grass which was subject to regular cutting and/or grazing.

### 3.3 Sward age and aphid populations

Only the numbers of *Rhopalosiphum* spp. and *R. insertum* were affected by sward age (Table 26), although the variation was between sward age categories and not directly related to increasing age of swards.

### 3.4 Regional variation in aphid numbers

Both *Rhopalosiphum* spp. and *S. avenae* populations varied significantly with region (Table 27). *Rhopalosiphum* spp. were abundant in Dumfries, Wigtown and Ayrshire and rare in Renfrew and Stirling. The regional distribution of *S. avenae* was less clear with the relatively large number of observations and the high level of abundance in Ayrshire being the main feature.

## STRATEGIC MONITORING

It is evident in western areas, where cereal growing generally is less intensive than the east, where crops often are interspersed with grass fields and where early drilling and mild autumns encourage aphid survival that the Infectivity Indexing Scheme may be inadequate for several reasons.

1. Many aphids entering crops do so by local movement from grass fields, ploughed-in grass or weedy stubbles to following cereal crops. In these situations the risk appears to be high irrespective of 'migrant pressure'.

2. Offspring of migrant aphids causing secondary spread by walking within cereal crops in the autumn.

3. Aphids overwintering in a mild winter.

4. Problems initiated by the grain aphid, *S. avenae* which is not caught effectively in the 12.2 m suction trap.

It is felt that in western areas at least, the effective identification of BYDV high risk must include a major element of crop monitoring.

As a result of the extensive and detailed epidemiological data obtained from this investigation it has been possible to identify a number of occasions in the year when valuable early information on potential risk to autumn-sown cereals can be gained. These opportunities are described in this section along with the results of evaluations in 1989 and 1990. Infectivity Indexing data from Auchincruive and Belfast is included for

comparison. Finally, a crop-based monitoring scheme called STRATEGIC MONITORING is proposed.

## Pre-harvest sampling

The aim

BYDV infection of winter barley crops is probably the result of virus spread by local and migrant aphids. For local aphids, the BYDV infection in barley leaves and grass weeds of the previous season's winter barley crops could be important, either as ploughed-in weeds and volunteers leading to direct transfer via the 'green bridge', or in the form of adjacent stubble fields from which alate local aphids may disperse. By assessing the abundance of *P. annua*, ladybirds and aphid parasitoids, the importance of these factors in determining the abundance of local aphids in a region in late summer and early autumn can be determined.

In this section, the pre-harvest sampling data are analysed to determine the relative importance of local and migrating aphids in introducing BYDV in the autumns of 1989 and 1990, and to assess the efficiency of the methodology used in achieving its objectives.

## Methods

Sampling took place in July in both 1989 and 1990. At that time of the season, aphids had had an opportunity to colonise cereals and the leaves had not senesced to any extent.

The following criteria were used to select the survey fields:-

a. Crops should have, or be suspected of having, BYDV infection.

b. Selected fields should be widely separated within regions.

c. The previous crop should not have been a grass ley.

Thus fields were selected on a 'worst case' scenario basis but avoiding the atypical high risk situation of crops drilled into ploughed leys.

During a circuit of the fields using tramlines, seven assessments were made. No more than two barley leaf samples or samples of *P.annua* were taken from headlands. The samples were taken from a one metre wide band on either side of the tramlines.

The assessments were as follows:-

1. BYDV strain incidence in barley leaf samples

   In 1989, 50 leaves which were at least partly green were collected from each field, and tested for BYDV by ELISA in five batches of 10. In 1990, 10 single leaves which were at least partly green were collected and tested individually by ELISA.

2. BYDV strain incidence in Poa annua

Ten well-established *P. annua* plants were collected from tramlines and tested for BYDV by ELISA.

3. Transmissibility of aphids on cereals

Ten aphids which were representative of aphid infestation on barley plants were collected and tested for the presence of, and ability to transmit, BYDV.

4. Transmissibility of aphids on P. annua and/or other grasses

Ten aphids which were representative of aphid infestations on grass weeds were collected and tested for the presence of and ability to transmit BYDV.

5. The extent of infestation by P. annua and or other grasses

After a visual assessment of grass weed infestation, the field was allocated to one of three categories.

(i) Scattered plants in tramlines.

(ii) Appreciable proportion of tramlines infested (at least 1-5%).

(iii) Extensive areas of field infested.

6. Abundance of ladybirds

After a visual estimate of the abundance of ladybird larvae and/or adults, the field was allocated to one of three categories.

(i) No ladybirds

(ii) Few ladybirds

(iii) Many ladybirds

7. Abundance of aphid parasitoids

After a visual estimate of the abundance of aphid mummies, the field was allocated to one of three categories.

(i) No aphid mummies

(ii) Few aphid mummies

(iii) Many aphid mummies

## Results

### Pre-harvest sampling results 1989

Data were collected from 14 winter barley crops in the west of Scotland.

1. BYDV strain incidence in winter barley leaves and Poa annua

Regional differences in the incidence of BYDV in winter barley were identified (Table 28). The three strains of BYDV were found in all regions except Renfrew where only the MAV strain was detected. As might have been expected from the BYDV problem in the spring of 1989, the MAV strain was most frequently found overall.

*Poa annua* was extensively infected with BYDV in all regions (Table 29), and basically followed a similar pattern to that seen in winter barley. There was a higher incidence of RPV and PAV strains in *P. annua*, particularly in Dumfries, Wigtown and Ayrshire. Statistical analysis showed that the extent of infection of barley leaf samples with a particular strain of BYDV was related to the extent of infection of *P. annua* samples with that strain.

2. Aphids on barley plants and P. annua

The sample of 10 aphids representative of aphid infestations of each host plant type in each crop could not be achieved in most fields. Table 30 shows the number of aphids tested and the number transmitting each BYDV strain. Some 93% of the aphids collected were *S. avenae*. The proportion of aphids transmitting BYDV was lower than expected.

3. Grass weed abundance

Grass weed infestation was extensive in most cereal fields in July 1989 (Table 31). There was a trend towards higher infestation levels in Dumfries, Wigtown and Ayrshire than in Renfrew and Stirling.

4. Abundance of ladybirds

Ladybirds were found in all fields except one in Renfrew (Table 32). Fifty-seven percent of fields were allocated to the intermediate ladybird abundance category (i.e. few ladybirds).

5. Abundance of aphid parasitoids

No data collected in 1989.

### Pre-harvest sampling results 1990

Data were collected from nine winter barley crops in three regions of the

west of Scotland from 2-12 July 1990.

In Northern Ireland three fields in Antrim and three fields in Down were examined during the same period.

1. BYDV strain incidence in winter barley leaves and *Poa annua*

West of Scotland

Relatively little virus was found in winter barley leaves compared to 1989 (Table 33). Detection levels, particularly of the MAV strain, were highest in Dumfries.

Overall, there was a higher incidence of BYDV in *P. annua* (Table 34). As in cereals, the MAV was most frequently detected. In contrast to the situation in cereals, no RPV or PAV were found in *P. annua* in Dumfries.

Northern Ireland

As in western Scotland, little virus was found in winter barley leaves in 1990 (Table 35). MAV was found in 25% of samples and RPV in 5%. No PAV was detected.

More BYDV was found in *P. annua* (Table 36). The MAV strain was most common (32%), and occurred with a similar frequency to that found in the west of Scotland. Both RPV and PAV were more frequently detected than in Scotland.

2. Aphids on barley plants and P. annua

West of Scotland

*S. avenae* was observed in all fields except one in Wigtown. *M. dirhodum* was seen in two Stirling and one Dumfries field. A couple of *R. padi* were found in one Stirling field. Aphids were found on cereal plants, wheat volunteers and *P. annua* but were common only in the latter.

The sample of 10 aphids representative of aphid infestations of each host plant type could not be achieved in most fields. Only 8% of those aphids from cereals contained BYDV (Table 37). The only strain detected was MAV. More aphids from *P.annua* were tested. The MAV strain again was most frequently transmitted (22%), although there was a low incidence of PAV. Regional differences were apparent with no virus being found in aphids collected from *P. annua* in Dumfries.

Northern Ireland

Very few aphids were found on winter barley in July, and those tested only transmitted the MAV strain.

No aphids were found on *P. annua*.

3. Grass weed abundance

West of Scotland

Grass weed infestation was highest in Wigtown where all fields were allocated to the highest category (Table 38). Two of the Dumfries fields were relatively weed free. Overall, 66% of fields were allocated to the two higher categories.

Northern Ireland

Five of the six fields had significant infestation levels (Table 39). There were differences between the two regions, with fields in Down being weedier than those in Antrim.

4. Abundance of ladybirds and aphid mummies

West of Scotland

Ladybirds were observed in 45% of fields (Table 40). No field was allocated to the highest abundance category.

Aphid mummies were observed in seven fields (Table 41). Two Wigtown and one Stirling field were allocated to the highest aphid mummie abundance category. Both parasitised *S. avenae* and *M. dirhodum* were observed.

Northern Ireland

Ladybirds were observed in five of the six fields examined. In all five the abundance was assessed as 'few'.

## Post-harvest cereal stubble assessments

The aim

Cereal stubbles may be extensively infested with grass weeds which may be infected with BYDV, and which may support colonies of aphid vectors. An additional risk may be created by volunteer cereal seedlings. These may be colonised by early-migrating aphids or by aphids which have moved from grass weeds. Ploughed-in stubbles drilled with a winter cereal or unploughed stubbles adjacent to a newly emerged cereal crop may pose a threat of early colonisation by aphids carrying BYDV. Assessment of this risk will enable advice to be given on the need to apply pre-ploughing desiccant treatment or an insecticide treatment soon after emergence.

## Methods

In late August and early September 1990, cereal stubbles were examined for aphids. In western Scotland, 16 stubble fields were surveyed, and in Northern Ireland six.

In western Scotland in each field, aerial parts of five grass weeds were examined during a circuit of the field. In winter barley stubble fields, five groups of 10 barley volunteers (each adjacent to a selected grass weed) also were examined.

In Northern Ireland aphids were sampled using a sweep net. No differentiation was made between aphids collected from volunteers and grass weeds.

## Results

West of Scotland

*R. padi* was the most numerous aphid on both grass weeds and barley volunteers (Table 42). It was observed in 11 winter barley stubble fields compared to *S. avenae* and *M. dirhodum* which were observed in six and *R. insertum* in four. Overall, 27% of grass weeds examined were aphid infested compared to 54% of volunteer barley plants.

*R. padi* and *S. avenae* were twice as common on groups of volunteers as on grass weeds. *R. insertum* was found on both six grass weed and six volunteer groups. *M. dirhodum* was found only on volunteers (Fig. 7).

Regional differences in aphid incidence were detected, and no aphids were found in Stirling, nor were they found on four spring barley stubbles included in the survey.

Northern Ireland

As in the west of Scotland, *R. padi* was most numerous overall (Table 43). In Down, a similar number of *R. padi* to *S. avenae* were collected, but in Antrim, *S. avenae* was not detected. Apart from a few *R. padi*, all the aphids collected were apterae.

## Post-emergence crop monitoring

The aim

Pre and post-harvest assessments, provide early warning of the need to apply pre-drilling or early post-emergence treatments, and of the prospects for the autumn. Post-emergence crop monitoring is necessary to identify colonisation by aphids arriving by migrating or local movement, and to determine survival and multiplication whilst weather conditions remain favourable.

**Method**

From late September 1990 until the end of October, crops of winter barley were monitored weekly for aphids. Monitoring continued at 2-3 week intervals until mid-October when aphid colony numbers had declined or disappeared. In the west of Scotland 23 fields in three areas were monitored. In Northern Ireland, 13 fields were surveyed.

