BPC Final Report 1997-2002
Aphid monitoring as a management tool in seed production

(Incorporating projects 807/174 (1997-1999) and 807/216 (2000-2002)

Introduction

DEFRA funded disease survey work has indicated that *Potato virus Y* (PVY) remains the predominant virus disease of potatoes in the UK. The other principal viruses, *Potato leaf roll virus* and *Potato virus X* have occurred at much lower incidence, presumably being controlled by effective insecticide regimes and certification schemes respectively. The Central Science Laboratory (CSL) offers an aphid monitoring service to determine migrant aphid pressure on individual seed crops. CSL, along with Cambridge University Farm (CUF) have been undertaking BPC funded work to establish the relationships between aphid pressure and the likelihood or risk of subsequent spread of PVY in those seed crops. In addition, work was started in 2000 to determine whether aphid monitoring could be used as a guide to inform insecticide application schedules. This latter work reflects concern over increasing use of insecticides in seed crops, including years thought to be low risk.

Further monitoring work was carried out in 2000/2001 to build on the existing data set derived from a run of low aphid/virus years (1997-1999). Aphid monitoring data was collected from four ware sites in Yorkshire and five (2000), four (2001) in Cambridgeshire (CUF) (all grown from certified seed of PVY susceptible varieties) and part of a DEFRA funded Potato Disease Survey until 2000). The data comprised tuber indexing to determine in crop virus levels at planting and at harvest; aphid monitoring via in-crop yellow water traps with resultant aphid counts and aphid identification (predicts ability to transmit PVY) carried out at CSL.

Additionally, aphid monitoring data was collected from commercial seed sites, and in-crop colony counts were carried out at all ware sites to provide further aphid population data with which to assess the relationship between aphid/virus(vector) pressure and virus multiplication rates during the growing season and to start to investigate the relationship between water trap data and colonising aphids within the crop.

Experimental work on spread of PVY and mature plant resistance was carried out at CUF. Four experiments were carried out in the period 1998-2001 which examined the transmission of PVY within a crop in relation to the local incidence of infection. Further experiments to examine mature plant resistance to PVY comprised natural infection or the comparison of inoculation with mechanical methods and cultured aphids. This work was undertaken to provide a further level of refinement to place on the interpretation of virus vector indices.

For clarity, aphid monitoring data (CUF/CSL) collated by CSL, are given in Part A. CUF data on spread of PVY and mature plant resistance is given in Part B.

PART A

Materials and Methods

Colonising aphid count procedure

Colonising aphid counts were conducted weekly through the growing season .An in-crop colony count procedure to obtain colonising aphid data was carried out as follows at each of the 9 ware sites: In each crop 105 leaves (a top, middle and lower leaf) from 35 separate plants were examined for the presence of aphid colonies. A colony is defined as a leaflet containing 3 or more aphids of which at least 2 are wingless (apterae). This identifies the aphids as potato aphids of a species which will feed and develop on potatoes. This definition and procedure was supplied by Dr John Pickup, SASA and is consistent with that used in the SERAD seed crop monitoring scheme. The use of this protocol should allow comparisons to be made with the SASA/SERAD databases. It is also suitable for staff with no formal or extensive training in aphid identification and could be carried out by growers. Additionally at the pesticide efficacy site in N.Yorkshire, colonising aphid counts for each treated /untreated plot were carried out.

Aphid Monitoring

Water traps for aphid collection (Nickerson Bros) were placed at 20, 50 and 80m from the headland in each of the 9 trial ware sites. Traps were emptied weekly for aphid identification throughout the growing season from emergence in May 2000 until crop destruction. The entire contents of each trap were collected in muslin and trap water disposed of via a funnel. The sample wrapped in muslin was then placed in an individual screw top container and labelled with the site designation and trap position relative to the headland. Traps were re-filled with water and a little detergent to break surface tension. Trap aphid content for all 9 ware sites was subsequently identified at CSL and a weekly record produced detailing numbers of PVY vectors and non-vectors in each trap. Data was also analysed from a number of other seed sites which are part of the commercial aphid monitoring service.
The aphid species, which have been shown to transmit PVY, were given an efficiency rating based on their published ability to transmit the virus. *Myzus persicae* is the most efficient vector with an efficiency index of 1.0; other vectors (with efficiencies relative to *M. persicae*) include *Acyrthosiphon pisum* (0.7), *Rhopalosiphum padi* (0.4), *Aphis nasturtii/frangulae* (0.4), *Metopolophium dirhodum* (0.3), all other vectors have efficiencies ≤ 0.2. The cumulative and weekly vector indices were calculated and sent to growers to aid any decisions on the timing or need to defoliate the crop in relation to the risk of PVY transmission.

Virus Monitoring In Tubers

For each of the 9 ware sites virus levels were monitored at planting and post-harvest at ADAS Wolverhampton (2000) / CSL (2001), by growing on single sprouts taken

from each tuber of a one hundred tuber sample collected by ADAS or CSL staff. Testing of the resultant foliage was carried out by ELISA/ visual inspection to confirm presence of PLRV & PVY/severe mosaic virus. The grown-on samples were also further monitored for any growth abnormalities. Information on virus levels at planting and post-harvest were also obtained by CUF from some of the participating seed growers who collect this valuable information .

Insecticide Efficacy Trial 2000

A pesticide efficacy trial was conducted in 2000 on a commercial ware site near Market Weighton. The effect of varying numbers and timing of insecticide applications were assessed on numbers of colonising aphids and spread of PVY. A tuber sample from the crop at planting revealed no detectable levels of PVY and so infected tubers were planted amongst the centre rows of each crop, to give a starting virus level of approximately 1%. Colonising aphids were monitored as above for each plot every 2 weeks. A 100 tuber sample was also taken from each plot at an approximate seed harvest date and assessed for PVY incidence. The insecticide used was "Dovetail" applied at 1.5 l/ha in 500 l/ha water . Maximum per ha label application rates were not exceeded. Sprays commenced at 50% emergence. Plots consisted 15m in length and 4 rows in width and a randomised block design was chosen for the experiment.

Insecticide Efficacy Trial 2001

A pesticide efficacy trial was conducted in 2001 on a commercial ware site at Garton, N. Yorkshire. The effect of varying numbers and timing of insecticide applications were assessed on numbers of colonising aphids and spread of PVY. Virus levels at the start and end of the growing season were recorded from ELISA data derived from growing on tests of 100 tuber samples. Colonising aphids were monitored as previously described weekly. Insecticides used were “Dovetail” applied at 1.5 l/ha , “Plenum” applied at 0.6kg/ha, and “Hallmark” applied at 150ml/ha. All in 500 l/ha water. See experimental design (Appendix). Maximum per ha label application rates were not exceeded. Sprays commenced at 50% emergence. Plots consisted 15m in length and 4 rows in width and a randomised block design was chosen for the experiment.

Results

Aphid Monitoring: By analysing the data generated during this project at three levels of resolution we can attain an overview of the distribution of aphids arriving into potato crops between regions, between sites in close proximity and between traps within fields. Investigating the aphid distributions on these three levels should allow us to comment on the potential risk of PVY spread associated with the seed potato production in the various regions and also on the validity of our trapping methods in comparison to (for example) the Rothamsted Insect Survey (RIS) suction trap network.

Regional Distribution of Aphids

The data has been separated on a crude regional level into Scotland, North and South (Figure 1) to investigate the timing of the aphid flights, the numbers of aphids

captured per trap in each region and how the mean cumulative vector pressure varies between regions.

Figure 2 shows the distribution of sites across the UK over the last two years. Throughout the period of this project, the number of sites in the scheme has increased year on year and most of the participants stay within the scheme each year once they have joined. This shows that the service is of increasing interest to potato growers and that the results provided are found to be of use.

Figure 1: Map showing imposed regional boundaries.

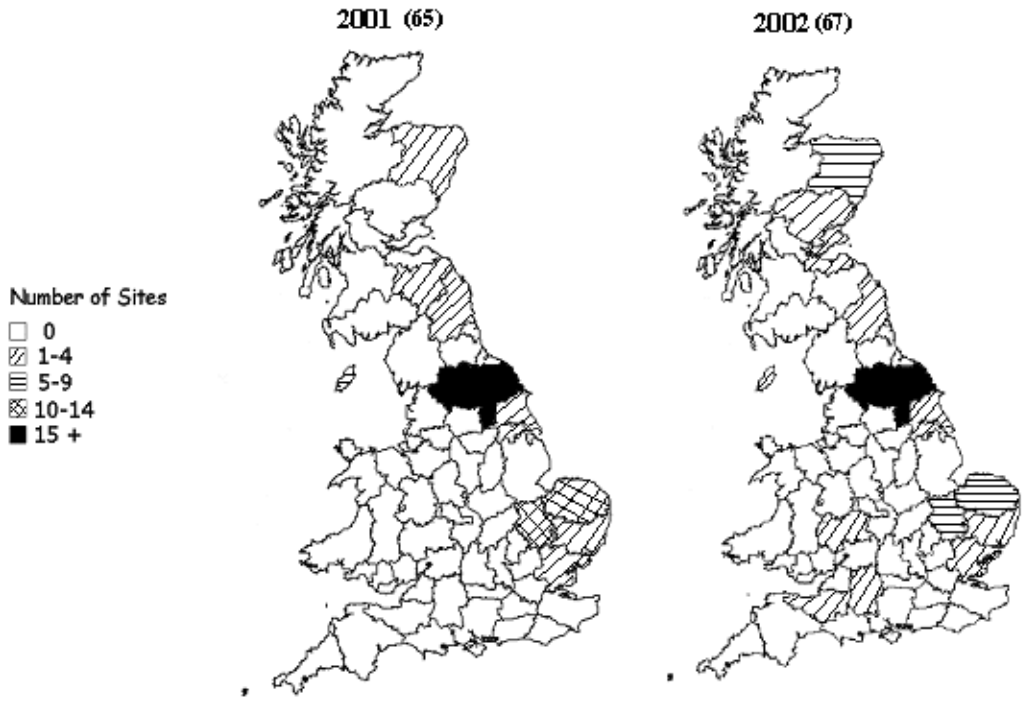


Figure 2: Maps showing site distribution

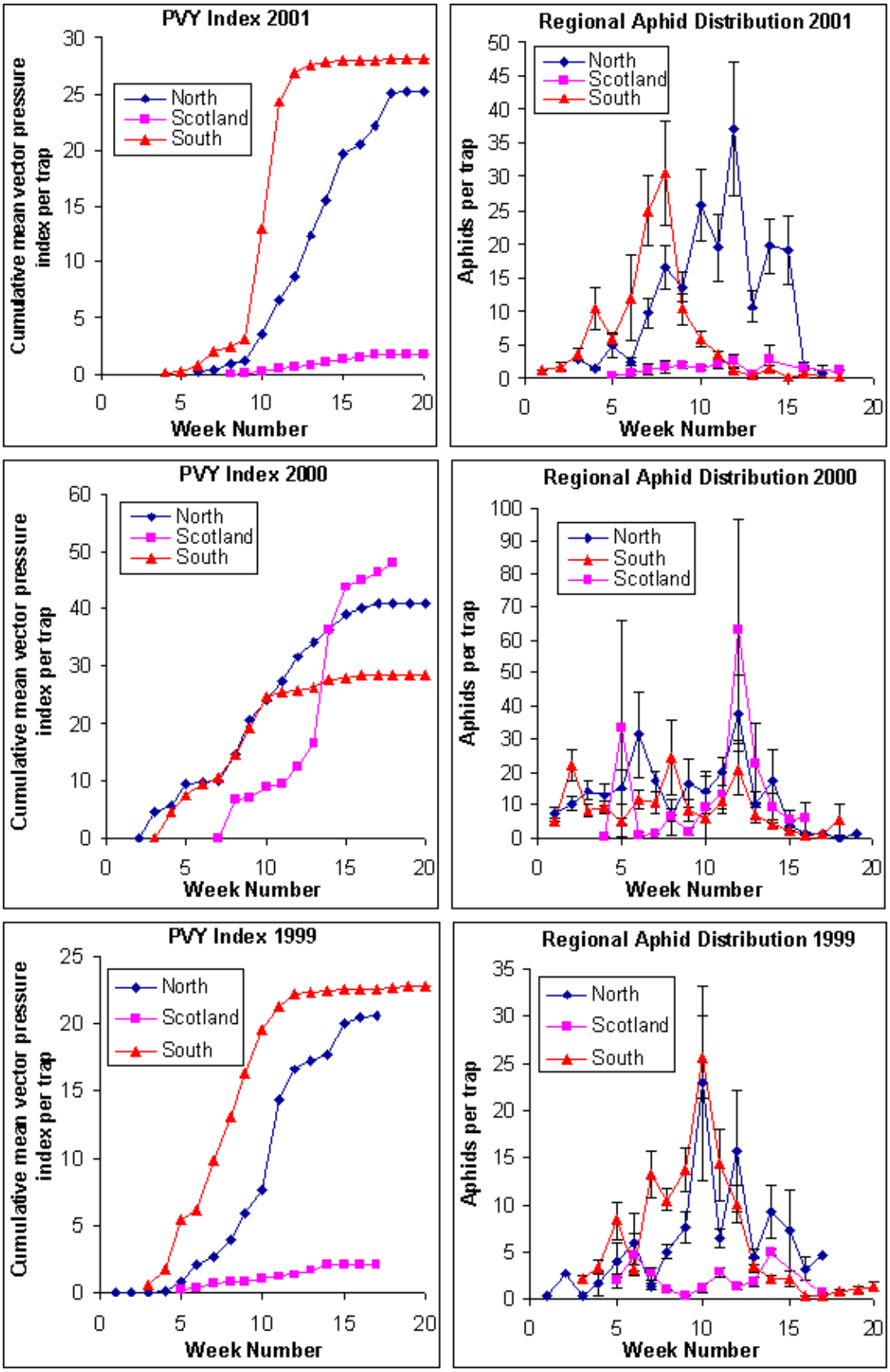


Figure 3: Regional Cumulative PVY vector pressure index and aphid distribution, 1999 – 2001.