In each field at each visit, 10 x 1 m lengths of drill at widely spaced locations across the field were assessed for the presence of aphid colonies. The numbers found and those identified as R. padi were recorded.

Crop selection procedures are detailed in the later section on Strategic Monitoring.

**Results**

West of Scotland

Regular monitoring of selected crops clearly identified differences in aphid colonisation and survival between regions and between fields in regions (Figs 8a-c).

Northern Ireland

Differences in aphid colony incidence between fields within regions and between regions were identified (Figs. 9a & b). Aphid numbers declined rapidly in late November/December with the onset of cold weather.

**Relationship between pre-harvest sampling measurements and BYDV incidence in the following spring**

The aim

To gain an idea of the relative importance of local and migrating aphids in a particular season, the incidence of BYDV and aphids pre-harvest and in the following spring were compared. Tower trap data were used to assess the importance of migrating *Rhopalosiphum* spp. Data for 1989 and 1990 were analysed.

1. Incidence of BYDV strains

   The percentage BYDV infection by each strain in barley leaves and *P. annua* samples in July 1989 and May 1990 are shown in Table 44. In July 1989, all three strains of BYDV were present in barley leaves and *P. annua* collected from Dumfries, Wigtown and Ayrshire. In May 1990, the MAV strain was predominant in these three areas, with the levels of RPV and PAV low relative to observations the previous July. In Renfrew, the incidence of strains in the spring was in very similar proportions to pre-harvest 1989. Again the MAV strain was most frequently detected. The Stirling data shows a clear pattern,

with an increase in PAV and a reduction of MAV in the spring.

In Wigtown, Ayrshire and Stirling the incidence of the different strains between July 1989 and May 1990 was significant ($P < 0.001$, $P < 0.01$ and $P < 0.05$ respectively).

In July 1990 in the three regions surveyed, RPV and PAV were present in few of the barley leaves or *P. annua* tested (Table 45). MAV was found more frequently, particularly in *P. annua*, but there were clear regional differences in the extent of the infection and the principal host species. In spring 1990, the percentage of plant samples infected with the PAV strain had increased markedly in all three areas. The incidence of the MAV strain in all areas was consistent with the detection in winter barley leaves or *P. annua* the previous July.

The increase in PAV in spring 1990 compared to the general decline in the incidence of this strain (and RPV) in 1989 can be related to some degree to the size of the tower trap catches during the autumn (Plumb, 1988).

Thus at the Auchincruive trap in 1989 and 1990 during September and October the total numbers of *R. padi* and *R. insertum* caught were 1298 and 2506 respectively.

## Infectivity Indexing

### The aim

Infectivity Indexing provides an assessment of the risk of BYDV being introduced into autumn-sown cereal crops by migrating *R. padi* (and *R. insertum*). This method of forecasting has been used for several years in parts of the UK and northern Europe. It was included in this study as a standard for comparison with alternative crop-based systems.

## Methods

At Auchincruive and Belfast, aphids were sampled at 12.2 m using a Rothamsted Tower Trap (Macaulay et al., 1988). Daily catches were counted at SOAFD Scientific Services, East Craigs (Auchincruive) or the Queen's University of Belfast (Belfast).

Live aphids were caught using 1.2 m 'commode' traps with a nominal airflow of 5093 $m^2/h$.

Individual aphids from the 'commode' trap were tested for BYDV using the biological method described in the General Materials and Methods.

### Calculation of the weekly Infectivity Index

The weekly Infectivity Index was calculated for both *R. padi* and *R. insertum* using the following formula:-

$$\text{Infectivity Index} = \frac{\text{Number of aphids infective}}{\text{Total number of aphids trapped}} \times 100$$

The Infectivity Index is a cumulative figure on a weekly basis and high risk occurs when the arbitrary threshold value of 50 is reached. Crops which have emerged prior to that date are deemed to be at risk of damaging infection by BYDV.

*S. avenae* is not caught effectively at 12.2 m in the autumn and is not included in the Infectivity Index calculation.

**Results**

Auchincruive 1987

The number of migrating *R. padi* and *R. insertum* peaked in the week ending 4 October (Table 46). Infectivity tests on aphids trapped during that week showed that 5.6% of *R. padi* and 10.0% of *R. insertum* were carrying virus. Thus an Infectivity Index of 163 indicated that crops which had emerged by that date were at high risk (Table 47), in spite of low values in most of the previous weeks.

Very little BYDV was reported in winter cereal crops in the spring of 1988.

Auchincruive 1988

The index remained low throughout the autumn due to the low infectivity of migrating aphids (Table 48), and a later and smaller peak of aphid numbers (weeks ending 14 October and 21 October). Although the arbitrary threshold value of 50 was exceeded in late October (Table 49), 1988 was regarded as a low risk year for primary spread of BYDV by *R. padi*.

In the spring of 1989, there was the most serious BYDV ever experienced in Scotland.

Auchincruive 1989

The number of migrant *R. padi* was extremely low in 1989 (Table 50) and this was reflected in the small number tested for infectivity (47 compared to 280 in 1988 over same running period for the trap).

When the Infectivity Index was calculated on the basis of *R. padi* alone (Table 51) it never approached the threshold of 50. This was mainly because none of the seven aphids caught during the peak fortnight of migrant flight was found to be infective.

When the Infectivity Index included *R. insertum* (based on an independent calculation for the two species) the Infectivity Index never reached the

threshold of 50 for any crop emerging from 9 October onwards (Table 52). It was achieved by 24 September for crops emerged up till then, and by 15 October for crops emerged between 25 September and 8 October.

Auchincruive 1990

Between 31 August and 1 November, 193 aphids were tested. Of these, 62 were identified as *R. padi* and 94 as *R. insertum*. Around 20% of the aphids tested were infective. There was an early peak of aphids in late August, but this was discounted as biological testing had not commenced, and crops had not been drilled. Further peaks occurred in late September and late October (Table 53).

The threshold value of 50 was exceeded on 30 October (Table 54). At the end of October all crops which had emerged by 14 October were classed as at risk on the Infectivity Index scheme.

Very little BYDV infection was seen in cereal crops in spring 1991.

Belfast 1988

The incidence of BYDV in *R. padi* and *R. insertum* in Northern Ireland was much higher than at Auchincruive (Table 55). This combined with high aphid numbers, produced a very high Infectivity Index. All crops of winter barley were considered at risk of damaging infection (Table 56).

Only low levels of infection were found in crops in 1989.

Belfast 1989

As at Auchincruive, the numbers of *Rhopalosiphum* spp. caught in the tower and commode traps in 1989 were much lower than in 1988 (Table 57). The Infectivity Index, whether calculated on *R. padi* alone (Table 58) or on *R. padi* and *R. insertum* together (Table 59) did not reach the threshold value for high risk of 50.

Belfast 1990

Aphid numbers were greater than in 1989, but still less than in 1988 (Table 60). The Infectivity Index was high, attaining the 50 threshold value on 16 September for crops emerged by that data (Table 61). By the end of October, all crops emerged by 14 October were considered at risk.

**The ryegrass reservoir of BYDV**

West of Scotland

BYDV was found in 16 of the 17 fields examined monthly between March and August 1988. The number of samples tested which gave a positive result varied greatly between fields in a region and between regions.

Relatively low levels of infection were found in the Dumfries area.

The predominant strain of BYDV in ryegrass was RPV (Table 62), which occurred in 42% of the 425 samples tested. The PAV strain was found in 19% of samples and MAV in 12%. The regional variation in the incidence of the different strains was identified, with higher than average levels of PAV and MAV in the Stirling area, relatively little RPV and PAV in Dumfries, and little MAV in Wigtown.

In half of the fields examined, the ryegrass plants were infected with a complex of all three strains (Table 63). PAV was found only in plants infected with RPV or with RPV and MAV. MAV occurred on its own in 12% of fields, and RPV on its own in 6%.

Figures 10, 11 & 12 show the fluctuation in detection of strains of BYDV in ryegrass crops in Ayrshire, Dumfries and Stirling during the period March 1988 to February 1989.

A decline in detection of all three strains occurred between March and May. Whilst the detection rate of RPV then stabilised or recovered, that of PAV and MAV continued to decline in most areas until June or July. There was a marked increase in the detection of MAV in all three regions in August. The high rate of detection of this strain persisted throughout the winter in Dumfries (Fig. 11) and Stirling (Fig. 12), but declined again in Ayrshire (Fig. 10). The RPV strain, overall, was most frequently detected and remained at a high level throughout the year in Ayrshire and Stirling, but declined in the spring and summer in Dumfries. The PAV strain did not show a seasonal response.

Very few aphids were found in grass crops before May when *R. padi* began to build up in some fields. Where the grass was kept cut and/or grazed, few aphids were found throughout the year. Where the grass was longer, particularly in the autumn, *R. padi* became numerous (up to 23 aphids in 50 sweeps). After August very few *S. avenae* or *R. insertum* were detected, *R. padi* being the only aphid present.

Field examined from January 1989 yielded virtually no aphids of any species, regardless of the length of the grass.

Incidence of BYDV in ryegrass fields in Northern Ireland 1988

In a preliminary survey of ryegrass crops in Northern Ireland, BYDV was found in 23 of 26 crops. Strains detected by the B antiserum (RPV/PAV) occurred in 16, and the strain detected by the F antiserum (MAV) in 10. Seven of the fields were infected with a mixture of strains.

**Strategic Monitoring - post-emergence monitoring**

Strategic Monitoring is the name given to a crop-based scheme for identifying high risk situation. It is designed to provide the following information:-

1. Pre-ploughing advice on the need to desiccate weedy stubbles or to apply an insecticide early post-emergence.

2. A guide as to the likely risk to autumn-sown barley, particularly from aphids moving locally.

3. Aphid colonisation, replication and survival in emerged crops and associated needs to apply insecticide treatments and to continue monitoring.

This information is obtained by monitoring a number of identified precursors of BYDV high risk.

| BYDV high risk precursor | Strategic monitoring activity |
|---|---|
| Spring or summer aphid populations in cereals | Pre-harvest sampling |
| High weed infestations in cereals | Pre-harvest sampling |
| Virus inoculum in cereals and grass weeds | Pre-harvest sampling |
| Aphid/virus build-up in stubbles | Pre-harvest sampling |
| Late summer build-up of *R. padi* in ryegrass pastures | Post-harvest sampling |
| Aphid colony development and survival in autumn-sown crops | Post-emergence monitoring |

Pre and post-harvest sampling and testing is conducted by specialists. Post-emergence monitoring is designed to be conducted by advisers and farmers.

Tower trap data on migrations of *R. padi* can provide supplementary information.

Post-emergence monitoring

Advisers or farmers selected suitable fields to monitor weekly during the autumn and follow a field guide designed to identify years when BYDV is a problem. Unless otherwise stated in the pre-drilling advice, decisions to spray are made after aphid colony development has been detected in at least one field in an area.

Field selection

Strategic Monitoring will not operate satisfactorily if fields which tend to escape BYDV infection in a high risk year are selected for monitoring. Selection of suitable fields is an important part of the scheme. The optimum number of fields per region which should be monitored to give a reliable risk assessment has yet to be determined. However, the indications are that five fields should be sufficient even in the most varied of districts. On individual farms it may be sufficient to monitor the field which is deemed to be at the highest risk.

Field selection criteria are as follows:-

1. Aphids/BYDV seen in previous crop.

2. Untreated grass weeds/volunteers in stubble of previous crop.

3. Untreated grass weeds/volunteers in unploughed stubble in adjacent field.

4. Ungrazed grass in adjacent field

5. Crop drilled before 14 September

Aphid monitoring procedure

Whilst aphids can be found in most crops every autumn, the presence of winged individuals does not necessarily indicate high risk. Problems with BYDV occur when the winged adults produce offspring. Given favourable conditions for survival then these offspring move out creating damaging patches of infected plants. In the Strategic Monitoring scheme the aim is to identify when aphid colony development occurs and for how long conditions permit this to increase.

The procedure for monitoring aphid colony development is simple and as follows:-

1. Using a metre stick, examine 10 x 1 metre lengths of drill at widely spaced points across the field.

2. Examine plants closely for aphids. Avoid wet days.

3. Count colonies of aphids. Colonies are groups of individual aphids, often surrounded by nymphs. There may be several colonies on one leaf.

4. Note the number of colonies on the aphid count record sheet (Fig. 13). If more than five colonies are found in one metre length of drill then > 5 is noted.

5. *R. padi* colonies are identified from all others. A note of the number of these is made on the aphid count record sheet.

6. The sampling line in each field is followed as closely as possible

each week.

Distribution of information and advice

An important feature of Strategic Monitoring is the availability of advice and information to the farmer.

It is proposed that pre-ploughing advice on the need for desiccation or early post-emergence treatment and the prospects for the autumn be issued via Crop Protection Reports and via a recorded telephone message.

Updates on post-emergence monitoring could also be provided by the same means. Farmers conducting their own monitoring will have the best possible source of information.

## DISCUSSION

This investigation has highlighted the complexity of the interaction between BYDV, its aphid vectors, local farming practice and prevailing environmental conditions. Variation in risk between regions in defined geographical areas, and between seasons in the occurrence of aphids and the consequent incidence of BYDV in autumn-sown cereals has been found.

The west of Scotland has proved valuable for the study of BYDV and the results have direct relevance to western and northern areas of the UK. Also, aspects of the work may have application to other parts of the UK too.

It is apparent that local movement of aphids, and in particular *S. avenae* (the grain aphid), plays an important role in the spread of BYDV. This source of aphids and virus is not detected by the remote Infectivity Indexing system. In the spring of 1989, when serious BYDV occurred in winter cereals in much of the UK, it was the MAV strain of the virus introduced by *S. avenae* which was the cause of most of the infection. However, it was apparent that *R. padi* (the bird-cherry aphid) could occur in local 'pockets' which were not detected by remote monitoring. It was in these 'pockets' that the crops were infected with the more damaging strains of BYDV which are transmitted by *R. padi*.

Serious yield reductions and even crop loss occurred in these areas. The Infectivity Index prediction for the autumn of 1988 based on the Auchincruive traps was low risk. The need for a locally-based monitoring system is reinforced by differences found in the relative importance of the main vector species between clearly defined regions within a small geographical area.

It is clear that the Infectivity Indexing scheme has a number of significant limitations. The scheme does provide an indication of risk of BYDV in the autumn resulting from the ingress of migrating *Rhopalosiphum* spp. It cannot identify aphid survival in a mild winter, nor can it detect local movement of aphids from grass fields and from volunteers and weedy stubbles.

Overall, both in the west of Scotland and in Northern Ireland during the

period of the project, there was not a good relationship between the Infectivity Index in the autumn and the incidence of BYDV infection in crops in the following spring.

BYDV, which is known to be common in ryegrass (Doodson, 1967; Holmes, 1985) has been shown to be widespread in a range of weed grasses in hedgerows. Plants are often infected with two or three strains of the virus whilst remaining essentially symptomless. Perhaps of greatest significance is that *Poa annua* growing amongst cereal plants is often heavily infected with virus as well as being colonised by aphids. It appears that the aphids move from cereal plants to the lusher grass weeds as the cereals begin to senesce. *P. annua* is a very common weed of cereal crops, often forming a green carpet towards harvest. As it has no direct effect on cereal production, it is not a target for weed control. In view of its importance in the epidemiology of BYDV, the economics of controlling *P. annua* to reduce virus risk need evaluation.

Although grass weeds and ryegrass crops constitute a large perennial reservoir of BYDV, their value as a source of virus depends on their desirability as a host of aphid vector species. In hedgerows, *S. avenae* can quite readily be found, particularly on the inflorescences where it is known to feed preferentially (George, 1978). In contrast, few *R. padi* were found on weed grasses. Other potential vectors such as *Metopolophium* spp. did occur, but as they have not been found in significant numbers in cereal crops their contribution to risk may be minimal.

*S. avenae* began to leave the weed grass inflorescences when they started to senesce in August/September. For most of these aphids, the move to cereal crops would be relatively easy, and occurred at around the time that the cereals were emerging. In ryegrass crops, *Rhopalosiphum* spp. could be found but as expected, *S. avenae* occurred in low numbers except in those fields where the grass was longer and the ears present. The numbers of aphids available for migration in September/October have been relatively low. Thus whilst ryegrass constitutes a huge reservoir of BYDV it is not necessarily the most important source of the virus for the infection of cereal crops.

A further complication in defining the relative importance of the different aphid vector species and source plants is that the ability of a particular aphid species to acquire and transmit a particular strain of the virus varies with source plant species and the number of strains with which it is infected. For example, *S. avenae* will selectively transmit the MAV strain from plants infected with the RPV, PAV and MAV strains, even though it is an efficient vector of PAV. This is of some importance as the MAV strain generally causes less damage to cereals than the PAV strain. *R. padi* which transmits the RPV and MAV strains tends to select RPV from multiple-infected plants. It has also been found to transmit the MAV strain through the process known as transcapsidation where infection with the RPV and MAV strain can result in the wrong protein coat being put on the virus genetic code material.

Host plant species also exerts an influence. Cereal plants (volunteers) and *P. annua* appear to be better sources of virus for *S. avenae*, whilst ryegrass appears to be a better source for *R. padi*. Overall, efficiency of the vectors differs, with *R. padi* being a more efficient vector than

*S. avenae.*

Based on the detailed epidemiological investigation, a crop-based monitoring scheme called Strategic Monitoring has been devised. Recognising that much of the early infection of crops results from local movement of aphids from local source plants, it is possible to gain valuable early indications of likely risk by assessing virus and aphid incidence in cereal crops shortly before harvest, and in grass weeds growing amongst the cereal plants. Further assessments made after harvest but pre-ploughing enable advice to be given on the need for pre-ploughing desiccation and/or early insecticide application to newly emerged cereal crops. As the monitoring scheme is structured geographically it can provide regionally-based risk assessments.

Post-emergence crop monitoring is essential to detect ingress of aphids from local and remote sources. Under the proposed scheme, crops would be monitored from around the end of October (for crops sown in mid September). The monitoring continues weekly until the end of October and then fortnightly until conditions become favourable for aphid survival. Should crops be deemed to be at risk then monitoring is suspended for 2-3 weeks after application of the insecticide.

The key to in-crop monitoring is that it is conducted on a prescribed simple scheme designed to encourage advisers and farmers to look closely at groups of plants across the crop, rather than to have a rather vague general look around the field. Recording the incidence of aphid colonies instead of individual aphids avoids over-reaction to the annual background level of aphids which can be found in most crops each autumn. By identifying whether aphid offspring are being produced, and whether the number of colonies is increasing between assessments, sprays are only applied when there is genuine risk. Spray decisions are made on increasing rather than absolute numbers.

Selection of fields for monitoring is critical. For individual farmers it is essential that fields which are potentially at highest risk are monitored. This ensures that a developing problem will be identified on that farm and that the input required for monitoring is kept to an acceptable minimum. Crops drilled into ploughed leys are excluded from the system, being automatically classed as high risk and treated accordingly. Monitoring of selected crops within regions by advisers is an alternative or supplementary approach, providing a general awareness of risk which can be used to advise farmers of the need to inspect their own crops.

Strategic Monitoring is still at the development stage and will be developed and refined over the next three seasons with continued funding by of the Home-Grown Cereals Authority.

The main areas for study are listed below.

1. Relative importance of sources of virus and aphids and in particular weed grasses in hedgerows, headlands, weed grasses in crops and cereal volunteers.

2. Continuation of Infectivity Indexing at Auchincruive and Belfast for

comparison with Strategic Monitoring.

3. Detailed evaluation of relative importance of the various pre and post-harvest assessments of virus incidence, aphid species and numbers, weed infestation etc. proposed in the Strategic Monitoring scheme.

4. Development of post-emergence monitoring using field advisers and gradually involving farmers.

5. Determine applicability of in-crop assessments to surrounding crops.

6. Determine intensity and frequency of in-crop assessments required to give a reliable prediction of high risk.

7. Efficiency of aphid vectors in transmission of virus from weed grasses infected with mixtures of virus strains.

8. Relative importance of controlling *Poa annua* in cereal crops by the application of herbicide at an early stage of crop growth compared to pre-ploughing desiccation of weedy stubbles or deep ploughing.

9. Determine relationship between numbers of aphids detected visually in crops in the autumn and total numbers present as determined by more detailed laboratory examination.

10. Replicated field trials to provide practical tests of Strategic Monitoring as a method of forecasting the need for and timing of insecticide applications.

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**Table 1.** The incidence of aphids in winter barley in the autumn of 1988 (total for 25, 1 $m^2$ areas per field per visit).

| | *Rhopalosiphum padi* (Bird-cherry aphid) | | | *Sitobion avenae* (Grain aphid) | | |
|---|---|---|---|---|---|---|
| Date | Wigtown | Ayrshire | Stirling | Wigtown | Ayrshire | Stirling |
| 4 October | 9 | 4 | 0 | 10 | 8 | 7 |
| 11 October | 1 | 2 | 2 | 2 | 5 | 6 |
| 18 October | 5 | 0 | 0 | 5 | 0 | 2 |
| 25 October | 8 | 0 | 2 | 12 | 4 | 1 |
| 31 October | 5 | 0 | 0 | 14 | 12 | 5 |
| 7 November | 19 | 1 | 0 | 19 | 11 | 2 |
| 14 November | 0 | 0 | 0 | 28 | 0 | - |
| 28 November | 4 | 1 | 0 | 16 | 2 | - |
| Total | 52 | 5 | 4 | 96 | 41 | 23 |

**Table 2.** Total numbers of aphids in 25 $m^2$ of crop in three fields on 25 January 1989.

| | Number/25 $m^2$ crop | |
|---|---|---|
| Field | *R. padi* | *S. avenae* |
| W5 | 10 | 0 |
| W2 | 0 | 10 |
| A3 | 5 | 5 |
| Total | 15 | 15 |

**Table 3.** Regional incidence of aphid vectors of BYDV in winter barley in April/May 1989.

| | | No. of fields with aphid species | | |
|---|---|---|---|---|
| Region | No. of fields | *R. padi* | *M. dirhodum* | *S. avenae* |
| Dumfries | 10 | 1 | 4 | 10 |
| Wigtown | 5 | 4 | 2 | 2 |
| Ayr | 7 | 2 | 0 | 4 |
| Stirling | 7 | 0 | 1 | 7 |
| Lanark | 5 | 0 | 0 | 0 |
| Renfrew | 11 | 1 | 0 | 10 |
| Total | 45 | 8 | 7 | 33 |

**Table 4.** Infectivity of aphids from survey fields.

| | | Strain of BYDV | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Aphid species | Number tested | RPV | PAV | MAV | RPV/ MAV | RPV/ PAV | PAV/ MAV | % infective |
| *S. avenae* | 255 | 0 | 5 | 44 | 1 | 3 | 2 | 21.6 |
| *M. dirhodum* | 36 | 0 | 1 | 9 | 0 | 0 | 0 | 27.8 |
| *R. padi* | 53 | 3 | 7 | 0 | 17 | 0 | 0 | 50.9 |