Figure 3 shows the cumulative PVY vector pressure index and the distribution of aphids across the three regions for 1999 – 2001. These distributions are similar for 1999 and 2001 with greater numbers of aphids earlier in the season in the South and comparatively low numbers in Scotland. This is reflected in the higher PVY vector pressure indices for the South and the North. This was also seen in 1997 and 1998 with the South having larger aphid numbers and indices than the North however, the total number of sites was much lower, and there were none in Scotland so the data is less reliable than that from the later years of the project.

In all years except for 2000 large aphid flights occurred earlier in the South than in the North (though the peak numbers were similar) and in Scotland (1999 and 2001) there was not much variation throughout the year.

In 2000 the results were almost reversed, with Scotland having the highest final cumulative PVY vector pressure index followed by the North and then the South. The final vector pressure in the South was similar to 2001 and 1999, but it was greatly increased in the North and Scotland.

These results should be treated cautiously, as the sites are not the same from year to year, and it is likely that the sites (particularly in Scotland due low numbers) are not truly representative of the whole regions potato crops.

Local Distribution of Aphids (between sites in a region)

A group of seed potato growers (Yorkshire Highland Seed Potato Growers Association Ltd) on the Yorkshire Wolds became involved in the scheme in 2001 and decided to pool their aphid monitoring data. Figure 4 shows how the traps were distributed across the area. The data generated from these sites gave us an opportunity to compare aphid numbers and PVY vector pressure index between sites that are relatively close together.

Geostatistical analysis of the data found that there was no statistical relationship between aphid numbers trapped and distance between traps or between aphid numbers trapped and altitude (i.e. two traps within a few km of each other or at a similar altitude were no more likely to have a similar amount of aphids in the trap as two traps 50 km apart). This means that we are unable to predict the number of aphids found in a particular trap and thus fields without traps, by looking at traps close by or at the same altitude any better that those further away or at different altitudes.

Figure 5 illustrates how sites within five kilometres of each other can get big differences in the number of aphids in their traps in the same week. Although there are obvious differences between the numbers being captured the overall trend of many of the traps in the region were the same, for example traps 3 and 4 (top left of figure 5) have peaks in the same week. There were exceptions to this trend in the sites on the wolds.

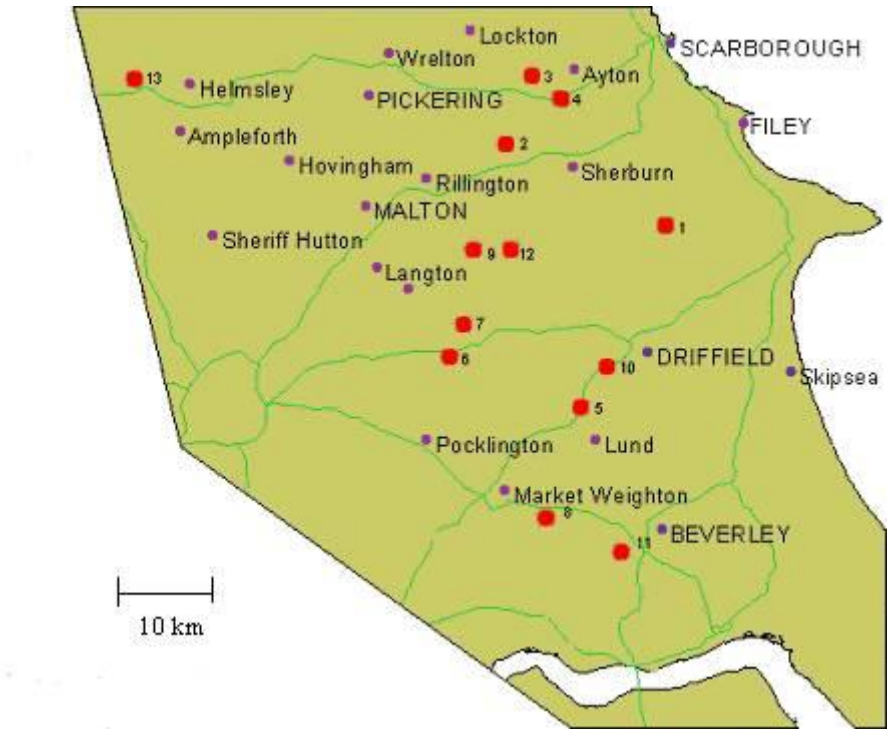


Figure 4: Distribution of the monitoring sites on the Yorkshire Wolds for 2001.

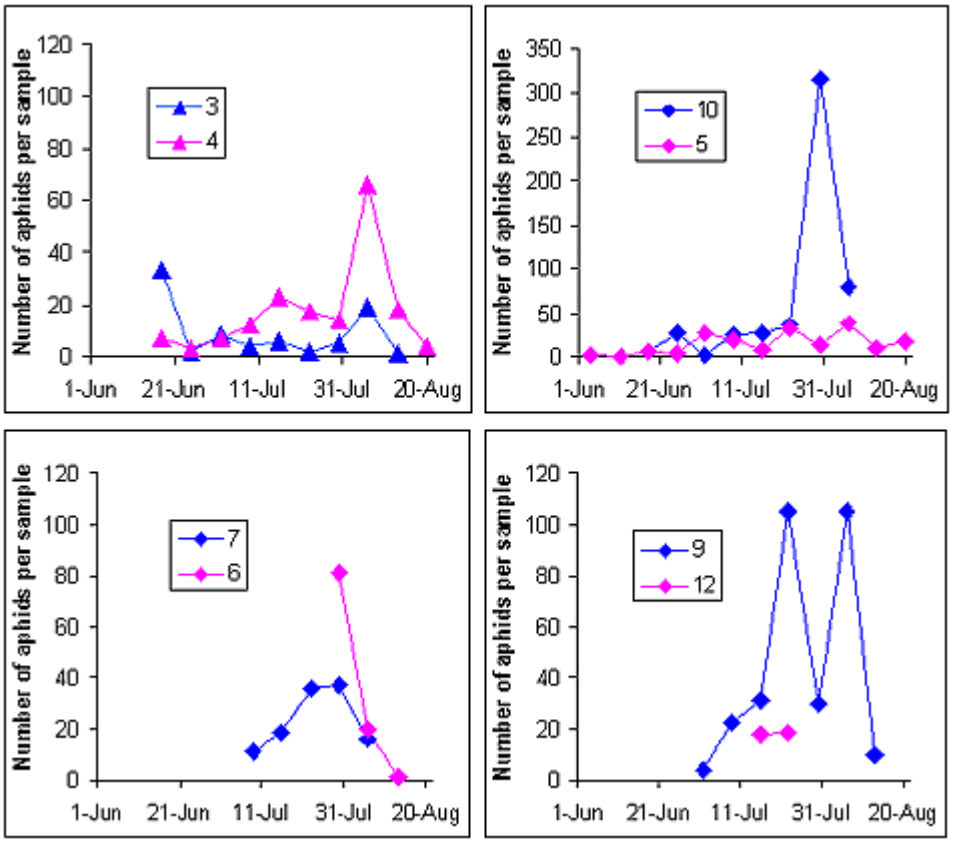


Figure 5: Comparison of traps within 5km of each other (numbers refer to site numbers of figure 4.

Figure 6 gives an example of a single site in the Southern region that has had a trap in a different field each year. This shows the variability in the timing and size of the vector aphid flights in the area across years. In 2000 and 2001 the main increase in vector pressure started at the same time, yet had a difference in size and duration. In 2002, the main increase came in the very first week of trapping, with only a slow rise from then on.

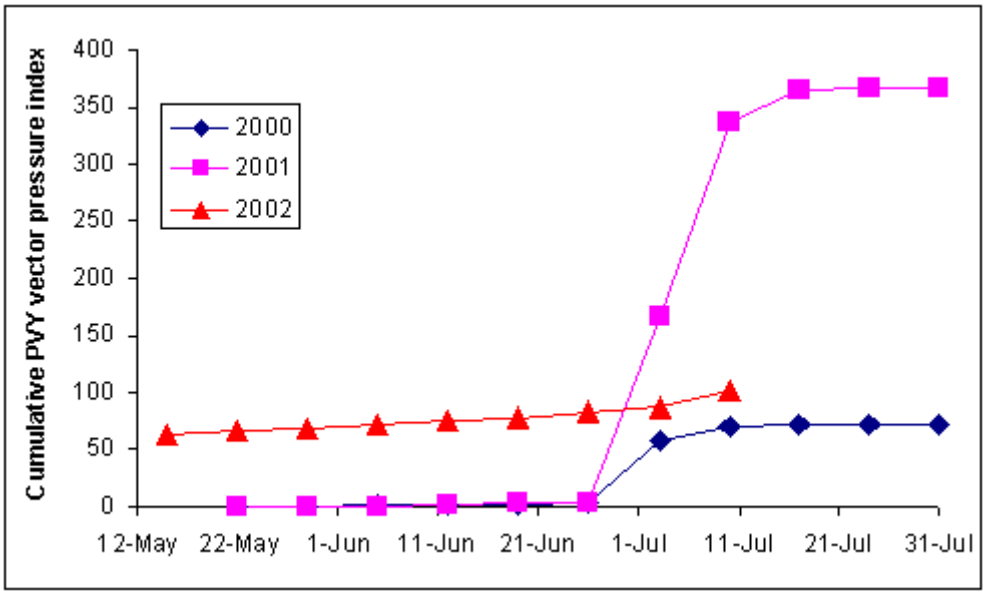


Figure 6: PVY vector pressure index in different fields at one site over 3 years

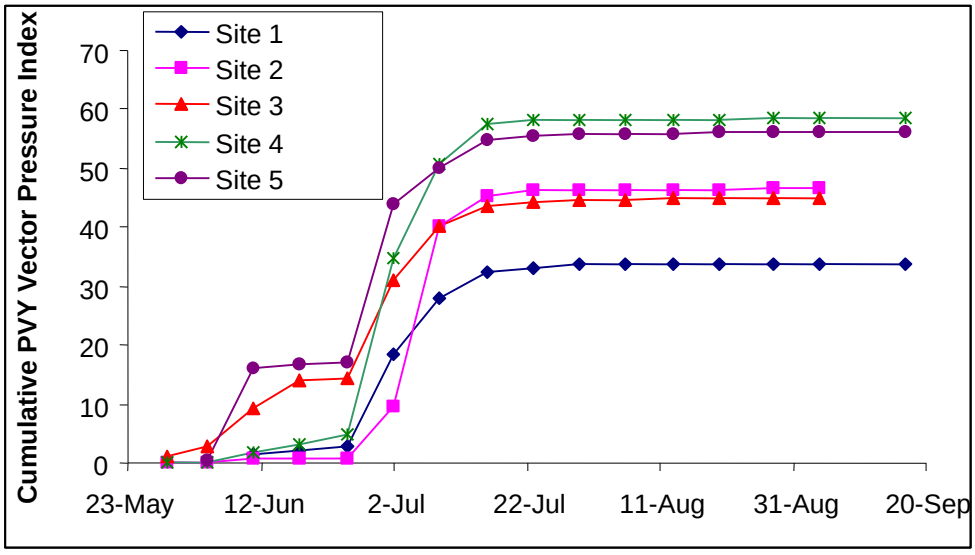


Figure 7: BPC funded traps (Southern Region) run by Cambridge University Farms 2001

Figures 7 and 8 show the vector pressure indices for the BPC funded traps in the 2001 growing season. These both reinforce the data from the Wolds growers (Figure 5) that although sites within the same general area are likely to have a similar trend in the timing of their vector pressure increases, the magnitude of these increases (and hence risk of PVY spread) can vary considerably.