**Table 5.** Total numbers of aphid colonies in 26 winter barley fields during the autumn 1989.

| | | | Numbers of aphid colonies | |
|---|---|---|---|---|
| Region | Field | No. of visits | *Rhopalosiphum spp.* | *Sitobion avenae* |
| **Dumfries** | D1 | 2 | 1 | 2 |
| | D2 | 3 | 4 | 7 |
| | D3 | 3 | 3 | 7 |
| | D4 | 3 | 0 | 0 |
| | D5 | 3 | 1 | 0 |
| | D6 | 2 | 0 | 1 |
| | D7 | 2 | 0 | 1 |
| | Totals | | 9 | 18 |
| **Wigtown** | W1 | 3 | 9 | 4 |
| | W2 | 3 | 1 | 0 |
| | W3 | 2 | 43 | 10 |
| | W4 | 3 | 2 | 3 |
| | Totals | | 55 | 17 |
| **Ayr** | A1 | 3 | 5 | 4 |
| | A2 | 3 | 4 | 19 |
| | A3 | 3 | 0 | 0 |
| | A4 | 4 | 47 | 0 |
| | A5 | 3 | 83 | 0 |
| | Totals | | 139 | 23 |
| **Renfrew** | R1 | 4 | 1 | 17 |
| | R2 | 4 | 2 | 13 |
| | R3 | 4 | 0 | 14 |
| | R4 | 3 | 0 | 1 |
| | R5 | 3 | 0 | 0 |
| | R6 | 3 | 0 | 0 |
| | R7 | 3 | 4 | 0 |
| | Totals | | 7 | 45 |
| **Stirling** | S1 | 4 | 0 | 0 |
| | S2 | 4 | 2 | 1 |
| | S3 | 3 | 12 | 0 |
| | Totals | | 14 | 1 |
| | Grand totals | | 224 | 104 |

**Table 6.** Total numbers of aphid colonies in 26 winter barley fields during the spring 1990.

| Region | Field | No. of visits | Numbers of aphid colonies | |
|---|---|---|---|---|
| | | | *Rhopalosiphum padi* | *Sitobion avenae* |
| **Dumfries** | D1 | 3 | 0 | 0 |
| | D2 | 3 | 0 | 0 |
| | D3 | 3 | 0 | 1 |
| | D4 | 3 | 0 | 1 |
| | D5 | 3 | 0 | 0 |
| | D6 | 3 | 0 | 2 |
| | D7 | 3 | 0 | 0 |
| | Totals | | 0 | 4 |
| **Wigtown** | W1 | 3 | 5 | 1 |
| | W2 | 3 | 120 | 0 |
| | W3 | 3 | 10 | 2 |
| | W4 | 3 | 0 | 8 |
| | Totals | | 135 | 11 |
| **Ayr** | A1 | 3 | 0 | 7 |
| | A2 | 3 | 0 | 3 |
| | A3 | 3 | 0 | 0 |
| | A4 | 4 | 0 | 3 |
| | A5 | 3 | 3 | 0 |
| | Totals | | 3 | 13 |
| **Renfrew** | R1 | 3 | 2 | 33 |
| | R2 | 3 | 0 | 14 |
| | R3 | 3 | 1 | 19 |
| | R4 | 3 | 0 | 1 |
| | R5 | 3 | 0 | 0 |
| | R6 | 3 | 0 | 1 |
| | R7 | 3 | 0 | 1 |
| | Totals | | 3 | 68 |
| **Stirling** | S1 | 3 | 2 | 0 |
| | S2 | 3 | 0 | 0 |
| | S3 | 3 | 0 | 0 |
| | Totals | | 2 | 0 |
| | Grand totals | | 143 | 96 |

**Table 7.** Percentage of yellow barley leaf samples infected with each BYDV strain; BYDV in winter barley 1989/90.

| Region | Number of | | Percentage of positive tests for BYDV strain | | |
|---|---|---|---|---|---|
| | Fields sampled | Leaves tested | RPV | PAV | MAV |
| Dumfriesshire | 7 | 34 | 9 | 18 | 26 |
| Wigtownshire | 4 | 20 | 20 | 15 | 45 |
| Ayrshire | 5 | 23 | 22 | 39 | 39 |
| Renfrewshire | 7 | 35 | 6 | 14 | 51 |
| Stirlingshire | 3 | 13 | 0 | 54 | 31 |
| Totals | 26 | 125 | | | |
| | | % | 11 | 24 | 39 |

**Table 8.** BYDV strain incidence in 10 leaves collected from patches of yellow plants in winter barley fields, spring 1990.

| Region | No. of leaves infected/ leaves tested | No. of positive tests for BYDV strain | | |
|---|---|---|---|---|
| | | RPV | PAV | MAV |
| Wigtown | 23/40 | 5 | 16 | 3 |
| Ayrshire | 33/50 | 5 | 21 | 12 |
| Renfrew | 15/15 | 6 | 9 | 0 |
| Stirling | 44/60 | 0 | 43 | 1 |
| Totals | 115/165 | 16 | 89 | 16 |

**Table 9.** Total numbers of aphid colonies in 25 winter barley crops; autumn 1990.

| Field | No. of visits | Total numbers of aphid colonies | |
|---|---|---|---|
| | | *Rhopalosiphum spp.* | *S. avenae* |
| **Dumfriesshire** | | | |
| [D1 + | 4 | 8 | 6] |
| D2 | 7 | 14 | 10 |
| D3 | 7 | 15 | 8 |
| D4 | 7 | 6 | 6 |
| D5 | 7 | 15 | 15 |
| D6 | 7 | 13 | 9 |
| D7 | 7 | 8 | 3 |
| Totals | | 71 | 51 |
| **Wigtownshire** | | | |
| [W1 + | 5 | 1 | 2 |
| W2 | 7 | 5 | 4 |
| W3 | 7 | 3 | 5 |
| W4 | 7 | 8 | 0 |
| W5 | 7 | 5 | 0 |
| W6 | 7 | 5 | 2 |
| W7 | 7 | 4 | 1 |
| W8 | 7 | 6 | 5 |
| [W9 + | 5 | 4 | 7] |
| Totals | | 36 | 17 |
| **Stirlingshire** | | | |
| S1 | 9 | 4 | 7 |
| S2 | 8 | 1 | 16 |
| S3 | 7 | 6 | 3 |
| S4 | 7 | 1 | 5 |
| [S5 | 2 | 0 | 2] |
| S6 | 8 | 16 | 7 |
| S7 | 8 | 3 | 1 |
| [S8 | 4 | 5 | 12] |
| S9 | 9 | 2 | 1 |
| Totals | | 33 | 40 |
| Grand totals | | 140 | 108 |

Totals from bracketed fields were not included in regional totals because sampling frequency by SAC advisers was mostly fortnightly throughout the autumn.

\+ sampled during early January.

**Table 10.** The incidence of BYDV in yellow leaves collected from winter barley crops in May 1991.

| Region | Number of | | % Leaves with BYDV strain | | |
|---|---|---|---|---|---|
| | Fields | Leaves tested | RPV | PAV | MAV |
| Dumfries | 6 | 25 | 8 | 24 | 24 |
| Wigtown | 9 | 37 | 3 | 16 | 30 |
| Stirling | 9 | 45 | 2 | 22 | 42 |
| Total | 25 | 107 | 4 | 21 | 34 |

**Table 11.** The incidence of BYDV in *Poa annua* collected from winter barley crops in July 1989.

| Region | No. of plants tested | Number of positive tests for BYDV strain | | |
|---|---|---|---|---|
| | | RPV | PAV | MAV |
| Dumfriesshire | 25 | 12 | 14 | 25 |
| Wigtownshire | 29 | 18 | 21 | 8 |
| Ayrshire | 19 | 13 | 15 | 8 |
| Renfrewshire | 29 | 0 | 3 | 19 |
| Stirlingshire | 30 | 1 | 4 | 16 |
| Total | 132 | 44 | 57 | 76 |
| | % | 33 | 43 | 58 |

**Table 12.** Incidence of BYDV strains in *P. annua* collected on two occasions from winter barley fields; BYDV survey, spring 1990.

| Field | No. of samples | Number of positive ELISA tests for BYDV strain | | | | | |
|---|---|---|---|---|---|---|---|
| | | RPV | | PAV | | MAV | |
| | | May/June | | May/June | | May/June | |
| **Dumfriesshire** | | | | | | | |
| D1 | 20 | 0 | 2 | 0 | 5 | 0 | 0 |
| D5 | 19 | 1 | 0 | 1 | 0 | 6 | 0 |
| **Wigtownshire** | | | | | | | |
| W3 | 18 | 0 | 0 | 2 | 1 | 0 | 0 |
| W4 | 20 | 1 | 0 | 4 | 0 | 1 | 0 |
| **Ayrshire** | | | | | | | |
| A2 | 20 | 6 | 3 | 7 | 5 | 6 | 3 |
| **Renfrewshire** | | | | | | | |
| R1 | 20 | 2 | 7 | 4 | 3 | 5 | 8 |
| R7 | 20 | 2 | 3 | 6 | 2 | 3 | 9 |
| **Stirlingshire** | | | | | | | |
| S2 | 19 | 0 | 0 | 3 | 2 | 3 | 6 |
| S3 | 20 | 0 | 0 | 0 | 2 | 8 | 6 |
| Grand totals | | 12 | 15 | 27 | 20 | 32 | 32 |

**Table 13.** Number of plants with at least one aphid colony (max. 100 plants/species).

| Grass weed | Number of aphid-infested plants | |
|---|---|---|
| | Leaves/stems | Inflorescences |
| *Alopecuris pratensis* | 7 | 6 |
| *Dactylis glomerata* | 3 | 18 |
| *Holcus lanatus* | 2 | 13 |
| *Lolium perenne* | 3 | 2 |
| *Poa annua* | 11 | 8 |

**Table 14.** BYDV strain incidence in five species of wild grass.

| Grass species | No. of samples | % infected | Number of positive tests for BYDV strain | | |
|---|---|---|---|---|---|
| | | | RPV | PAV | MAV |
| *Alopecuris pratensis* | 28 | 61 | 11 | 4 | 12 |
| *Dactylis glomerata* | 38 | 100 | 34 | 21 | 33 |
| *Holcus lanatus* | 40 | 43 | 2 | 3 | 17 |
| *Lolium perenne* | 33 | 82 | 16 | 10 | 22 |
| *Poa annua* | 39 | 49 | 3 | 11 | 10 |
| Total | 178 | | 66 | 49 | 94 |

**Table 15.** Transmission of BYDV to oat seedlings by *Sitobion avenae* collected from four habitats; 1988-1990.

| Habitat | *Sitobion avenae* | | No. of aphids transmitting BYDV strain or strain mixture to oat seedling | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. tested | No. transmitting BYDV to oats (%) | RPV | PAV | MAV | RP | RM | PM | RPM[a] |
| Winter barley | 600 | 130 (22) | 5 (*14*) | 7 *13* | 106 *115*) | 3 | 6 | 3 | 0 |
| Grass weeds in winter barley | 211 | 48 (23) | 2 ( *8* | 4 *10* | 32 *40*) | 2 | 4 | 4 | 0 |
| Grass weeds in[b] hedgebottoms | 156 | 16 (10) | 2 ( *3* | 2 *3* | 10 *12*) | 0 | 1 | 1 | 0 |
| Ryegrass pastures | 159 | 24 (15) | 6 ( *7* | 2 *8* | 13 *15*) | 1 | 0 | 2 | 0 |
| Totals | 1126 | 218 (19) | 15 (*33* | 15 *32* | 161 *182*) | 6 | 11 | 10 | 0 |

a Two and three-way infections: R = RPV; P = PAV; M = MAV.
b both *avenae* and *fragariae* were collected.

*Italicised* figures in brackets are the total numbers of aphids transmitting each BYDV strain alone or as part of a mixture.

**Table 16.** Transmission of BYDV to oat seedlings by *Rhopalosiphum padi* collected from four habitats; 1988-1990.

| Habitat | *Rhopalosiphum padi* | | No. of aphids transmitting BYDV strain or strain mixture to oat seedling | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. tested | No. transmitting BYDV to oats (%) | RPV | PAV | MAV | RP | RM | PM | RPM[a] |
| Winter barley | 330 | 106 (32) | 28 (*60* | 28 *59* | 16 *33*) | 17 | 3 | 2 | 12 |
| Grass weeds in winter barley | 17 | 5 (29) | 2 ( *3* | 0 *0* | 2 *3*) | 0 | 1 | 0 | 0 |
| Grass weeds in hedgebottoms | 60 | 12 (20) | 3 ( *7* | 3 *5* | 2 *4*) | 2 | 2 | 0 | 0 |
| Ryegrass pastures | 405 | 151 (37) | 71 (*104* | 22 *53* | 16 *40*) | 18 | 11 | 9 | 4 |
| Totals | 812 | 274 (34) | 104 (*177* | 53 *119* | 36 *82*) | 37 | 17 | 11 | 16 |

a Two and three-way infections: R = RPV; P = PAV; M = MAV.

*Italicised* figures in brackets are number of aphids transmitting a pure BYDV strain either alone or as part of a mixture.

**Table 17.** Transmission of BYDV to oat seedlings by *Metopolophium dirhodum* collected from four habitats; 1988-1990.

| Habitat | *Metopolophium dirhodum* | | No. of aphids transmitting BYDV strain or strain mixture to oat seedlings | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. tested | No. transmitting BYDV to oats (%) | RPV | PAV | MAV | RP | RM | PM | RPM[a] |
| Winter barley | 48 | 13 (27) | 1 (*2* | 1 *2* | 10 *10*) | 1 | 0 | 0 | 0 |
| Grass weeds in winter barley | 13 | 2 (15) | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| Grass weeds in hedgebottoms | 51 | 11 (22) | 0 | 0 | 11 | 0 | 0 | 0 | 0 |
| Ryegrass pastures | 13 | 1 (8) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 125 | 27 (22) | 2 (*3* | 2 *3* | 22 *22*) | 1 | 0 | 0 | 0 |

a Two and three-way infections: R = RPV; P = PAV; M = MAV.

*Italicised* figures in brackets are number of aphids transmitting a pure BYDV strain either alone or as part of a mixture.

**Table 18.** Transmission of BYDV to oat seedlings by *Rhopalosiphum insertum* collected from four habitats; 1988-1990.

| Habitat | *Rhopalosiphum insertum* | | No. of aphids transmitting BYDV strain or strain mixture to oat seedling | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. tested | No. transmitting BYDV to oats (%) | RPV | PAV | MAV | RP | RM | PM | RPM[a] |
| Winter barley | 59 | 9 (17) | 2 | 1 | 6 | 0 | 1 | 0 | 0 |
| Ryegrass pastures | 28 | 5 (18) | 1 | 3 | 0 | 0 | 1 | 0 | 0 |
| Grass weeds in winter barley | 6 | 1 (17) | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Ryegrass pastures | 28 | 5 (18) | 1 | 3 | 0 | 0 | 1 | 0 | 0 |
| Totals | 121 | 21 (17) | 4 | 8 | 6 | 0 | 3 | 0 | 0 |

a Two and three-way infections: R = RPV; P = PAV; M = MAV.

**Table 19.** Transmission of BYDV to oat seedlings by *Metopolophium festucae* collected from four habitats; 1988-1990.

| Habitat | *Metopolophium festucae* | | No. of aphids transmitting BYDV strain or strain mixture to oat seedling | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. tested | No. transmitting BYDV to oats (%) | RPV | PAV | MAV | RP | RM | PM | RPM[a] |
| Winter barley | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ryegrass pastures | 129 | 9 (7) | 1 | 2 | 5 | 0 | 1 | 0 | 0 |
| Totals | 131 | 9 (7) | 1 | 2 | 5 | 0 | 1 | 0 | 0 |

a Two and three-way infections: R = RPV; P = PAV; M = MAV.

**Table 20.** Transmission of BYDV to oat seedlings by aphids collected from grass weeds (mostly *Poa annua*) in winter barley fields; 1988-1990.

| Season | No. tested | No. transmitting BYDV to oats (%) | % of aphids which transmitted BYDV strain to an oat seedling | | |
|---|---|---|---|---|---|
| | | | RPV | PAV | MAV |
| *R. padi* | | | | | |
| Summer 1989 | 4 | 1 (25) | 25 | 0 | 0 |
| Autumn 1989 | 9 | 4 (44) | 22 | 0 | 33 |
| Summer 1990 | 4 | 0 | 0 | 0 | 0 |
| *S. avenae* | | | | | |
| Summer 1989 | 77 | 17 (22) | 3 | 8 | 14 |
| Autumn 1989 | 9 | 7 (78) | 56 | 0 | 67 |
| Summer 1990 | 112 | 21 (19) | 0 | 4 | 19 |
| Autumn 1990 | 13 | 3 (23) | 8 | 0 | 15 |
| *M. dirhodum* | | | | | |
| Summer 1989 | 3 | 0 | 0 | 0 | 0 |
| Summer 1990 | 10 | 1 (10) | 0 | 10 | 10 |

**Table 21.** Transmission of BYDV to oat seedlings by aphids collected from winter barley; 1988-1990.

| Season | No. tested | No. transmitting BYDV to oats (%) | % of aphids which transmitted BYDV strain to an oat seedling | | |
|---|---|---|---|---|---|
| | | | RPV | PAV | MAV |
| *R. padi* | | | | | |
| Summer 1988 | 16 | 0 | 0 | 0 | 0 |
| Autumn 1988 | 55 | 14 (26) | 18 | 2 | 7 |
| Summer 1989 | 107 | 36 (34) | 18 | 24 | 5 |
| Autumn 1989 | 31 | 24 (77) | 61 | 32 | 39 |
| Summer 1990 | 32 | 10 (31) | 3 | 25 | 6 |
| Autumn 1990 (volunteers in stubble fields) | 47 | 16 (34) | 11 | 23 | 15 |
| Autumn 1990 | 42 | 6 (14) | 7 | 7 | 7 |
| *S. avenae* | | | | | |
| Summer 1988 | 39 | 4 (10) | 2 | 0 | 8 |
| Autumn 1988 | 135 | 6 (5) | 1 | 1 | 3 |
| Summer 1989 | 287 | 75 (26) | 4 | 4 | 22 |
| Autumn 1989 | 15 | 8 (53) | 0 | 0 | 53 |
| Summer 1990 | 75 | 23 (31) | 0 | 1 | 31 |
| Autumn 1990 (volunteers in stubble fields) | 9 | 5 (56) | 0 | 0 | 56 |
| Autumn 1990 | 40 | 9 (23) | 0 | 0 | 23 |
| *M. dirhodum* | | | | | |
| Summer 1988 | 10 | 2 (20) | 10 | 0 | 10 |
| Summer 1989 | 34 | 11 (32) | 3 | 6 | 27 |
| Summer 1990 | 4 | 0 | 0 | 0 | 0 |

**Table 22.** Transmission of BYDV to oat seedlings by aphids collected from ryegrass pastures; 1988-1990.

| Season | No. tested | No. transmitting BYDV to oats (%) | % of aphids which transmitted BYDV strain to an oat seedling | | |
|---|---|---|---|---|---|
| | | | RPV | PAV | MAV |
| *R.padi* | | | | | |
| Summer and autumn 1988 | 213 | 66 (31) | 26 | 8 | 1 |
| Summer and autumn 1989 | 61 | 36 (59) | 36 | 20 | 25 |
| Summer and autumn 1990 | 131 | 49 (37) | 21 | 18 | 16 |
| *S. avenae* | | | | | |
| Summer and autumn 1988 | 75 | 7 (9) | 8 | 1 | 1 |
| Summer and autumn 1989 | 23 | 8 (35) | 4 | 13 | 22 |
| Summer and autumn 1990 | 61 | 9 (15) | 0 | 3 | 15 |
| *M. dirhodum* | | | | | |
| Summer and autumn 1988 | 8 | 0 | 0 | 0 | 0 |
| Summer and autumn 1989 | 3 | 1 (33) | 33 | 0 | 0 |
| Summer and autumn 1990 | 2 | 0 | 0 | 0 | 0 |

**Table 23.** Transmission of BYDV to oat seedlings by aphids collected from four species of wild grasses in hedgebottoms at two farms in Ayrshire; summer 1990.

| Season | No. tested | No. transmitting BYDV to oats (%) | % of aphids which transmitted BYDV strain to an oat seedling | | |
|---|---|---|---|---|---|
| | | | RPV | PAV | MAV |
| *R. padi* | | | | | |
| A. pratensis | 1 | 0 | 0 | 0 | 0 |
| D. glomerata | 26 | 0 | 0 | 0 | 0 |
| P. annua | 33 | 12 (36) | 21 | 15 | 12 |
| *S. avenae* | | | | | |
| A. pratensis | 13 | 0 | 0 | 0 | 0 |
| D. glomerata | 41 | 4 (10) | 2 | 2 | 7 |
| H. lanatus | 51 | 3 (6) | 0 | 2 | 4 |
| P. annua | 51 | 9 (18) | 4 | 2 | 14 |
| *M. dirhodum* | | | | | |
| A. pratensis | 3 | 0 | 0 | 0 | 0 |
| D. glomerata | 4 | 0 | 0 | 0 | 0 |
| P. annua | 44 | 11 (25) | 0 | 0 | 25 |

**Table 24.** Mean numbers of aphids per 100 $m^2$ of ryegrass pasture sampled in 1988 and 1990 from April to October.

| | Mean numbers of aphids/100 $m^2$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | M.d. | | M.f. | | Rh. spp. | | R.i. | S.a. | |
| Month | 1988 | 1990 | 1988 | 1990 | 1988[a] | 1990 | 1990 | 1988 | 1990 |
| April | - | 0 | - | 0 | - | 0 | 0 | - | 0 |
| May | - | 0 | - | 9 | - | 7 | 0 | - | 1 |
| June | 15 | 0 | 397 | 58 | 7 | 5 | 0 | 64 | 103 |
| July | 3 | 0 | 70 | 50 | 242 | 187 | 107 | 68 | 30 |
| August | 1 | 3 | 5 | 99 | 160 | 2607 | 1111 | 17 | 146 |
| September | 0 | 0 | 0 | 1 | 214 | 221 | 50 | 4 | 1 |
| October | 0 | 20 | 0 | 10 | 243 | 110 | 0 | 3 | 0 |
| Anova on pooled data | $P < 0.01$ | | $P < 0.001$ | | $P < 0.001$ (Rh. spp.) | | | $P < 0.001$ | |

a alate *Rhopalosiphum* spp. not separated in 1988.