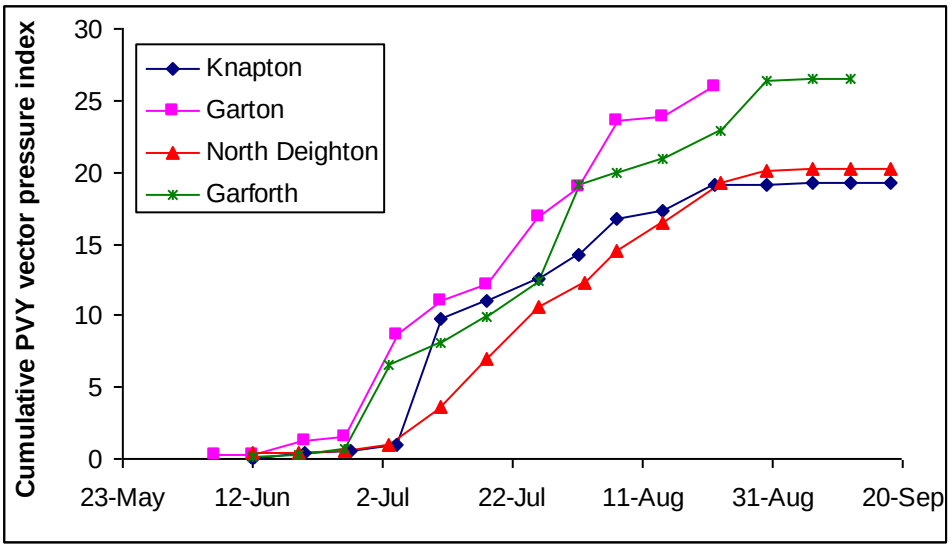


Figure 8: BPC funded traps (Northern Region) run by Central Science Laboratory, 2001

Local Distribution of Aphids (within sites)

Analysis of the trap catches from sites with three traps show that there are significant differences (p=0.009; df=2,32; f=5.02) in the number of aphids that are trapped.

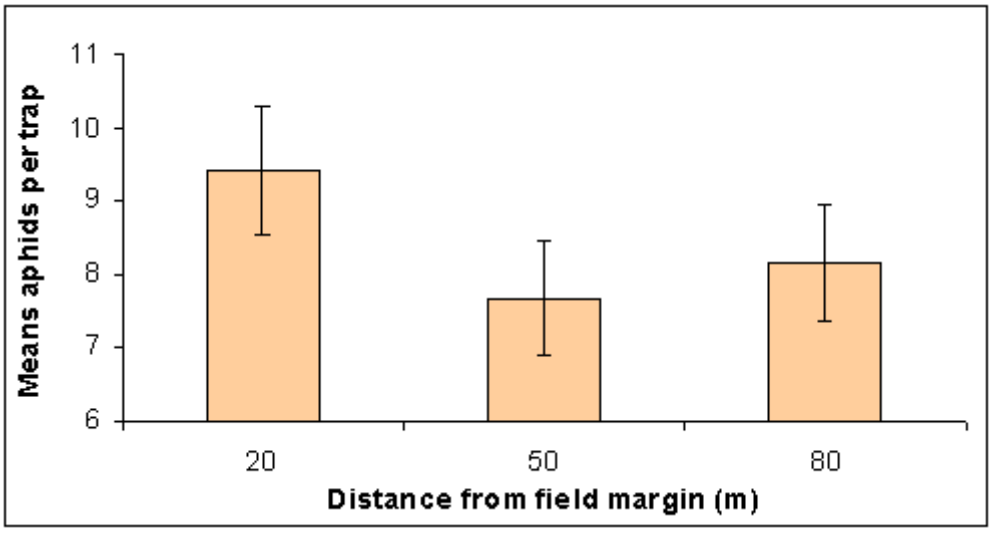


Figure 9: Comparison of the aphids caught within fields. (Bars are 2 standard errors)

Figure 9 shows that, on average, traps placed 20 metres into the crop catch the most aphids. The two traps further into the field are not significantly different from each other.

Aphid Colonisation

Pesticide efficacy trials took place, the results of which are shown in figure 10 (2001). This shows that spray regimes 1&2 breached the 2nd week SASA threshold. Spray regimes 3&4 breached the first week SASA threshold and the remainder did not trigger the 1st week threshold. Spray regime 9 gave zero aphid tolerance.

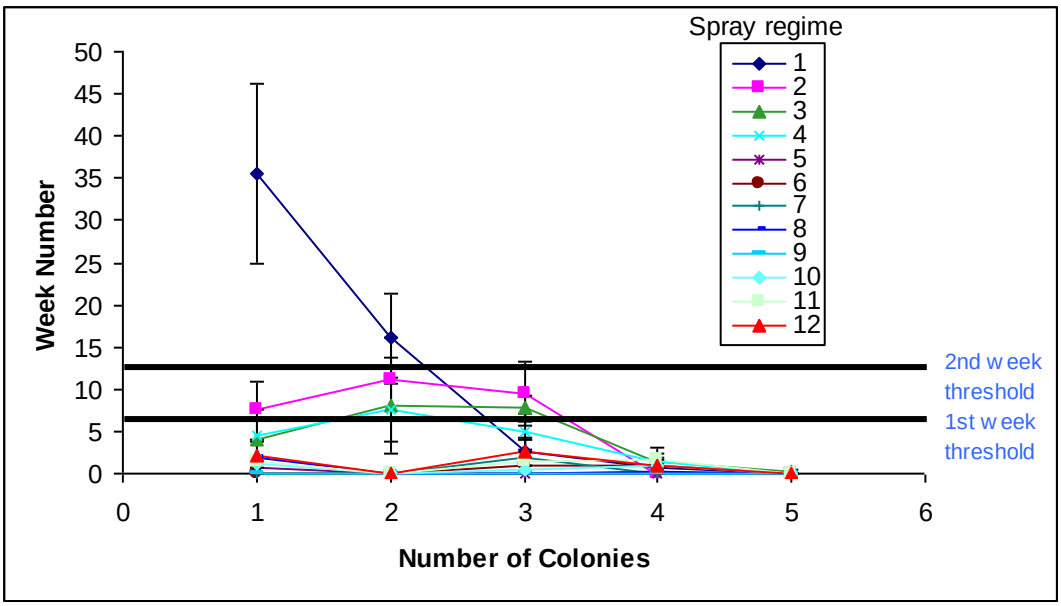


Figure 10: Aphid colony counts in plots with different insecticide spray regimes.

A pre-planting virus level of approximately 0.8% PVY per plot was recorded. No virus was detected in progeny tubers after harvest.

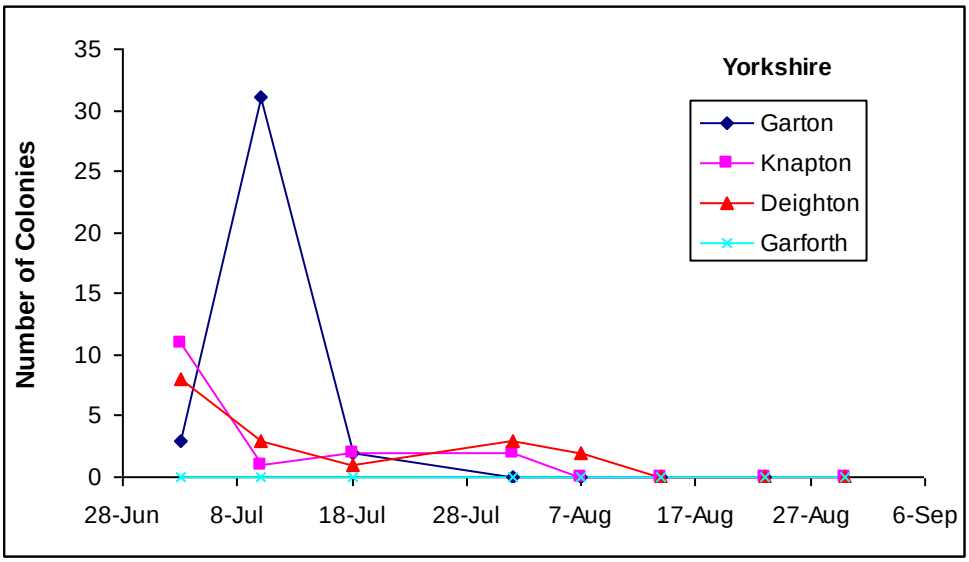


Figure 11: Aphid colony counts in Yorkshire ware crops 2001.

In Yorkshire (Fig 11), colonising aphids were detected in low numbers at all ware sites (except the most south westerly positioned site Garforth) from the beginning of July, and numbers decreased at these sites in August. Colonies were not found at any site post mid-August. 'Highest' numbers were recorded at the efficacy site (see also more detailed colony count data for efficacy site). The total number of aphid colony counts was slightly higher than in 2000 as well as distributed across a wider area (colonising aphids in only one site in 2000).

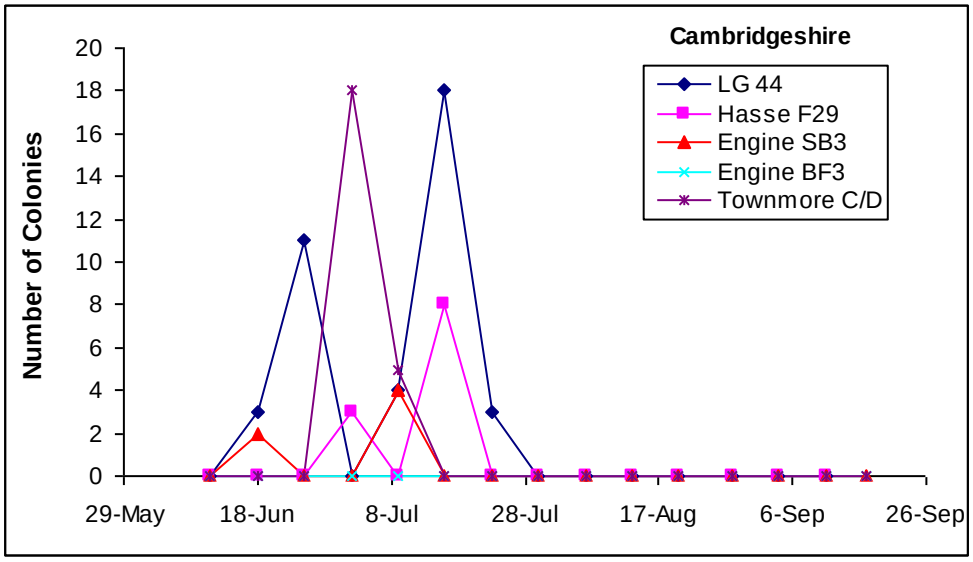


Figure 12: Aphid colony counts in Cambridgeshire ware crops

In Cambridgeshire (Fig 12), colonising aphids were recorded from mid-June in low numbers at four of the five sites. The 'highest' numbers were recorded in July, and colonies were not found at any site from the last week of July onward. As in the

previous year the largest number of colonies in both regions was recorded in mid-July.

Investigations took place to see whether the number of aphid colonies in a field could be related to the number of colonising aphids caught in the traps. Regression analysis suggests that it is difficult to predict the number of colonies based solely on the trap catches. Other data (e.g. the dates these crops were sprayed) will have had an effect on colony numbers and we were unfortunately unable to ascertain the spray dates for these crops.

Virus Monitoring in Tubers and Final Trap Index Data

All data from those sites in the scheme that had their virus input and output measured have been analysed to see if the PVY vector pressure index is capable of predicting which sites are at risk from virus spread. Regression analysis was used for the current index, three alternative indices using different vector efficiency values and the current index after four weeks monitoring.

The results showed that only the current index after four weeks had a significant relationship ($p=0.005$, $f=8.234$, $R^2=0.102$) with the virus multiplication in the crop. This is not a particularly strong relationship and would most likely be strengthened by the inclusion of the trap data for the rest of the monitoring season but with a reduced index to take into account the onset of mature plant resistance and a more accurate measurement of virus incidence at planting. It is noticeable that little virus spread occurred in the absence of PVY vector pressure, which is encouraging.

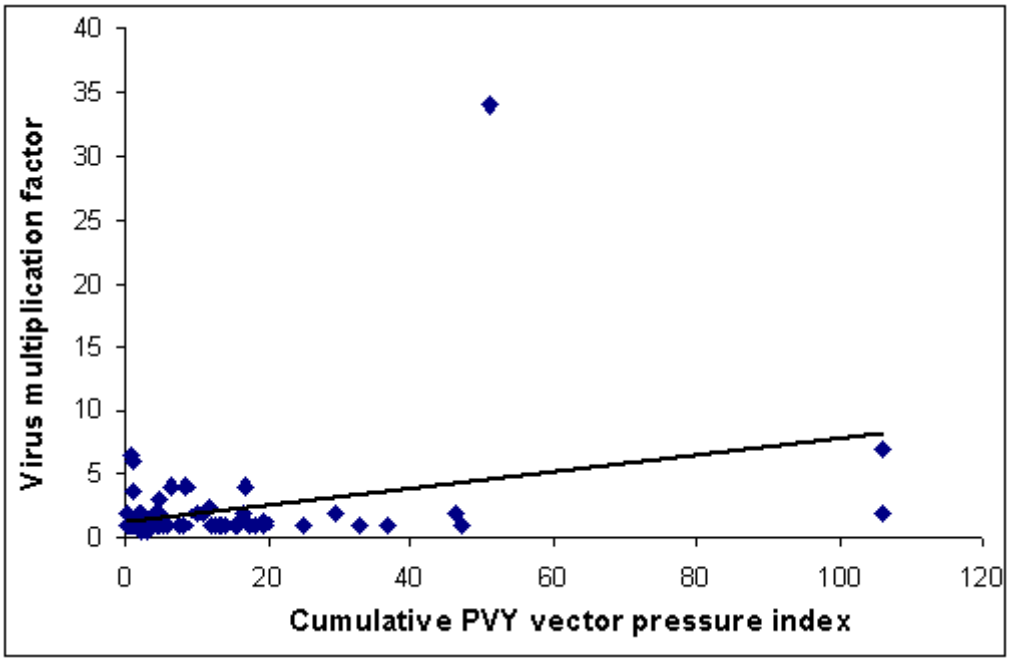


Figure 13: CSL index after 4 weeks as a predictor of virus multiplication

There are others factors that will also have an effect on virus spread, including pesticide application and varietal resistance. By incorporating more of these factors into the vector pressure index we would be able to produce a better assessment of the risk to a particular crop.