R.p. *R. padi* Rh. *Rhopalosiphum* M.d. *M. dirhodum*
M.f. *M. festucae* S.a. *S. avenae* R.i. *R. insertum*

**Table 25.** Mean numbers of aphids per 100 $m^2$ of ryegrass pasture sampled in 1988 and 1990 in the three grasslength categories.

| Grasslength[a] category | Mean numbers of aphids/100 $m^2$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | M.d. | | M.f. | | Rh. spp. | | R.i. | S.a | |
| | 1988 | 1990 | 1988 | 1990 | 1988[b] | 1990 | 1990 | 1988 | 1990 |
| 1 | 1.5 | 0.0 | 13 | 0 | 84 | 87 | 67 | 7 | 0 |
| 2 | 2.7 | 2.2 | 90 | 24 | 75 | 969 | 301 | 20 | 27 |
| 3 | 5.5 | 0.6 | 129 | 43 | 241 | 334 | 207 | 41 | 61 |
| Anova on pooled data | N.S. | | N.S. | | N.S. (Rh. spp.) | | | $P < 0.05$ | |

a 1 - Generally short ( < 4 cm high)
2 - Obviously grazed but with lusher areas associated with dunging
3 - Even, long grass throughout (> 4 cm high)

b alate Rh. spp. not separated in 1988.

**Table 26.** Mean numbers of aphids per 100 $m^2$ of ryegrass pasture sampled in 1988 and 1990 in the four pasture age categories.

| Pasture age (years) | Mean numbers of aphids/100 $m^2$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | M.d. | | M.f. | | Rh. spp. | | R.i. | S.a | |
| | 1988 | 1990 | 1988 | 1990 | 1988[a] | 1990 | 1990 | 1988 | 1990 |
| < 2 | 1.1 | 0.0 | 12 | 40 | 291 | 2011 | 328 | 6 | 58 |
| 2 to 5 | 4.5 | 0.0 | 85 | 13 | 90 | 27 | 0 | 25 | 27 |
| 6 to 10 | 5.0 | 3.8 | 132 | 66 | 234 | 739 | 508 | 45 | 70 |
| > 10 | 3.9 | 0.0 | 133 | 14 | 61 | 262 | 100 | 29 | 28 |
| Anova on pooled data | N.S. | | N.S. | | P < 0.001 (Rh. spp.) | | | N.S. | |

a alate *Rhopalosiphum* spp. not separated in 1988.

**Table 27.** Mean numbers of aphids per 100 $m^2$ of ryegrass pasture sampled in 1988 and 1990 in different regions.

| | Mean numbers of aphids/100 $m^2$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | M.d. | | M.f. | | Rh. spp. | | R.i. | S.a. | |
| Region | 1988 | 1990 | 1988 | 1990 | 1988[a] | 1990 | 1990 | 1988 | 1990 |
| Dumfriesshire | 2.6 | 0.0 | 32 | 6 | 186 | 22 | 11 | 8 | 23 |
| Wigtownshire | 3.2 | 0.0 | 33 | 0 | 196 | 212 | 24 | 5 | 0 |
| Ayrshire | 6.3 | 2.0 | 184 | 45 | 178 | 900 | 375 | 56 | 45 |
| Renfrewshire | - | 0.0 | - | 33 | - | 0 | 0 | - | 200 |
| Stirlingshire | 0.0 | 0.0 | 40 | 22 | 159 | 34 | 22 | 11 | 32 |
| Anova on pooled data | N.S. | | N.S. | | $P < 0.001$ (Rh. spp.) | | | $P < 0.05$ | |

[a] alate *Rhopalosiphum* spp. not separated in 1988

R.p. *R. padi* Rh. *Rhopalosiphum* spp. M.d. *M. dirhodum*
M.f. *M. festucae* S.a. *S. avenae*

**Table 28.** Incidence of BYDV in winter barley leaf samples, 1989.

| Region | No. of samples | No. of positive ELISA tests for BYDV strain | | |
|---|---|---|---|---|
| | | RPV | PAV | MAV |
| Dumfriesshire | 15 | 2 | 1 | 8 |
| Wigtownshire | 5 | 2 | 5 | 2 |
| Ayrshire | 10 | 3 | 6 | 6 |
| Renfrewshire | 10 | 0 | 0 | 7 |
| Stirlingshire | 15 | 2 | 1 | 8 |
| Totals | 55 | 9 | 13 | 31 |
| | % | 16 | 24 | 56 |

**Table 29.** Incidence of BYDV in *Poa annua* leaf samples, 1989.

| Region | No. of samples | No. of positive ELISA tests for BYDV strain | | |
|---|---|---|---|---|
| | | RPV | PAV | MAV |
| Dumfriesshire | 25 | 12 | 14 | 25 |
| Wigtownshire | 29 | 21 | 24 | 9 |
| Ayrshire | 19 | 10 | 11 | 6 |
| Renfrewshire | 29 | 0 | 3 | 22 |
| Stirlingshire | 30 | 1 | 5 | 19 |
| Totals | 132 | 44 | 57 | 81 |
| | % | 33 | 43 | 61 |

**Table 30.** The number of aphids tested and the number of positive BYDV transmission tests for the aphid samples collected from barley plants and *P. annua* host plants in each region in 1989.

| | | Number of positive tests for BYDV strain | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Aphids on barley plants | | | | Aphids on *P. annua* | | |
| Region | No. tested | RPV | PAV | MAV | No. tested | RPV | PAV | MAV |
| Dumfriesshire | 8 | 0 | 0 | 0 | 6 | 0 | 0 | 4 |
| Wigtownshire | 24 | 4 | 1 | 1 | 0 | 0 | 0 | 0 |
| Ayrshire | 0 | 0 | 0 | 0 | 26 | 2 | 2 | 2 |
| Renfrewshire | 9 | 0 | 1 | 1 | 22 | 0 | 1 | 4 |
| Stirlingshire | 12 | 1 | 0 | 3 | 23 | 1 | 2 | 1 |
| Totals | 53 | 5 | 2 | 5 | 77 | 3 | 5 | 11 |
| | % | 9 | 4 | 9 | | 4 | 6 | 14 |

**Table 31.** Extent of field infestation with *Poa annua* or *Lolium perenne* in each region in 1989.

| | No. of fields in each category | | |
|---|---|---|---|
| Region | 1 | 2 | 3 |
| Dumfriesshire | 1 | 2 | 0 |
| Wigtownshire | 0 | 1 | 2 |
| Ayrshire | 0 | 2 | 0 |
| Renfrewshire | 1 | 1 | 1 |
| Stirlingshire | 2 | 1 | 0 |
| Totals | 4 | 7 | 3 |

Category 1 Scattered plants in tramlines

Category 2 Appreciable proportion of tramlines infested (at least 1-5%

Category 3 Extensive areas of crop infested

**Table 32.** Regional abundance of ladybirds in 1989.

| | No. of fields in each category | | |
|---|---|---|---|
| Region | None | Few | Many |
| Dumfriesshire | 0 | 2 | 1 |
| Wigtownshire | 0 | 2 | 1 |
| Ayrshire | 0 | 2 | 0 |
| Renfrewshire | 1 | 0 | 2 |
| Stirlingshire | 0 | 2 | 1 |
| Totals | 1 | 8 | 5 |

**Table 33.** Number of barley leaf samples infected with each BYDV strain in each region, west of Scotland 1990.

| Region | No. of samples | No. of postive ELISA tests for BYDV strain | | |
|---|---|---|---|---|
| | | RPV | PAV | MAV |
| Dumfriesshire | 27 | 5 | 1 | 11 |
| Wigtownshire | 20 | 0 | 0 | 1 |
| Stirlingshire | 20 | 1 | 0 | 0 |
| Totals | 67 | 6 | 1 | 12 |
| | % | 9 | 1 | 18 |

**Table 34.** Number of *Poa annua* infected with each BYDV strain in each region in 1990.

| Region | No. of samples | No. of positive ELISA tests for BYDV strain | | |
|---|---|---|---|---|
| | | RPV | PAV | MAV |
| Dumfriesshire | 26 | 0 | 0 | 3 |
| Wigtownshire | 30 | 2 | 2 | 24 |
| Stirlingshire | 30 | 1 | 2 | 6 |
| Totals | 86 | 3 | 4 | 33 |
| | % | 3 | 5 | 38 |

**Table 35.** Number of barley leaf samples infected with each BYDV strain in Northern Ireland 1990.

| Region | No. of samples | No. of positive ELISA tests for BYDV strain | | |
|---|---|---|---|---|
| | | RPV | PAV | MAV |
| Down | 10 | 2 | 0 | 5 |
| Antrim | 30 | 0 | 0 | 5 |
| Total | 40 | 2 | 0 | 10 |
| | % | 5 | 0 | 25 |

**Table 36.** Number of *Poa annua* infected with each BYDV strain in Northern Ireland, 1990.

| Region | No. of samples | No. of positive ELISA tests for BYDV strain | | |
|---|---|---|---|---|
| | | RPV | PAV | MAV |
| Down | 30 | 4 | 5 | 16 |
| Antrim | 30 | 3 | 3 | 3 |
| Total | 60 | 7 | 8 | 19 |
| | % | 12 | 13 | 32 |

**Table 37.** The number of aphids tested and the number of postive BYDV transmission tests for the aphid samples collected from barley plant and *Poa annua* host plants in each region in the west of Scotland, 1990.

| | | No. of positive tests for BYDV strain | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Aphids on barley plants | | | | Aphids on *Poa annua* | | |
| Region | No. tested | RPV | PAV | MAV | No. tested | RPV | PAV | MAV |
| Dumfriesshire | 19 | 0 | 0 | 1 | 15 | 0 | 0 | 0 |
| Wigtownshire | 0 | 0 | 0 | 0 | 18 | 0 | 1 | 9 |
| Stirlingshire | 5 | 0 | 0 | 1 | 32 | 0 | 3 | 5 |
| Totals | 24 | 0 | 0 | 2 | 65 | 0 | 4 | 14 |
| | % | 0 | 0 | 8 | % | 0 | 6 | 22 |

**Table 38.** Extent of field infestation with *Poa annua* or *Lolium perenne* in each region in the west of Scotland, 1990.

| | Number of fields in each category | | |
|---|---|---|---|
| Region | 1 | 2 | 3 |
| Dumfriesshire | 2 | 0 | 1 |
| Wigtownshire | 0 | 0 | 3 |
| Stirlingshire | 1 | 2 | 0 |
| Totals | 3 | 2 | 4 |

Category 1 Scattered plants in tramlines

Category 2 Appreciable proportion of tramlines infested (at least 1-5%)

Category 3 Extensive areas of field infested

**Table 39.** Extent of field infestation with *Poa annua* or *Lolium perenne* in Northern Ireland, 1990.

| | Number of fields in each category* | | |
|---|---|---|---|
| Region | 1 | 2 | 3 |
| Down | 0 | 2 | 1 |
| Antrim | 1 | 1 | 1 |
| Totals | 1 | 3 | 2 |

* Weediness scale as for Table 38.

**Table 40.** Abundance of ladybirds in each region in the west of Scotland, 1990.

| | No. of fields in each category | | |
|---|---|---|---|
| Region | None | Few | Many |
| Dumfriesshire | 2 | 1 | 0 |
| Wigtownshire | 1 | 2 | 0 |
| Stirlingshire | 2 | 1 | 0 |
| Totals | 5 | 4 | 0 |

**Table 41.** Abundance of aphid mummies in each region in the west of Scotland, 1990.

| | No. of fields in each category | | |
|---|---|---|---|
| Region | None | Few | Many |
| Dumfriesshire | 0 | 3 | 0 |
| Wigtownshire | 1 | 0 | 2 |
| Stirlingshire | 1 | 1 | 1 |
| Totals | 2 | 4 | 3 |

**Table 42.** Aphid infestation of grass weeds and barley volunteers in winter barley stubble fields in the west of Scotland in August, 1990.

| Region | No. of samples | Mean number of plants infested | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Grass weeds | | | | Volunteers | | | |
| | | M.d. | R.i. | R.p. | S.a. | M.d. | R.i. | R.p. | S.a. |
| Dumfriesshire | 25 | - | - | 0.3 | 0.1 | 0.1 | - | 0.4 | 0.3 |
| Wigtownshire | 35 | - | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.3 | 0.2 |
| Ayrshire | 15 | - | - | 0.2 | - | 0.1 | 0.1 | 0.4 | - |
| Stirlingshire | 10 | - | - | - | - | - | - | - | - |
| Total number of plants infested | | - | 6 | 16 | 8 | 6 | 6 | 29 | 15 |

Key

M.d. *M. dirhodum* R.p. *R. padi*

R.i. *R. insertum* S.a. *S. avenae*

**Table 43.** Aphid infestation of cereal stubble fields in Northern Ireland in August, 1990.

| Region | No. of aphids collected | No. of each of following species | | |
|---|---|---|---|---|
| | | *R. insertum* | *R. padi* | *S. avenae* |
| Down | 27 | 5 | 10 | 12 |
| Antrim | 63 | 11 | 52 | 0 |

**Table 44.** Percentage of barley leaf and *P. annua* samples collected in July 1989 and barley leaf samples collected in May 1990 infected with each BYDV strain.

| Region | Host plant | Sampling date | % of samples with BYDV strain | | |
|---|---|---|---|---|---|
| | | | RPV | PAV | MAV |
| Dumfriesshire | | | | | |
| | Barley | July 1989 | 13 | 7 | 53 |
| | *P. annua* | July 1989 | 48 | 56 | 100 |
| | Barley | May 1990 | 9 | 18 | 26 |
| Wigtownshire | | | | | |
| | Barley | July 1989 | 40 | 100 | 40 |
| | *P. annua* | July 1989 | 72 | 83 | 31 |
| | Barley | May 1990 | 10 | 0 | 70 |
| Ayrshire | | | | | |
| | Barley | July 1989 | 30 | 60 | 60 |
| | *P. annua* | July 1989 | 53 | 58 | 32 |
| | Barley | May 1990 | 8 | 23 | 69 |
| Renfrewshire | | | | | |
| | Barley | July 1989 | 0 | 0 | 70 |
| | *P. annua* | July 1989 | 0 | 10 | 76 |
| | Barley | May 1990 | 8 | 23 | 69 |
| Stirlingshire | | | | | |
| | Barley | July 1989 | 13 | 7 | 53 |
| | *P. annua* | July 1989 | 4 | 17 | 63 |
| | Barley | May 1990 | 0 | 54 | 31 |

**Table 45.** Percentage of barley leaf and *P. annua* samples collected in July 1990 and barley leaf samples collected in May 1991 infected with each BYDV strain.

| Region | Host plant | Sampling date | % of samples with BYDV strain | | |
|---|---|---|---|---|---|
| | | | RPV | PAV | MAV |
| Dumfriesshire | | | | | |
| | Barley | July 1989 | 11 | 4 | 41 |
| | *P. annua* | July 1989 | 0 | 0 | 5 |
| | Barley | May 1990 | 8 | 24 | 24 |
| Wigtownshire | | | | | |
| | Barley | July 1989 | 0 | 0 | 5 |
| | *P. annua* | July 1989 | 7 | 7 | 80 |
| | Barley | May 1990 | 3 | 16 | 30 |
| Stirlingshire | | | | | |
| | Barley | July 1989 | 5 | 0 | 0 |
| | *P. annua* | July 1989 | 3 | 7 | 20 |
| | Barley | May 1990 | 2 | 22 | 42 |

**Table 46.** Numbers of aphids tested, number infective, total numbers caught in Tower Trap, and the weekly Infectivity Index at Auchincruive 1987.

| | Number of aphids | | | | | | |
|---|---|---|---|---|---|---|---|
| | Tested | | Infective | | Tower Trap catches | | |
| Week ending | R.p. | R.i. | R.p. | R.i. | R.p. | R.i. | Index |
| 30.8 | 4 | 8 | 0 | 0 | 34 | 37 | 0 |
| 6.9 | 27 | 5 | 3 | 1 | 24 | 15 | 6 |
| 13.9 | 30 | 7 | 4 | 1 | 16 | 3 | 3 |
| 20.9 | 23 | 3 | 0 | 1 | 258 | 119 | 40 |
| 27.9 | 18 | 0 | 1 | 0 | 33 | 73 | 2 |
| 4.10 | 38 | 30 | 2 | 3 | 1448 | 868 | 163 |
| 11.10 | 49 | 12 | 1 | 0 | 466 | 138 | 10 |
| 18.10 | 44 | 14 | 0 | 0 | 127 | 28 | 0 |
| 25.10 | 60 | 10 | 1 | 0 | 138 | 69 | 3 |
| 1.11 | 33 | 18 | 2 | 0 | 37 | 66 | 2 |
| 8.11 | 18 | 24 | 0 | 0 | 18 | 21 | 0 |

**Table 47.** Infectivity Index for *R. padi* and *R. insertum* at Auchincruive 1987.

| | | CUMULATIVE WEEKLY INDEX | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 30.8 | 6.9 | 13.9 | 20.9 | 27.9 | 4.10 | 11.10 | 18.10 | 25.10 | 1.11 |
| | 30.8 | 0 | 6 | 9 | 49 | 51 | 214 | 224 | 224 | 227 | 229 |
| | 6.9 | - | 6 | 9 | 49 | 51 | 214 | 224 | 224 | 227 | 229 |
| E | 13.9 | - | - | 3 | 43 | 45 | 208 | 218 | 218 | 221 | 223 |
| M | | | | | | | | | | | |
| E | 20.9 | - | - | - | 40 | 42 | 205 | 215 | 215 | 218 | 220 |
| R | | | | | | | | | | | |
| G | 27.9 | - | - | - | - | 2 | 165 | 175 | 175 | 178 | 180 |
| E | | | | | | | | | | | |
| N | 4.10 | - | - | - | - | - | 163 | 173 | 173 | 176 | 178 |
| C | | | | | | | | | | | |
| E | 11.10 | - | - | - | - | - | - | 10 | 10 | 13 | 15 |
| | | | | | | | | | | | |
| D | 18.10 | - | - | - | - | - | - | - | 0 | 3 | 5 |
| A | | | | | | | | | | | |
| T | 25.10 | - | - | - | - | - | - | - | - | 3 | 5 |
| E | | | | | | | | | | | |
| | 1.11 | - | - | - | - | - | - | - | - | - | 2 |
| | 8.11 | - | - | - | - | - | - | - | - | - | - |

**Table 48.** Numbers of aphids tested, number infective, total number caught in Tower Trap, and the weekly Infectivity Index at Auchincruive 1988.

| | Tower Trap catches | | |
|---|---|---|---|
| Week ending | R.p. | R.i. | Index |
| 2.9 | 12 | 17 | 12 |
| 9.9 | 69 | 5 | 5 |
| 16.9 | 46 | 143 | 7 |
| 23.9 | 167 | 248 | 35 |
| 30.9 | 156 | 176 | 8 |
| 7.10 | 247 | 355 | 18 |
| 14.10 | 679 | 443 | 25 |
| 21.10 | 639 | 583 | 12 |
| 28.10 | 133 | 165 | 0 |
| 4.11 | 18 | 17 | 0 |

**Table 49.** Infectivity Index for *R. padi* and *S. insertum* at Auchincruive 1988.

| | | CUMULATIVE WEEKLY INDEX | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.9 | 9.9 | 16.9 | 23.9 | 30.9 | 7.10 | 14.10 | 21.10 | 28.10 | 4.11 | 11.1 |
| | 2.9 | 12 | 17 | 23 | 58 | 66 | 84 | 109 | 121 | 121 | 121 | 121 |
| | 9.9 | - | 5 | 11 | 46 | 54 | 72 | 97 | 109 | 109 | 109 | 109 |
| E | 16.9 | - | - | 6 | 41 | 49 | 67 | 92 | 104 | 104 | 104 | 104 |
| M | | | | | | | | | | | | |
| E | 23.9 | - | - | - | 35 | 43 | 61 | 86 | 98 | 98 | 98 | 98 |
| R | | | | | | | | | | | | |
| G | 30.9 | - | - | - | - | 8 | 26 | 51 | 63 | 63 | 63 | 63 |
| E | | | | | | | | | | | | |
| N | 7.10 | - | - | - | - | - | 18 | 43 | 55 | 55 | 55 | 55 |
| C | | | | | | | | | | | | |
| E | 14.10 | - | - | - | - | - | - | 25 | 37 | 37 | 37 | 37 |
| D | 21.10 | - | - | - | - | - | - | - | 12 | 12 | 12 | 12 |
| A | | | | | | | | | | | | |
| T | 28.10 | - | - | - | - | - | - | - | - | 0 | 12 | 12 |
| E | | | | | | | | | | | | |
| | 4.11 | - | - | - | - | - | - | - | - | - | - | 12 |
| | 11.11 | - | - | - | - | - | - | - | - | - | - | - |

**Table 50.** Aphid trapping and infectivity data used to calculate the Infectivity Index at Auchincruive in autumn 1989.

| | No. of *R. padi* | | No. of *R. insertum* | |
|---|---|---|---|---|
| Week ending | Tower | Index | Tower | Index |
| 10 September | 13 | 13 | 33 | - |
| 17 September | 19 | - | 53 | - |
| 24 September | 93 | 0 | 440 | 73 |
| 1 October | 84 | 0 | 180 | 0 |
| 8 October | 31 | 16 | 134 | 27 |
| 15 October | 1 | 0 | 78 | 26 |
| 22 October | 10 | 0 | 63 | 21 |

**Table 51.** Infectivity Index - *Rhopalosiphum padi* only - Auchincruive 1989.

| | | CUMULATIVE WEEKLY INDEX | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10.9 | 17.9 | 24.9 | 1.10 | 8.10 | 15.10 | 22.10 |
| | 10.9 | 13 | 13 | 13 | 13 | 29 | 29 | 29 |
| E | 17.9 | | 0 | 0 | 0 | 16 | 16 | 16 |
| M | | | | | | | | |
| E | 24.9 | | | 0 | 0 | 16 | 16 | 16 |
| R | | | | | | | | |
| G | 1.10 | | | | 0 | 16 | 16 | 16 |
| E | | | | | | | | |
| N | 8.10 | | | | | 16 | 16 | 16 |
| C | | | | | | | | |
| E | 15.10 | | | | | | 0 | 0 |
| | 22.10 | | | | | | | 0 |

**Table 52.** Infectivity Index - *Rhopalosiphum* spp. - Auchincruive 1989.

| | | CUMULATIVE WEEKLY INDEX | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10.9 | 17.9 | 24.9 | 1.10 | 8.10 | 15.10 | 22.10 |
| | 10.9 | 13 | 13 | 86 | 86 | 129 | 155 | 176 |
| E | 17.9 | | 0 | 73 | 73 | 116 | 142 | 163 |
| M | | | | | | | | |
| E | 24.9 | | | 73 | 73 | 116 | 142 | 163 |
| R | | | | | | | | |
| G | 1.10 | | | | 0 | 43 | 69 | 90 |
| E | | | | | | | | |
| N | 8.10 | | | | | 43 | 69 | 90 |
| C | | | | | | | | |
| E | 15.10 | | | | | | 26 | 47 |
| | 22.10 | | | | | | | 21 |