Summary of data (ware crops), 2000

Site	Virus In	Virus out	Final Aphid Index
00/3	0	1% PVA	91.81
00/10	0	1% PLRV	63.16
00/11	0	0	69.21
00/12	0	0	65.96
00/37	1% PLRV	13% severe mosaic	26.72
00/40	0	1% severe mosaic	81.79
00/41	0	1% severe mosaic	69.47
00/42	0	0	46.77
00/43	0	0	30.74

Commercial Seed Sites

Site	County	Virus In	Virus out	Final Aphid Index
K	Suffolk	0	0	12.1
F	Suffolk	0	1	15.13
H	Suffolk	0	0	8.45
T	Suffolk	-	0	57.13
C	Cambs	0	0	6.66
Si	Cambs	0	0	217.61
Ca	Cambs	0	0	97.45
S	Cambs	0	1	13.84
N	Wilts	-	0	136.55
M	Norfolk	0	0	18.35
R	Norfolk	0	0	19.2
Fo	Norfolk	0	1	51.75
Th	Norfolk	0	0	12.93
Whf	Norfolk	0	0	15.51

Recorded virus incidence at harvest was again very low for both the 9 ware sites and the seed sites presumably reflecting the very low input virus levels as well as the generally low virus vector indices. Zero PVY levels were also found in the control (unsprayed) plots in the2000 insecticide efficacy trial and the remaining plots were thus not tested. Numbers of colonising aphids in the 2000 insecticide efficacy trial plots were also too low over the monitoring period to produce meaningful statistical data.

Discussion

Analysis of the distribution of aphids and the cumulative PVY vector pressure during this project between the 3 imposed regions points to a general trend where there is greater risk of PVY infection in the South than the North and least risk in Scotland. This reflects the historical distribution of GB seed potato growing. However, the data from 2000 shows that this trend is not uniform between years and that in certain conditions large flights of aphids can threaten crops right across Great Britain. This conclusion, coupled with an inability to accurately predict which years are going to be bad years, reinforces the need for seed potato growers to maintain the current low virus input levels in the crop and that aphid monitoring has a role to play in assessing the current seasons risk of virus spread.

During the period 1997-1999 of the study it was found that aphid monitoring needs to take place at a local level if results are to be used to inform crop management practices. Further to this, in 2001 data indicate that aphid traps in individual fields are required rather than a larger scale (RIS) trapping system, since there was no correlation found for 2001 Wolds seed growers between the numbers of aphids trapped and either the distance between the traps, or the elevation of the site.

Further statistical analysis showed that there is a small, but statistically significant, variability in trap catches in the field and suggests that optimal trap position is 20m from the headland. This trap will catch more aphids than the other positions and will therefore provide the grower with an estimate of aphid arrival and activity that takes a more cautious approach to the risk assessment process. Using this trap is possibly more likely to overestimate the risk than the other two traps, but it is accepted that when developing risk assessment systems it is better to overestimate the risk (worst case scenario: application of unnecessary treatment) than to underestimate the risk (worst case scenario: non-application of necessary treatment leading to damaging virus spread).

Very little or no PVY virus spread was recorded in the sites monitored during 2000 (see Appendix). Thus it was clear that growers planting seed crops with 0-1% input virus levels can easily tolerate the range of aphid pressures experienced during the season. In 2001 as in previous years of the study except 2000 the Yorkshire and CUF sites had dissimilar final cumulative PVY indices, and aphid activity was not as early as in 2000. The simple SASA scoring method for colonising aphids proved easy to perform, including by staff not trained in aphid identification and presumably could be performed by growers in the future. Statistical analysis of data from the 2001 pesticide efficacy trial site show that spray regimes 5 and above were required to keep aphid numbers below SASA threshold 1, and 3&4 below threshold 2. Zero aphid tolerance was given by spray regime 9. It is not clear whether the cut off between spray regimes 4 and 5 for breaching 1st SASA threshold are due to timing of spray application or number of application). PVY spread did not occur at the pesticide efficacy site during 2001, in line with year 2000 data discussed above, although an epidemic year has not been experienced during the study.

Low overall aphid pressures occurred in the 2001 growing season. It was found from the 2001 efficacy trial that differing levels of aphid control were achieved with the insecticide spray regimes as compared with control plot (1: untreated). Seed with up to 0.8% input virus per plot levels tolerated the range of aphid pressures experienced during the season with regard to virus spread (although virus spread could not be statistically evaluated in this trial with zero virus output at the end of the season). This data is in line with the mature plant resistance work at CUF where it was found that where aphid vector indices are low, little transmission of PVY is likely to occur even in young plants of susceptible varieties in the presence of ready sources of infection.

Further work is needed to determine minimum spray applications required, for a given aphid pressure, to maintain aphid populations (as expressed by colony counts) below the SASA thresholds. Ideally this work should be carried out in conjunction with virus spread data from the site, covering a range of virus input loadings and from a number of varieties with varying degrees of virus resistance. There would however appear to be scope for reducing insecticide usage in seed crops in low aphid/virus years.

Appendix: layout of experiment, Garton 2001

Potato Aphid Experiment, Garton 2001

Rep 1	Rep 2	Rep 3	Rep 4
8	10	12	10
4	1	10	2
3	5	2	7
6	11	6	9
12	2	4	3
1	7	1	5
9	4	11	11
2	3	7	6
10	12	8	4
5	9	3	1
7	8	9	12
11	6	5	8

TRAMLINE

<4 rows> <1 row> <4 rows> <2 rows> <4 rows> <1 row> <4 rows>

Total size 24 m by 193 m

Treatments: Dovetail 29.7 ml 4/plots, Plenum 11.9 g/4 plots, Hallmark 2.97 ml/4 plots. 4 plots/ tank of 9.9 litres												
Date	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6	Tr 7	Tr 8	Tr 9	Tr 10	Tr 11	Tr 12
50% Em. 30/5/01		D	D	D		D		D	D	D	D	D
06/06/01			D	D		D		D	D		Ha + Pl	Ha + Pl
13/06/01				D		D		D	D		D	D
20/06/01						D	D	D	D	D	Pl	Ha + Pl
27/06/01						D	D	D	D		D	D
04/07/01					D		D	D	D			
13/07/01					D		D	D	D	D		
20/07/01					D		D		D			

Ha = Hallmark (lambda-cyhalothrin), 150 All in 500 l/ha water ml/ha

Pl = Plenum (pymetrozine), 0.6 kg/ha.

D= Dovetail (lambda-cyhalothrin and pirimicarb) 1.5 l/ha

Colonising Aphid Data Summary - Garton Trial Site 2001

11-Jul	**REP1**	**REP2**	**REP3**	**REP4**
PLOT	**Total colony number**			
1	22	16	41	63
2	4	18	4	4
3	0	11	0	5
4	0	5	0	13
5	0	0	3	0
6	0	0	0	0
7	0	0	0	0

8	0	8	0	0
9	0	0	0	0
10	0	0	0	5
11	0	6	0	0
12	0	7	0	2

18-Jul	**REP1**	**REP2**	**REP3**	**REP4**
PLOT	**Total colony number (top, middle and lower leaf totals)**			
1	0	20	20	24
2	9	23	13	0
3	0	8	24	0
4	0	2	13	15
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0

25-Jul	**REP1**	**REP2**	**REP3**	**REP4**
PLOT	**Total colony number (top, middle and lower leaf totals)**			
1	0	7	3	0
2	18	13	1	6
3	11	4	7	9
4	9	3	0	8
5	0	0	0	0
6	0	0	0	4

7	0	0	0	8
8	0	0	0	0
9	0	0	0	0
10	0	0	0	2
11	0	0	2	4
12	6	0	0	4

10-Aug	**REP1**	**REP2**	**REP3**	**REP4**
PLOT	**Total colony number (top, middle and lower leaf totals)**			
1	1	2	0	0
2	0	0	0	0
3	0	0	6	0
4	1	0	4	1
5	0	0	0	0
6	0	4	0	0
7	0	0	0	0
8	0	0	0	1
9	0	0	0	0
10	0	4	0	0
11	2	2	3	0
12	0	1	3	0

08-Aug	**REP1**	**REP2**	**REP3**	**REP4**
PLOT	**Total colony number (top, middle and lower leaf totals)**			
1	0	0	0	0
2	0	0	0	0
3	1	0	0	0
4	0	0	0	0
5	0	0	0	0

6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0

Colonising aphid count data 2001

Aphid Colony counts Cambridge

Date	LG 44	Hasse F29	Engine SB3	Engine BF3	Townmore C/D
11-Jun-01	0	0	0	0	0
18-Jun-01	3	0	2	0	0
25-Jun-01	11	0	0	0	0
02-Jul-01	0	3	0	0	18
09-Jul-01	4	0	4	0	5
16-Jul-01	18	8	0	0	0
23-Jul-01	3	0	0	0	0
30-Jul-01	0	0	0	0	0
06-Aug-01	0	0	0	0	0
13-Aug-01	0	0	0	0	0
20-Aug-01	0	0	0	0	0
28-Aug-01	0	0	0	0	0

04-Sep-01	0	0	0	0	0
11-Sep-01	0	0	0	0	0
17-Sep-01			0	0	0

Yorkshire

Date	**Garton**	**Knapton**	**Deighton**	**Garforth**
03-Jul-01	3	11	8	0
10-Jul-01	31	1	3	0
18-Jul-01	2	2	1	0
01-Aug-01	0	2	3	0
07 Aug-01	0	0	2	0
14 Aug-01	0	0	0	0
23 Aug-01	0	0	0	0
30 Aug-01	Burnt	0	0	0

A copy of a previous report is included here for continuity.

Project (807/174)

BPC: Strategies for minimising virus infection of potato crops (807/174)

Introduction

The work was carried out during the 1997, 1998 and 1999 field seasons. Further work on timing of haulm destruction, virus spread and the role played by mature plant resistance will be reported on separately by CUF. Aphid monitoring data from commercial seed crops, where growers had also kept a record of virus levels at planting and at harvest, was used to provide the core data set. The cropping seasons 1997-1999 form a run of low aphid/virus years and a decision was taken towards the end of the project to start additional monitoring in English ware crops in the hope of finding more virus. Thus in 1999, aphid monitoring data was collected from four ware sites in Yorkshire and five in Cambridgeshire (CUF) (all grown from certified seed of PVY susceptible varieties) and part of a DEFRA funded Potato Disease Survey). The data comprised tuber indexing to determine in crop virus levels at planting and at harvest; aphid monitoring via in-crop yellow water traps with resultant aphid counts and aphid identification (predicts ability to transmit PVY) carried out at CSL.

Materials and Methods

Aphid monitoring sites (ware sites 1999 only)

Aphid monitoring site designation was as follows:
Cambridgeshire (CUF)
00/37 pvt 506
00/40 pvt 487
00/41 pvt 488
00/42 pvt 489
00/43 pvt 490

Yorkshire
00/10 pvt 536
00/11 pvt 531
00/12 pvt 533
00/3 pvt 534

Aphid Monitoring

Water traps for aphid collection (Nickerson Bros) were placed at 20, 50 and 80m from the headland in each of the 9 trial ware sites. Traps were emptied weekly for aphid identification throughout the growing season from emergence in May 2000 until crop destruction. The entire contents of each trap were collected in muslin and trap water disposed of via a funnel. The sample wrapped in muslin was then placed in an individual screw top container and labelled with the site designation and trap position relative to the headland. Traps were re-filled with water and a little detergent to break surface tension. Trap aphid content for all 9 ware sites was subsequently identified at CSL and a weekly record produced detailing numbers of PVY vectors and non-

vectors in each trap. Data was also analysed from a number of other seed sites which are part of the commercial aphid monitoring service.
The aphid species, which have been shown to transmit PVY, were given an efficiency rating based on their published ability to transmit the virus. *Myzus persicae* is the most efficient vector with an efficiency index of 1.0; other vectors (with efficiencies relative to *M. persicae*) include *Acyrthosiphon pisum* (0.7), *Rhopalosiphum padi* (0.4), *Aphis nasturtii/frangulae* (0.4), *Metopolophium dirhodum* (0.3), all other vectors have efficiencies ≤ 0.2. The cumulative and weekly vector indices were calculated and sent to growers to aid any decisions on the timing or need to defoliate the crop in relation to the risk of PVY transmission.

Virus Monitoring in Tubers

For each of the 9 ware sites virus levels were monitored at planting and post-harvest at ADAS Wolverhampton, by growing on single sprouts taken from each tuber of a one hundred tuber sample collected by ADAS staff. Testing of the resultant foliage was carried out by ELISA/ visual inspection to confirm presence of PLRV & PVY/severe mosaic virus. The grown-on samples were also further monitored for any growth abnormalities. Information on virus levels at planting and post-harvest were also obtained by CUF from some of the participating seed growers who collect this valuable information.

Incidence of PVY in weeds
Forty-one weed samples were taken from a PVY-infected field, which were sent, by CUF, in five batches over a five month period **(**April - August 1997). Each sample was inoculated onto one indicator plant - *Nicotiana tabaccum*.

Mechanical inoculations were carried out using small amounts of plant material from each sample i.e. leaves, seeds, flowers and stems, which were then ground with a pestle and mortar with tap water and a small quantity of Celite to a dilution approximately 1:10. The homogenate was then rubbed onto 2-3 leaves of the indicator plant and rinsed off with tap water. These plants were kept in a glasshouse cubicle at a temperature of 18^{o}C, with 16hrs light. Samples were taken from the indicators to be ELISA tested 11-14 days from inoculation.

The range of weeds sampled were:-

COMMON NAME	BOTANICAL NAME	FAMILY
Groundsel	*Senecio vulgaris*	Compositae
Mayweed	*Anthemis*	Compositae
Dandelion	*Taraxacum officinale*	Compositae
Yarrow	*Achillea millefolium*	Compositae
Shepherd's Purse	*Capsella bursa-pastoris*	Cruciferae
Willow Herb	*Epilobium*	Onagraceae

Fat Hen	*Chenopodium album*	Chenopodiaceae
Field Pansy	*Viola arvensis*	Violaceae
Plantain	*Plantago*	Plantaginaceae
Black Nightshade	*Solanum nigrum*	Solonaceae
Sowthistle	*Sonchus species*	Compositae
Smooth Hawk' Beard	*Crepis capillaris*	Compositae
Bindweed	*Convolvulus druensis*	Convolvulaceae

Results

Incidence in weeds

From the 41 samples, one tested positive to PVY^{o} - sample 97/W005/1 (Black Nightshade, Family Solonaceae). The host plant showed slight symptoms to PVY^{o} at the time of testing - a mosaic effect could be seen when the leaf was held up to the light and leaf contortions were becoming obvious.

MEAN 405nm Reading @ 1hr	Bioreba Cocktail MAb	Bioreba ^{N}specific Mab	Adgen $^{o/c}$specific	Adgen ^{N}specific MAb
BUFFER	0.080	0.074	0.077	0.081
He. N. tabaccum	0.157	0.153	0.158	0.177
PVY^{N} + ve	0.349	0.142	0.378	0.356
PVY^{o} +ve	0.877	0.074	0.349	0.087
97/W005/1	2.402	0.088	3.365	0.093

MEAN 405nm Reading @ 2hr.	Bioreba Cocktail MAb	Bioreba ^{N}specific Mab	Adgen $^{o/c}$ specific MAb	Adgen ^{N}specific MAb
BUFFER	0.090	0.078	0.086	0.092
He. N. tabaccum	0.166	0.163	0.164	0.196
PVY^{N}+ve	0.602	0.206	0.680	0.658
PVY^{o}+ve	1.601	0.079	1.189	0.107
97/W005/1	OVER	0.109	OVER	0.116

Aphid monitoring

Fig. 1 shows the distribution of traps achieved by expansion of the aphid monitoring service up to 1999. Fig.2 shows the big differences between regions in aphid/virus pressure during the study period. As expected, virus pressure declines markedly as one travels North. Fig. 3 demonstrates the large differences at a single site between the years of the study. Such differences are also typically seen between sites within a year, including sites which are often only a few miles apart. It was often also noticeable that the traps sited near the edge of the crop caught more aphids than those sited further into the crop (Fig 4.). A comparison of the relationship between the different published aphid vector efficiency coefficients (annexe 1.) and the multiplication of virus was also carried out (data not shown). The general lack of virus in the years studied does not allow any conclusions to be drawn but this analysis will be repeated in the final report to the successor project.

Fig. 1. Regional distribution of aphid monitoring scheme sites in 1999

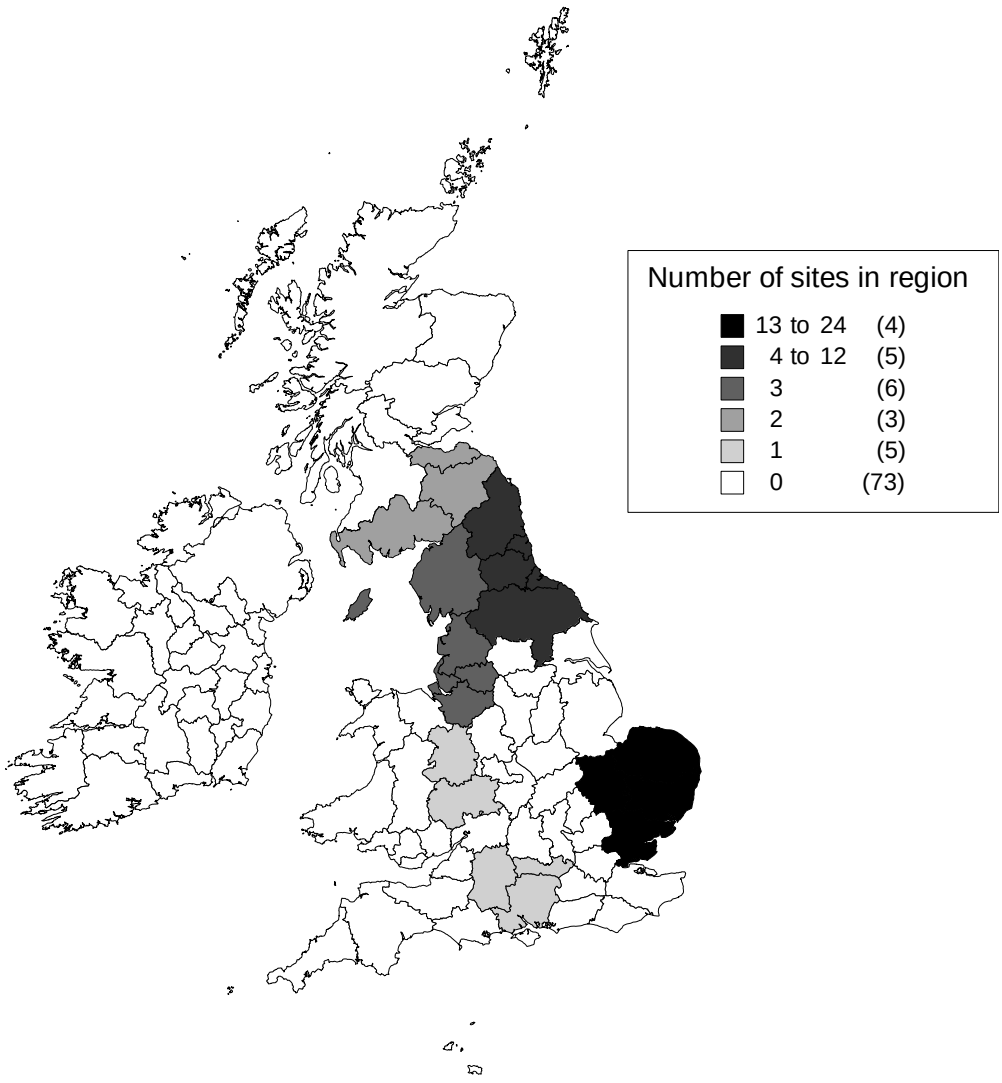
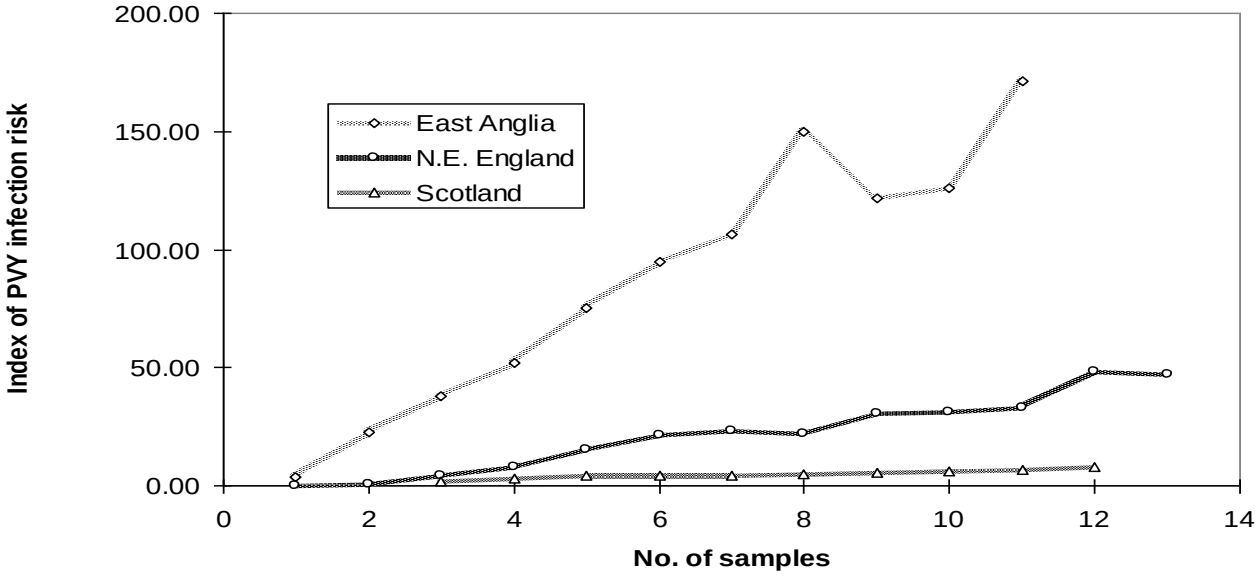


Fig. 2. Regional variation in the mean cumulative Index of PVY infection risk in 1999.



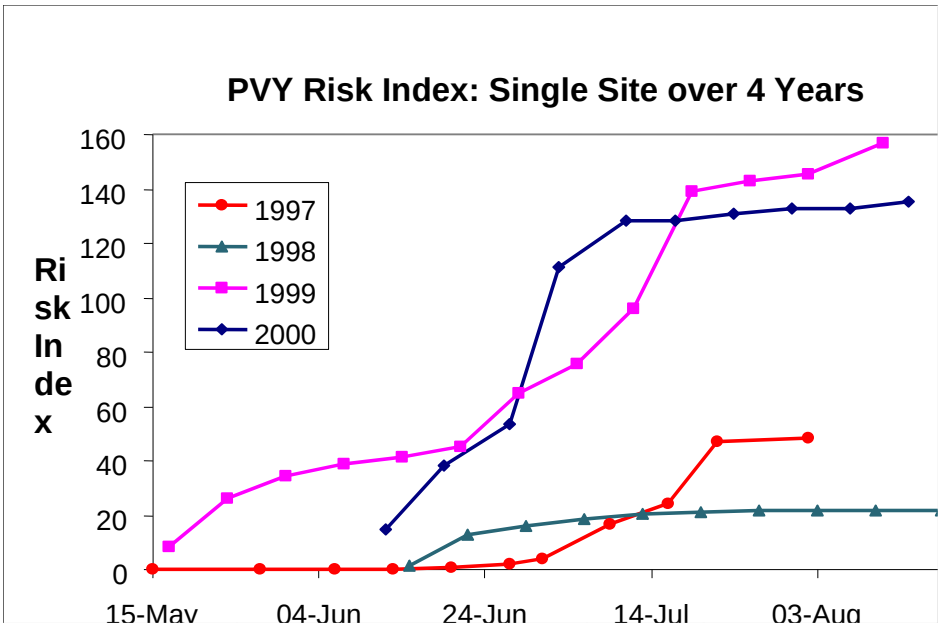

PVY Risk Index: Single Site over 4 Years
Risk Index
160
140
120
100
80
60
40
20
0
1997
1998
1999
2000
15-May
04-Jun
24-Jun
14-Jul
03-Aug