**Table 53.** Aphid trapping and infectivity data used to calculate the Infectivity Index in 1990.

| | *Rhopalosiphum padi* numbers | | | | *Rhopalosiphum insertum* numbers | | | |
|---|---|---|---|---|---|---|---|---|
| Week ending | Tower | Commode | Infective | Index | Tower | Commode | Infective | Index |
| 26 August | 655 | - | - | - | 744 | - | - | - |
| 2 September | 188 | 2 | 0 | 0 | 122 | 1 | 0 | 0 |
| 9 September | 22 | 3 | 1 | 7 | 16 | 2 | 0 | 0 |
| 16 September | 120 | 5 | 0 | 0 | 82 | 5 | 1 | 16 |
| 23 September | 23 | 1 | 0 | 0 | 52 | 1 | 0 | 0 |
| 30 September | 301 | 8 | 2 | 75 | 369 | 10 | 1 | 37 |
| 7 October | 17 | 4 | 1 | 4 | 42 | 17 | 1 | 2 |
| 14 October | 161 | 13 | 1 | 12 | 308 | 15 | 4 | 82 |
| 21 October | 279 | 3 | 0 | 0 | 557 | 7 | 0 | 0 |
| 28 October | 156 | 22 | 6 | 43 | 117 | 35 | 7 | 23 |
| 4 November | 25 | 1 | 1 | 25 | 12 | 1 | 1 | 12 |

**Table 54.** Infectivity Index based on species of *Rhopalosiphum* identified as either *padi* or *insertum* - Ayr 1990.

| | | CUMULATIVE WEEKLY INDEX | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.9 | 9.9 | 16.9 | 23.9 | 30.9 | 7.10 | 14.10 | 21.10 | 28.10 | 4.11 |
| EMERGENCE | 2.9 | 0 | 7 | 23 | 23 | 135 | 141 | 235 | 235 | 301 | 338 |
| | 9.9 | | 7 | 23 | 23 | 135 | 141 | 235 | 235 | 301 | 338 |
| | 16.9 | | | 16 | 16 | 128 | 134 | 227 | 227 | 293 | 330 |
| | 23.9 | | | | 0 | 128 | 134 | 227 | 227 | 293 | 330 |
| | 30.9 | | | | | 112 | 118 | 212 | 212 | 278 | 315 |
| | 7.10 | | | | | | 6 | 100 | 100 | 166 | 203 |
| | 14.10 | | | | | | | 94 | 94 | 166 | 203 |
| | 21.10 | | | | | | | | 0 | 66 | 103 |
| | 28.10 | | | | | | | | | 66 | 103 |
| | 4.11 | | | | | | | | | | 37 |

**Table 55.** Numbers of aphids tested, number infective, total number caught in Tower Trap at Belfast, 1988.

| | Number of aphids | | | | | | |
|---|---|---|---|---|---|---|---|
| | Tested | | Infective | | Tower Trap catches | | |
| Week ending | R.p. | R.i. | R.p. | R.i. | R.p. | R.i. | Index |
| 2.9 | 1 | 0 | 0 | 0 | 40 | 18 | 0 |
| 9.9 | 5 | 2 | 0 | 1 | 305 | 153 | 77 |
| 16.9 | 4 | 11 | 4 | 8 | 557 | 256 | 744 |
| 23.9 | 14 | 4 | 8 | 3 | 1109 | 434 | 958 |
| 30.9 | 28 | 6 | 7 | 2 | 952 | 502 | 404 |
| 7.10 | 18 | 5 | 3 | 1 | 402 | 290 | 126 |
| 14.10 | 7 | 7 | 1 | 1 | 453 | 868 | 185 |
| 21.10 | 7 | 16 | 2 | 6 | 200 | 563 | 272 |
| 28.10 | 5 | 22 | 3 | 12 | 96 | 305 | 226 |
| 4.11 | 2 | 20 | 0 | 8 | 15 | 34 | 14 |
| 1.11 | 2 | 5 | 0 | 2 | 7 | 17 | 7 |

**Table 56.** Infectivity Index for *R. padi* and *R. insertum* at Belfast 1988.

| | | CUMULATIVE WEEKLY INDEX | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.9 | 9.9 | 16.9 | 23.9 | 30.9 | 7.10 | 14.10 | 21.10 | 28.10 | 4.11 | 11.11 |
| | 2.9 | 0 | 77 | 821 | 1779 | 2183 | 2309 | 2494 | 2766 | 2992 | 3066 | 3013 |
| | 9.9 | 0 | 77 | 821 | 1779 | 2183 | 2309 | 2494 | 2766 | 2992 | 3066 | 3013 |
| EMERGENCE DATE | 16.9 | - | - | 744 | 1702 | 2106 | 2232 | 2417 | 2689 | 2915 | 2929 | 2936 |
| | 23.9 | - | - | - | 958 | 1362 | 1488 | 1673 | 1945 | 2171 | 2185 | 2192 |
| | 30.9 | - | - | - | - | 404 | 530 | 715 | 987 | 1213 | 1227 | 1234 |
| | 7.10 | - | - | - | - | - | 126 | 311 | 583 | 809 | 823 | 830 |
| | 14.10 | - | - | - | - | - | - | 185 | 457 | 683 | 697 | 704 |
| | 21.10 | - | - | - | - | - | - | - | 272 | 498 | 512 | 519 |
| | 28.10 | - | - | - | - | - | - | - | - | 226 | 240 | 247 |
| | 4.11 | - | - | - | - | - | - | - | - | - | 14 | 21 |
| | 11.11 | - | - | - | - | - | - | - | - | - | - | 7 |

**Table 57.** Aphid trapping and infectivity data used to calculate the Infectivity Index at Belfast, 1989.

| | No. of *R. padi* | | No. of *R. insertum* | |
|---|---|---|---|---|
| Week ending | Tower | Index | Tower | Index |
| 2 September | 0 | 0 | 0 | 0 |
| 9 September | 0 | 0 | 0 | 0 |
| 16 September | 15 | 0 | 24 | 0 |
| 23 September | 25 | 0 | 31 | 0 |
| 30 September | 37 | 0 | 31 | 4 |
| 7 October | 85 | 26 | 47 | 0 |
| 14 October | 41 | 0 | 23 | 6 |
| 21 October | 20 | 3 | 9 | 6 |
| 28 October | 10 | 0 | 10 | 0 |
| 4 November | 12 | 6 | 3 | 0 |

**Table 58.** Infectivity Index - *Rhopalosiphum padi* only - Belfast 1989.

| | | CUMULATIVE WEEKLY INDEX | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.9 | 9.9 | 16.9 | 23.9 | 30.9 | 7.10 | 14.10 | 21.10 | 28.10 | 4.11 |
| E | 2.9 | 0 | 0 | 0 | 0 | 0 | 26 | 26 | 28 | 28 | 34 |
| M | 9.9 | | 0 | 0 | 0 | 0 | 26 | 26 | 28 | 28 | 34 |
| E | 16.9 | | | 0 | 0 | 0 | 26 | 26 | 28 | 28 | 34 |
| R | 23.9 | | | | 0 | 0 | 26 | 26 | 28 | 28 | 34 |
| G | 30.9 | | | | | 0 | 26 | 26 | 28 | 28 | 34 |
| E | 7.10 | | | | | | 26 | 26 | 28 | 28 | 34 |
| N | 14.10 | | | | | | | 0 | 3 | 3 | 9 |
| C | 21.10 | | | | | | | | 3 | 3 | 6 |
| E | 28.10 | | | | | | | | | 0 | 6 |

**Table 59.** Infectivity Index - *Rhopalosiphum* spp. - Belfast 1989.

| | CUMULATIVE WEEKLY INDEX | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2.9 | 9.9 | 16.9 | 23.9 | 30.9 | 7.10 | 14.10 | 21.10 | 28.10 | 4.11 |
| 2.9 | 0 | 0 | 0 | 0 | 4 | 29 | 35 | 44 | 44 | 50 |
| 9.9 | | 0 | 0 | 0 | 4 | 29 | 35 | 44 | 44 | 50 |
| 16.9 | | | 0 | 0 | 4 | 29 | 35 | 44 | 44 | 50 |
| 23.9 | | | | 0 | 4 | 29 | 35 | 44 | 44 | 50 |
| 30.9 | | | | | 4 | 29 | 35 | 44 | 44 | 50 |
| 7.10 | | | | | | 26 | 31 | 40 | 40 | 46 |
| 14.10 | | | | | | | 6 | 15 | 15 | 21 |
| 21.10 | | | | | | | | 9 | 9 | 15 |
| 28.10 | | | | | | | | | 0 | 6 |
| 4.11 | | | | | | | | | | 6 |

**Table 60.** Aphid trapping and infectivity data used to calculate the Infectivity Index at Belfast, 1990.

| | No. of *R. padi* | | No. of *R. insertum* | |
|---|---|---|---|---|
| Week ending | Tower | Index | Tower | Index |
| 2 September | 111 | 0 | 76 | 0 |
| 9 September | 122 | 40 | 82 | 0 |
| 16 September | 104 | 23 | 96 | 28 |
| 23 September | 103 | 0 | 77 | 0 |
| 30 September | 662 | 63 | 285 | 20 |
| 7 October | 130 | 19 | 73 | 0 |
| 14 October | 495 | 38 | 215 | 60 |
| 21 October | 473 | 0 | 118 | 0 |
| 28 October | 288 | 12 | 66 | 0 |
| 4 November | 11 | 3 | 5 | 0 |
| 11 November | 14 | 0 | 5 | 0 |
| 18 November | 7 | 0 | 1 | 0 |

**Table 61.** Infectivity Index for *R. padi* and *R. insertum* at Belfast 1990.

| | CUMULATIVE WEEKLY INDEX | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2.9 | 9.9 | 16.9 | 23.9 | 30.9 | 7.10 | 14.10 | 21.10 | 28.10 | 4.11 | 11.11 |
| 2.9 | 0 | 40 | 91 | 91 | 174 | 193 | 290 | 290 | 303 | 306 | 306 |
| 9.9 | | 40 | 91 | 91 | 174 | 193 | 290 | 290 | 303 | 306 | 306 |
| 16.9 | | | 51 | 51 | 134 | 152 | 250 | 250 | 262 | 265 | 265 |
| 23.9 | | | | 0 | 83 | 102 | 199 | 199 | 212 | 214 | 214 |
| 30.9 | | | | | 83 | 102 | 199 | 199 | 212 | 214 | 214 |
| 7.10 | | | | | | 19 | 116 | 116 | 129 | 131 | 131 |
| 14.10 | | | | | | | 98 | 98 | 110 | 113 | 113 |
| 21.10 | | | | | | | | 0 | 12 | 15 | 15 |
| 28.10 | | | | | | | | | 12 | 15 | 15 |
| 4.11 | | | | | | | | | | 3 | 3 |
| 11.11 | | | | | | | | | | | 0 |

**Table 62.** Incidence of strains of BYDV in ryegrass crops in the west of Scotland, March to August 1988.

| Area | Number of samples | Strains of BYDV | | | |
|---|---|---|---|---|---|
| | | RPV | PAV | MAV | Total |
| Ayrshire | 125 | 68 | 19 | 14 | 101 |
| Dumfries | 100 | 17 | 6 | 14 | 37 |
| Stirling | 100 | 45 | 37 | 22 | 104 |
| Wigtown | 100 | 48 | 17 | 3 | 68 |
| Total | 425 | 178 | 79 | 53 | |
| | % | 42 | 19 | 12 | |

**Table 63.** The incidence of BYDV strains in ryegrass fields in the west of Scotland.

| Strain | % fields examined | % fields with particular strain alone or in combination |
|---|---|---|
| RPV | 6 | 82 |
| PAV | 0 | 65 |
| MAV | 12 | 77 |
| RPV/PAV | 12 | |
| RPV/MAV | 12 | |
| PAV/MAV | 0 | |
| RPV/PAV/MAV | 53 | |
| NONE | 6 | |