Fig. 3

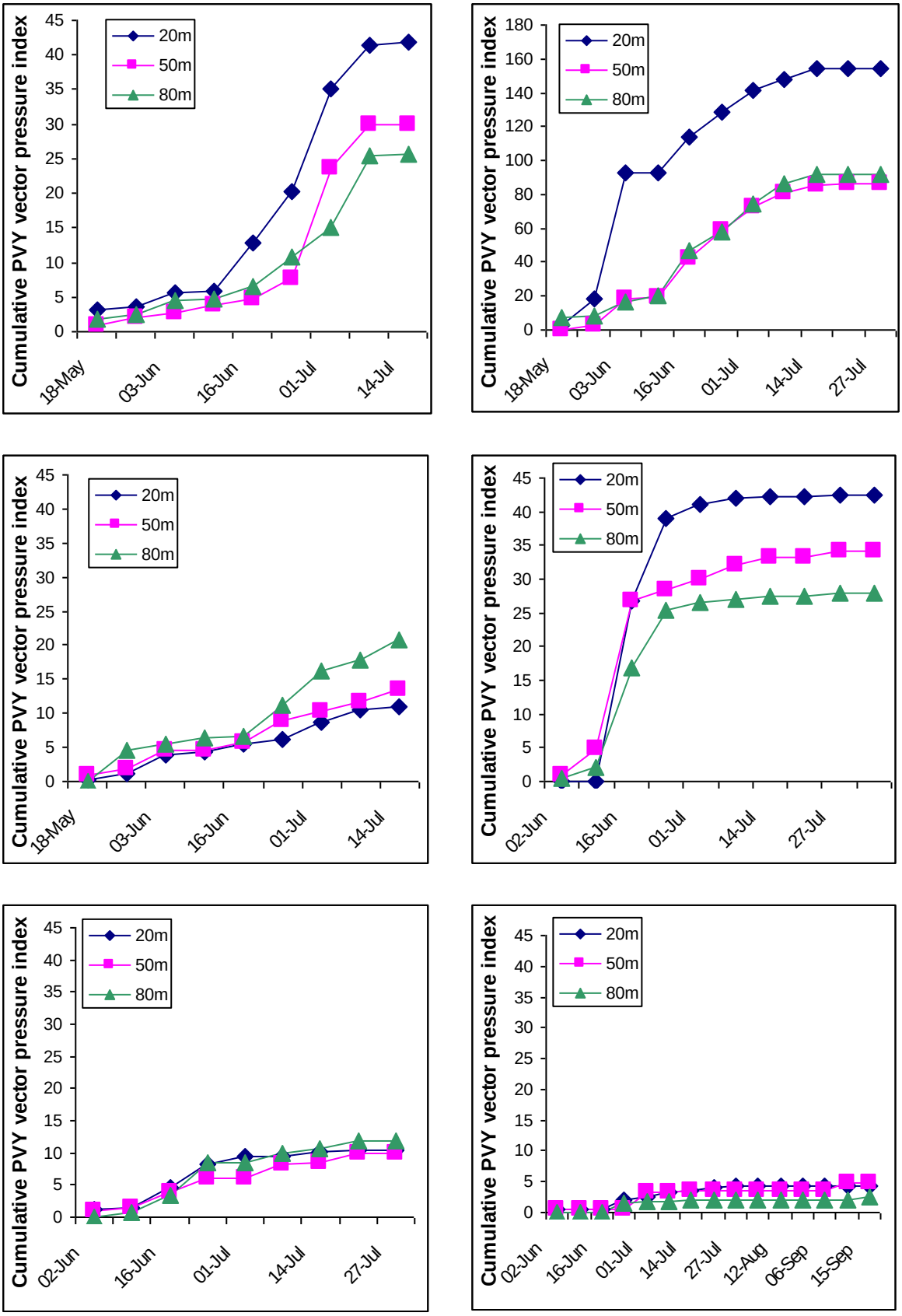


Figure 4: Cumulative vector pressure index at six sites in 1999, for each of three traps measured from the field margin.

Virus Monitoring in Tubers and Final Trap Index Data

Recorded virus incidences at harvest were generally very low throughout the period of study (Annexe 2.). This was also the case for the 9 ware sites in 1999 as well the seed sites, presumably reflecting very low input virus levels as well as the generally low virus vector indices. Graphing the final virus/aphid pressure index against recorded virus increase (Fig. 5) shows no obvious relationship. However, it is noticeable that no large virus increases were observed in the absence of significant aphid/virus pressure. Those sites with significant aphid/virus pressure but with no noticeable virus increase, might reflect crops with effectively zero levels of input virus (at the level of sampling).

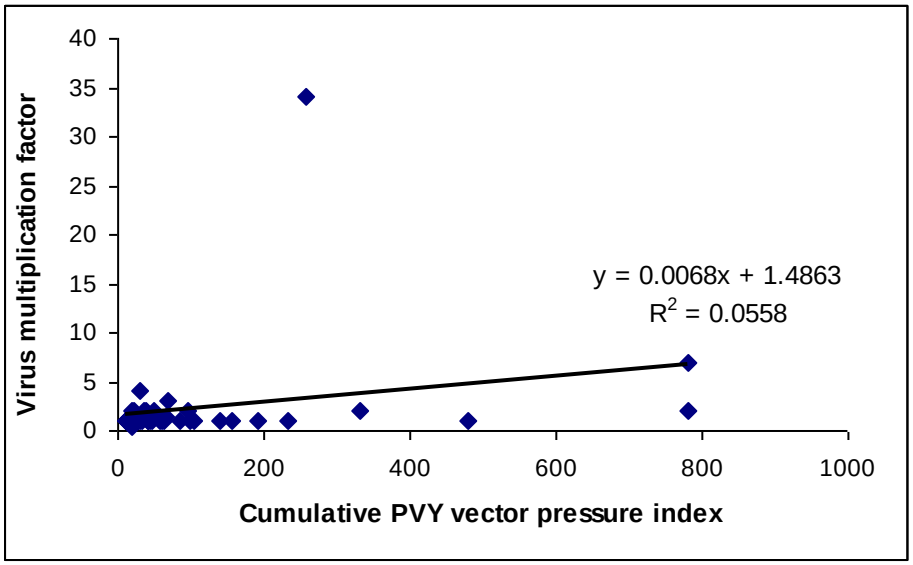


Figure 5: Cumulative vector pressure index at all sites 1997-1999 where PVY input and output were tested.

Discussion

Very little or no PVY virus spread was recorded in the sites monitored during the period under study. Thus it is clear that growers planting seed crops with 0-1% input virus levels can easily tolerate the range of aphid pressures experienced during the season. It is likely that the seed sites at least in this study would have received a number of insecticide applications during the season. Whilst it is undeniable that the growers achieved excellent results (including PLRV control), it must be questioned as to whether the average level of spraying generally seen in seed crops is warranted in such a season. The significance of the presence of PVY in black nightshade is uncertain. This weed is an annual and the virus is not thought seedborne (botanical seed). Thus it is perhaps unlikely that the weed could contribute to carry over of virus between seasons in the way that volunteers presumably do.

It was again noticeable during the study period that sites varied considerably in virus vector pressure which reinforces the message that aphid monitoring needs to be done at a local level if results are to be used to inform crop management practices. The aphid monitoring service grew to encompass 46 sites by 1999, but the problem still remains that we are unable to set threshold levels for concern for a given virus input level, emergence date and variety. It is hoped to continue monitoring for a further two years and carry out a full analysis of the data at the end of that period.

Annexe 1.

	Van Harte	**Sigvald 2**	**Harrington**	**De Bokx**	**Sigvald 1**
M. persicae	1	1	1	1	1
A. pisum	0.05	0.7		0.11	0.8
A. nasturtii		0.4		0.42	0.3
R. padi	0.02	0.4		0.14	0.1
M. dirhodum	0.01	0.3		0.1	
M. euphorbiae	0.1	0.2	0.7	0.07	
M. ornatus		0.2			
A. solani		0.2			
M. ascalonicus		0.2			
R. latysiphon		0.2			
A. fabae	0.1	0.1	0.5	0.07	0.2
B. brassicae		0.01			0.01
S. avenae		0.01			0.01
B. helichrysi	0.01		0.1	0.21	
H. lactucae				0.16	

Annexe 2.

	Site	Variety	PVY Input by ELISA	PVY Output by ELISA	Virus Multiplication Factor	PVY Vector Pressure Index
1997	1	Nicola	1	1	1	26.93
	2	Estima	1	1	1	63.59
	3	Bard	1	1	1	478.62
	4	Bintje	1	2	2	37.32
	5	Charlotte	1	1	1	26.3
	6	Estima	1	1	1	11.6
	7	Maris pier	1	1	1	22.84
	8	Estima	1	1	1	19.2
1998	9	Nicola	1	1	1	59.66
	10	Atlantic	1	2	2	22.5
	11	M. piper	1	2	2	49.73
	12	Marfona	1	2	2	95.55
	13	M.Peer	1	2	2	36.32
	14	Estima	1	4	4	29.7
	15	Charlotte	1	2	2	18.81
	16	Estima	1	1	1	41.36
	17	Bintje	1	1	1	29.46
	18	Cara	1	1	1	12.23
1999	19	Estima	1	1	1	21.69
	20	Estima	1	1	1	58.44

	21	M Peer	1	1	1	32.16
	22	Estima	1	1	1	104.39
	23	Bintje	2	1	0.5	19.77
	24	Nicola	1	1	1	231.66
	25	Estima	1	1	1	44.44
	26	M Bard	1	1	1	19.24
	27	Nicola	1	1	1	97.27
	28	Nicola	1	1	1	84.78
	29	Estima	1	2	2	780.84
	30	Estima	1	2	7	780.84
	31	M.Piper	1	2	2	332.4
	32	Estima	1	1	1	157.01
	33	Pentland Dell	1	1	1	41.06
	34	Pentland Dell	1	1	1	192.34
	35	Cara	1	1	1	12.31
	36	Pentland Dell	1	1	1	19.1
	37	M Piper	1	3	3	68.08
	38	Estima	1	34	34	257.12
	39	Estima	2	2	1	45.38
	40	M Piper	3	4	1.333333	65.23
	41	M Piper	1	1	1	139.19

	Site	Variety	PVY Input by ELISA	PVY Output by ELISA	Virus Multiplication Factor	PVY Vector Pressure Index
1997	1	Nicola	0	0	0	26.93
	2	Estima	0	0	0	63.59
	3	Bard	0	0	0	478.62
	4	Bintje	0	1	1	37.32
	5	Charlotte	0	0	0	26.3
	6	Estima	0	0	0	11.6
	7	Maris pier	0	0	0	22.84
	8	Estima	0	0	0	19.2
1998	9	Nicola	0	0	0	59.66
	10	Atlantic	0	1	1	22.5
	11	M. piper	0	1	1	49.73
	12	Marfona	0	1	1	95.55
	13	M.Peer	0	1	1	36.32
	14	Estima	0	3	3	29.7
	15	Charlotte	0	1	1	18.81
	16	Estima	0	0	0	41.36
	17	Bintje	0	0	0	29.46
	18	Cara	0	0	0	12.23
1999	19	Estima	0	0	0	21.69
	20	Estima	0	0	0	58.44
	21	M Peer	0	0	0	32.16

	22	Estima	0	0	0	104.39
	23	Bintje	1	0	0	19.77
	24	Nicola	0	0	0	231.66
	25	Estima	0	0	0	44.44
	26	M Bard	0	0	0	19.24
	27	Nicola	0	0	0	97.27
	28	Nicola	0	0	0	84.78
	29	Estima	0	1	1	780.84
	30	Estima	0	1	1	780.84
	31	M.Piper	0	1	1	332.4
	32	Estima	0	0	0	157.01
	33	Pentland Dell	0	0	0	41.06
	34	Pentland Dell	0	0	0	192.34
	35	Cara	0	0	0	12.31
	36	Pentland Dell	0	0	0	19.1
	37	M Piper	0	2	2	68.08
	38	Estima	0	33	33	257.12
	39	Estima	1	1	1	45.38
	40	M Piper	2	3	1.5	65.23
	41	M Piper	0	0	0	139.19

Results taken from follow-on report 807-216 (2000)

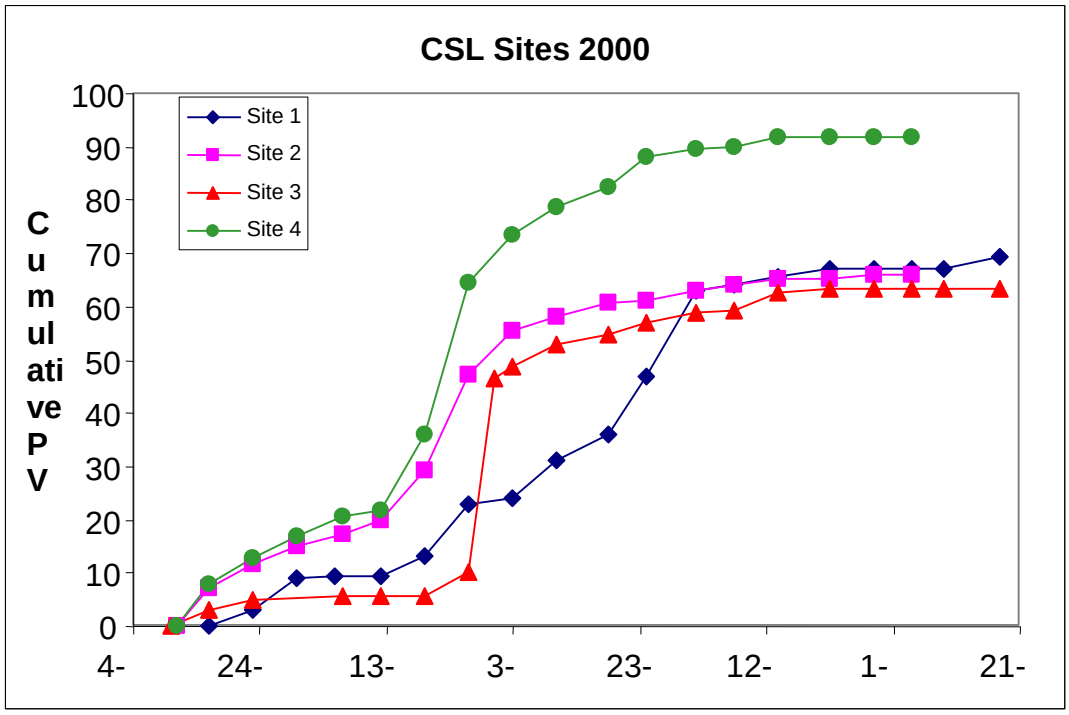
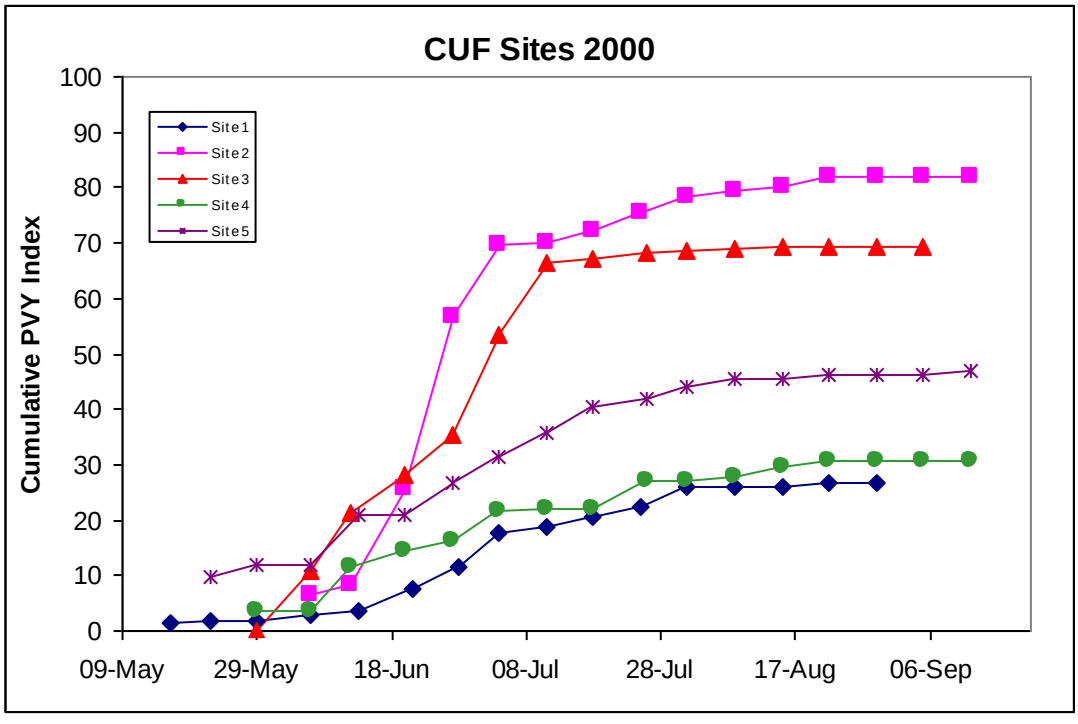

CSL Sites 2000
Cumulative PV
100
90
80
70
60
50
40
30
20
10
0
Site 1
Site 2
Site 3
Site 4
4-
24-
13-
3-
23-
12-
1-
21-

Fig.1

Fig 3.


CUF Sites 2000
Cumulative PVY Index
100
90
80
70
60
50
40
30
20
10
0
Site1
Site2
Site3
Site4
Site5
09-May
29-May
18-Jun
08-Jul
28-Jul
17-Aug
06-Sep

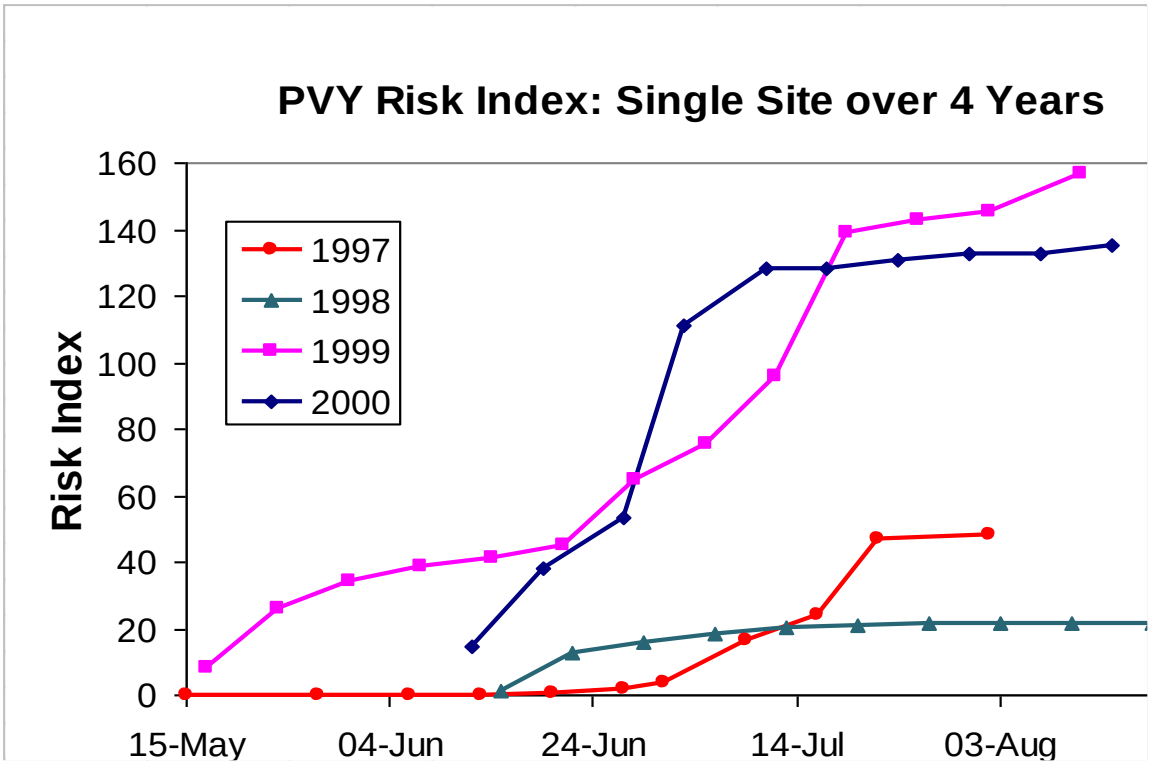


Fig. 2

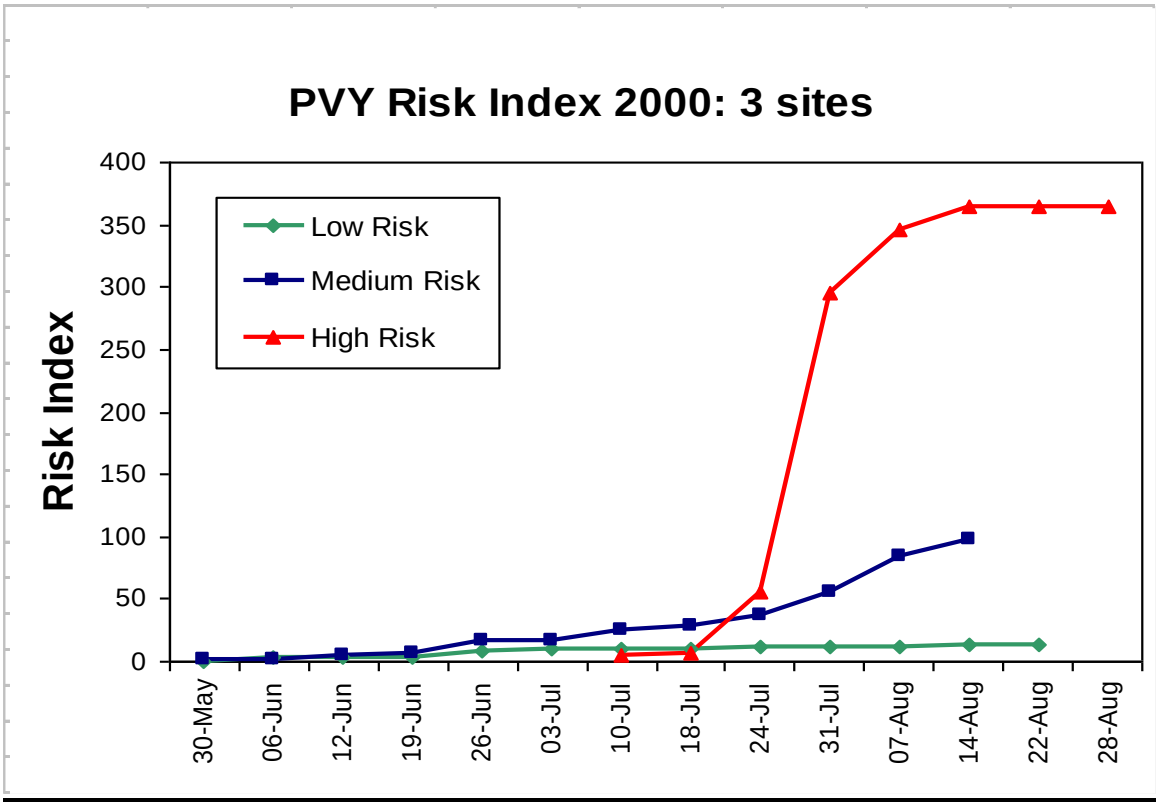


Fig 4

The graphs above depict the cumulative PVY (aphid) index during the growing season for the Yorks and CUF sites. The incidence of the main vectors of PVY (a non-persistent virus) remained relatively low throughout the 2000 growing season. On average (Fig3.), the 2000 season represented a higher risk than 97/98 but lower than 1999 which showed early aphid activity not seen in 2000. In general the five

Cambridgeshire sites ended up with similar final cumulative PVY indices as the four Yorkshire sites (unlike previous years) but possibly showed earlier aphid activity (Fig.1.& 2.). As in previous years, considerable variation was seen between sites in a single year (Fig. 4).

Colonising aphid count data

In crop assessments for colonising aphids commenced in June 2000 for the 4 Yorkshire ware sites and continued until crop destruction in September 2000. Colonising aphids were first noted at the beginning of June at site 00/12 pvt 533 near Wetherby. This site which was the most northerly of the four Yorkshire sites and remained the only site during the growing season where colonising aphids were detected. At the efficacy site an increase in colonising aphids was found at the end of the growing season. Colonising aphids were recorded in Cambridgeshire at all sites from mid-June in low numbers. The highest colony numbers were recorded between mid-July to early August at site 00/41, and site 00/37 was colonised in higher numbers than the other sites in June.

Numbers of aphid colonies in ware crops – Yorkshire (CSL)

	00/03	00/10	00/11	00/12
19-Jun-00	0	0	0	0
26-Jun-00	0	0	0	0
03-Jul-00	0	0	0	3
10-Jul-00	0	0	0	18
17-Jul-00	0	0	0	20
24-Jul-00	0	0	0	5
07-Aug-00	0	0	0	5
14-Aug-00	0	0	0	1
23-Aug-00	0	0	0	1

Numbers of aphid colonies in ware crops – Cambridgeshire (CUF)

	00/40	00/41	00/43	00/42	00/37
06-Jun-00	0	0	0	0	0
13-Jun-00	0	0	1	0	7
20-Jun-00	1	0	1	3	6
27-Jun-00	4	5	0	4	11

04-Jul-00	0	9	2	2	3
11-Jul-00	0	4	0	1	0
18-Jul-00	0	10	0	5	0
25-Jul-00	0	21	1	7	1
01-Aug-00	0	15	0	1	0
08-Aug-00	0	0	1	0	0
15-Aug-00	0	0	0	1	0
22-Aug-00	2	1	0	0	0
29-Aug-00	0	6	0	1	1
05-Sep-00	0	*	3	4	2
12-Sep-00	0	*	9	13	*

Discussion

Very little or no PVY virus spread was recorded in the sites monitored during 2000. Thus it is clear that growers planting seed crops with 0-1% input virus levels can easily tolerate the range of aphid pressures experienced during the season. It is likely that the seed sites at least in this study would have received a number of insecticide applications during the season. Whilst it is undeniable that the growers achieved excellent results (including PLRV control), it must be questioned as to whether the average level of spraying generally seen in seed crops is warranted in such a season. The simple SASA scoring method for colonising aphids proved easy to perform, including by staff not trained in aphid identification and presumably could be performed by growers in the future.

It was again noticeable during 2000 that sites varied considerably in virus vector pressure which reinforces the message that aphid monitoring needs to be done at a local level if results are to be used to inform crop management practices. The aphid monitoring service grew to encompass 66 sites in 2000 (up from 46 in 1999) but the problem still remains that we are unable to set threshold levels for concern for a given virus input level, emergence date and variety. It is hoped that analysis of the results all 5 years of the study in spring 2002 will provide some definitive guidance, although we have yet to experience an epidemic year during the study. Experimental work on mature plant resistance at CUF should also provide a further level of refinement which could be placed on the interpretation of virus vector indices (described in Part B).

807/216 PART B

Spread of Potato Virus Y

These four experiments in 1998-2001 examined the transmission of PVY within a crop in relation to the local incidence of infection.

Materials and Methods

Similar experiments were conducted over four years (YS1-YS4) and full details are described below for YS1 followed by details for subsequent experiments where different.

Expt YS1 (1998)

Within a field planted on 31 March with a stock of Maris Piper free from PVY infection, 16 plots of 22 m by 24 rows were marked out in four blocks with each plot separated from the next by 22 m along the row and 24 rows. The population density of the field crop was approximately 26 000 plants/ha with a row width 0.91 m. On 8 April three of the four plots in each block were planted with PVY infected tubers at 1, 4 or 9 stations to give an approximate 'local' incidence in each plot of 0.08, 0.33 and 0.7 % PVY (referred to as low, medium and high) with the fourth plot left without infector plants. The crop reached 50% emergence on 1 May. Yellow water traps were placed 10, 50 and 80 m into the crop and the contents emptied weekly and aphids identified by CSL to calculate an index for PVY transmission from the efficiency with which each species transmits PVY. On 18 August one tuber was removed from 100 plants in each plot (one from each of 10 plants per row from alternate rows from 3 to 21 with *c.* 2 m between plants along the row) and grown on to test for PVY by ELISA.

Expt YS2 (1999)

The field crop of Maris Piper was planted on 30-31 March and reached 50% emergence *c.* 29 April. On 18 May infected plants were transplanted at 1, 4 or 9 stations in three of the four plots in each block to give an approximate 'local' incidence in each plot as in YS1. Tubers were harvested for virus testing on 15 September.

Expt YS3 (2000)

The field crop of Maris Piper was planted on 8 April. Tubers infected with PVY were planted on 10 April at 4, 9 or 16 stations in three of the four plots in each block to give an approximate 'local' incidence in each plot of 0.3, 0.7 and 1.3 % PVY (referred to as low, medium and high) with the fourth plot left without infector plants. Tubers were harvested for virus testing on 19 September.

Expt YS4 (2001)

The field crop of Maris Piper was planted 26 April – 6 May. Tubers infected with PVY were planted on 15 May at 4, 9 or 16 stations in three of the four plots in each block as in YS3. Tubers were harvested for virus testing on 19 September.

Results and Discussion

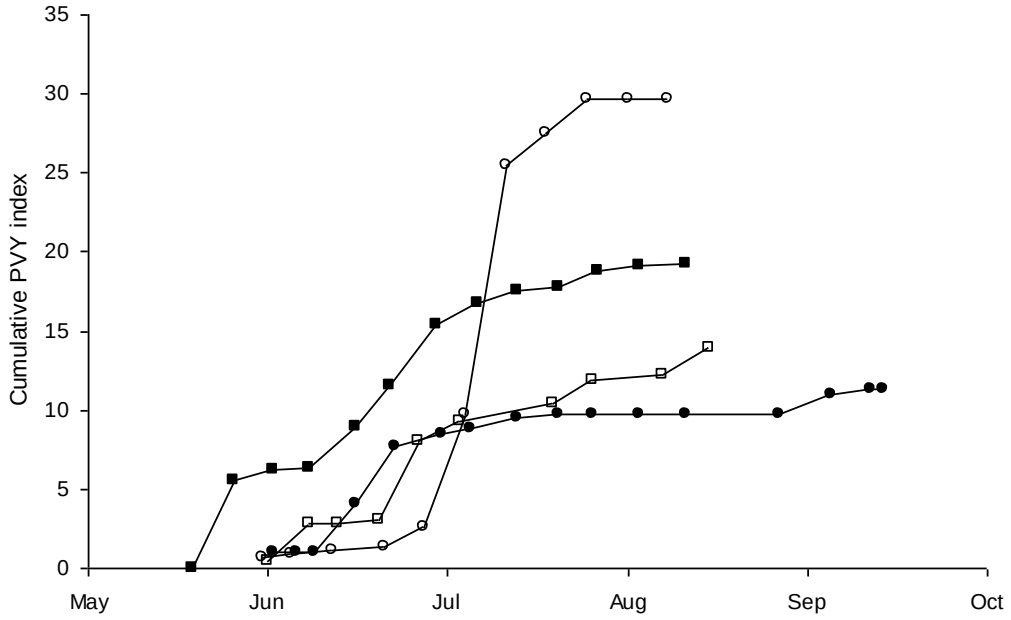
The PVY vector indices were relatively low in all experiments (Figure 1) and whilst the final index in Expt YS4 was greater than in other years, early in the season very few vector aphids were caught. In all experiments ELISA tests indicated some plots remained free from PVY but PVY was detected in all experiments and in all years within at least some control plots where no infected plants were placed. The maximum plot incidences (%) in Expts YS1-YS4 were 8, 4, 8 and 7 respectively and there were no significant differences between treatments (Table 1). The relatively low incidence of PVY in tubers at the end of the season reflected a relatively low vector index but comparison with the monitored seed sites (in which initial inoculum and final infection was generally lower) suggests that the additional inoculum increased the extent of virus transmission. As there was no evidence that the differences in inoculum between plots affected the spread of PVY within plots it is likely that that spread from aphid flights (as opposed to colonizing vectors) is not localized to the relatively small areas but operate at a greater scale.

Table 1. Effect of initial incidence of PVY within plots on incidence of PVY (%) in daughter tubers following harvest in Expts YS1-YS4

	Initial incidence of PVY†				
Expt	0	Low	Medium	High	S.E.
YS1	2.6 (7.9)	4.3 (11.8)	5.0 (11.2)	3.2 (9.6)	(3.03)
YS2	1.3 (4.3)	1.5 (6.0)	1.5 (6.1)	2.0 (7.8)	(1.59)
YS3	1.6 (6.2)	1.1 (5.2)	4.2 (11.2)	4.5 (11.8)	(1.22)
YS4	0.6 (2.2)	1.9 (3.6)	0.5 (2.1)	1.7 (3.7)	(2.99)

† See text for details, numbers in parenthesis are for angular transformed data

Figure 1. PVY vector index over the season for the experiments YS1 closed square, YS2 closed circle, YS3 open square, YS4 open circle



Mature plant resistance to Potato Virus Y

The purpose of these experiments was to examine the extent to which plants become resistant to PVY with age. The experiment in 1998 compared inoculation with mechanical methods and cultured aphids whilst experiments in 2000-2001 were conducted to provide data from natural infection by exposing plants of different ages to aphid vectors in the presence of infector plants.

Materials and Methods

Expt YA1 (1998)

This experiment compared Estima and Maris Piper, varieties with NIAB ratings of 2 for susceptibility to PVY, with Cara rated 7 (relatively resistant). Treatments consisted of all combinations of variety, date of inoculation, method of inoculation (mechanical or using viruliferous aphids) and isolate of PVY (PVY^O or PVY^N) arranged as a a split-split-plot design with a single replicate. Mainplots consisted of date of inoculation grouped together and enclosed in aphid proof netting. Subplots consisted of each combination of variety and PVY isolate with15 plants in 6 rows and the outer two rows as guard rows with pairs of the four central rows as sub-subplots inoculated either mechanically or by aphids. In each sub-subplot, guard plants were left at the ends of plots so that there were 26 plants to inoculate. The experiment was planted on 15 May, and there were five dates of inoculation from *c.* 2 weeks after 50 % emergence then every 2 weeks (24 June - 19 August). For mechanical inoculation, a virus suspension obtained from grinding infected leaves of tobacco plants (previously infected with the appropriate isolate at CSL) was rubbed onto the entire upper leaf surface of the five apical leaflets of the uppermost expanded leaf and the leaf five nodes below. For aphid inoculation, cultured aphids (*Myzus persicae*) were starved by removing them from their host plants for *c.* 4 hours then allowing them to

feed for *c.* 10 minutes on detached leaves of infected tobacco plants. These viruliferous aphids were then shaken from the leaf, loaded onto a small paintbrush and shaken over the apex of stems of each target plant (*c.* 10 aphids per plant). On 14 September one tuber was harvested from each inoculated plant and leaves grown from these tubers were tested for PVY^{O} or $PVY^{N\ by}$ ELISA.

Expt YA2 (2000)

Treatments consisted of all combinations of four planting dates; 17 May, 1, 15 and 29 June, and four varieties, Estima, Russet Burbank, Lady Rosetta and Cara in a randomised block design with three replicates. The varieties chosen differed in susceptibility to PVY according to the NIAB rankings (2, 4, 5 and 7 respectively). Plots consisted of five rows of ten plants grown from 25 – 35 mm seed spaced at 20 cm along 76 cm rows and were covered by netting after planting to exclude aphids. On 2 Aug, *c*. 2 weeks after emergence of the final planting, pots with PVY infected plants were placed around the experiment adjacent to each plot (local incidence of PVY *c.* 2 %) and the net covers were removed. Three yellow water traps were placed along the length of the experiment and after one week, the contents of the traps were collected and the PVY index vector for the week calculated. After exposure for one week, the plots were sprayed with insecticide and recovered with netting. On 30 August, *c.* 50 tubers were collected from plants in the central rows in each plot and grown on for testing for PVY by ELISA.

Expt YA3 (2001)

Details of this experiment were as YA2. The first planting date was 18 May, subsequent planting dates and dates of exposure to aphids were as in YA2. The experiment was desiccated with 4l/ha of Reglone (diquat) on 29 August and tubers sampled on 14 September for virus testing.

Results and Discussion

Expt YA1

Following the first date of inoculation, almost all daughter tubers of Maris Piper were infected with PVY^{N} from both mechanical and aphid inoculation whilst in Cara a high proportion were also infected with mechanical inoculation but aphid inoculation was less effective (Table 2). In Estima mechanical inoculation with PVY^{N} at the first date infected fewer than half of daughter tubers and aphid inoculation was entirely unsuccessful (Table 2). In Maris Piper efficiency of infection of PVY^{N} with mechanical inoculation decreased gradually with delay in date of inoculation until at 10 weeks after emergence no infection was detected whereas in Cara there was little infection after the first date and in Estima fewer than a fifth of plants affected at the second inoculation date and none thereafter (Table 2). Aphid inoculation with PVY^{N} was largely unsuccessful after the first date although at the latest date 35 % of Cara plants were found to be affected (Table 2). Inoculation with PVY^{O} was almost completely unsuccessful at all dates with only a few isolated instances of infection detected.

Table 2. Effect of date and method of inoculation with PVY^N in three potato varieties on incidence of tuber infection (%) in Expt YA1

Method	Variety	Date of inoculation (weeks after emergence)				
		2	4	6	8	10
Mechanical	Cara	90	0	0	8	0
	Estima	39	17	0	0	0
	M Piper	95	69	37	35	0
Aphid	Cara	33	0	9	0	35
	Estima	0	0	0	0	0
	M Piper	94	17	0	0	0

Expt YA2

During the week in which plants were exposed, a total of 45 aphids were trapped of which 31 were PVY vectors (including one *Myzus persicae*, one *Acyrthosiphon pisum* and several less efficient vectors) and the PVY index was 5.0. For most plots, no daughter tubers were found to be affected with PVY, but the incidence of PVY in individual plots was up to 4%. On average 1% of daughter tubers of Cara were affected at the first planting as were tubers of Russet Burbank from the first and second planting and Lady Rosetta from the third planting, but PVY was not detected from other treatments.

Expt YA3

During the week in which plants were exposed, a total of 21 PVY vector aphids were trapped (these included three *Macrosiphum euphorbiae*, but were mainly less efficient vectors such as *Aphis fabae*) and the PVY index was 2.14. For most plots, no daughter tubers were found to be affected with PVY, but the incidence of PVY in individual plots was up to 7%. PVY was not detected in Estima or Cara from any plantings but on average 1% of daughter tubers of Lady Rosetta were affected from both the second and third plantings (first and final plantings not affected) whilst for Russet Burbank 1% of daughter tubers were affected at the second planting and 3% at the final planting (first and third plantings not affected).

Expts YA1-YA3

Although a high incidence of infection was achieved for mechanical inoculation of young plants with PVY^N in Expt YA1, negligible infection was achieved for PVY^O and limited infection was achieved with aphids for either virus. The data from Expt YA1 provide some further evidence that plants become more resistant to virus

infection with age and suggest that mature plant resistance develops rapidly in Cara and more gradually in Maris Piper, but data from Expts YA2 and YA3 do not enable quantification of the importance of this with natural infection as no substantial infection occurred. It is, however, apparent from the body of data that where aphid vector indices are low, little transmission of PVY is likely to occur even in young plants of susceptible varieties in the presence of nearby sources of infection.