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PROJECT REPORT No. 206

THE IMPORTANCE OF BARLEY YELLOW DWARF VIRUS (BYDV) INFECTION IN SPRING BARLEY AND OPPORTUNITIES TO MANAGE THE DISEASE

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by

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ABSTRACT

Barley Yellow Dwarf Virus (BYDV) is an aphid transmitted disease which can severely reduce the yield of barley. Management techniques to control BYDV infection in autumn sown barley are now well understood and regularly adopted. However BYDV can also cause severe problems in spring sown barley and the full extent of the problem has only been realised since the introduction of varieties possessing tolerance of BYDV infection.

Control of BYDV infection primarily revolves around control of the vector, the aphid. As the autumn progresses and temperatures decrease management techniques have been timed to control primary infections (infected aphids flying into crops) before secondary infections (infected aphids moving within crops) develop. Both foliar sprays and seed treatments can be successfully used to control aphids in the winter sown crops. Control in the spring sown barley crop has always been considered to be more difficult. BYDV infections have tended to increase as the spring progresses as temperatures rise thereby encouraging more aphid activity. It has not been considered feasible to use foliar insecticides as a reliable method of control as primary infection will always be taking place as temperatures increase in the spring.

However the potential of both BYDV resistance in varieties and the seed treatment imidacloprid in reducing the incidence of BYDV infections in spring sown barley crops were considered to be important and were evaluated in a series of trials conducted over three seasons.

Three varieties of spring barley, (two resistant to BYDV - CORK and OPTIC and one susceptible to BYDV - DERKADO) were drilled on two drilling dates at four locations in England. Treatments involving both seed and foliar applied insecticides were compared over the three seasons of the study.

BYDV infection levels were heavy in one season but not severe in the other two seasons, and whilst the susceptible variety did exhibit more BYDV infection the differences between varieties were not as marked as had been anticipated.

Delaying the drilling date, typically by about one month from March to April had a marked effect on yield the greatest reduction from later drilling being in the season that illustrated the highest BYDV infection levels. Later drillings reduced yields by 14.9% to 37.6% and the overall average over the three seasons of trials was -26.9%.

The different combinations of insecticidal seed treatment and foliar insecticide application produced very inconsistent results, and no treatment satisfactorily controlled primary BYDV infections from in flying aphids.

The main management techniques to reduce the impact of BYDV infection on spring barley crops would appear to be earlier drilling dates and the use of resistant varieties.

Summary

All spring crops have wide drilling windows, but it is well established that later drillings are invariably lower yielding primarily as a result of restricting the already limited growing period. However spring barley does suffer a further problem if drilling is delayed. It is now recognised that later drillings can suffer significantly from infection from Barley Yellow Dwarf Virus. The so called Cuckoo barley (drilled late and lower yielding) and the symptoms referred to as 'May - yellows' are now known to be mainly the result of BYDV infection.

This aphid-borne virus infection can reduce yield by up to 50% in plots, but there has been no recent research into the true extent of the problem on a field scale. The autumn infections of BYDV have been extensively researched to the point of developing forecasting techniques of infection levels (HGCA Project Report No 87).

However the importance of the infection of spring-sown crops, barley especially, was not fully recognised in the past and has been neglected in research terms primarily because techniques for controlling infection were not readily available. Recent developments have provided the techniques to investigate the significance of BYDV in spring barley and methods of managing infection.

- the development of spring barley varieties that possess field resistance to BYDV
- diagnostic techniques to evaluate infection have improved and become widely available
- the availability of an insecticide seed treatment (imidacloprid)

In addition aphicidal sprays which have been very widely used on winter crops have rarely been tested on spring barley. This project sought to combine all these developments to provide a thorough investigation of the current status of BYDV in spring barley and ways of preventing or limiting any damage caused

The three year study commenced in spring 1996 the primary objectives being to:

- define yield losses in spring barley infected with BYDV
- determine the importance of resistant varieties in this yield relationship
- evaluate the influence of sowing date on the incidence of BYDV and its subsequent yield
- determine the effectiveness of a seed treatment (Imidacloprid) and foliar insecticides in controlling BYDV.

Ultimately the intention was to define management strategies for growers to minimise losses from BYDV.

Effective control of BYDV in winter barley depends upon an understanding of conditions that affect the number and movement of infective aphids into the crop during the autumn migration period of early September to early November. This primary infection is rarely sufficiently widespread to cause direct damage but secondary spread from the initial foci of infection can cause serious yield losses. Drilling date has an important effect of the incidence of virus with the earlier sowings generally being more infected than those sown later. As manipulating sowing date is often not seen as a sensible option most control has relied upon an appropriately timed insecticide spray. This strategy works only because the weather during the autumn is deteriorating, and especially getting colder. This prevents aphid flight and the consequent frequent introduction of new virus into the crop. In the spring the reverse is true so that newly emerging spring-sown crops are exposed to progressively warmer weather that encourages aphid flight and multiplication. What little evidence there is of BYDV infection on spring barley suggests that later sowing increased the risk of BYDV infection as a result of more active aphids and a more favourable, i.e. younger, crop for aphid colonization and virus damage. There is also evidence that crops become less attractive to aphids when they meet across the rows. Thus even with the same number of aphids flying over the crop more are likely to land on the later sown crop, where rows may still be visible, than on the earlier sown crop where ground cover is more complete.

Drilling Date In each season and at each site the plots were sown on two dates. The first drilling was at the normal time for the region that is as soon as conditions permit. The second drilling was about a month later.

Seed Treatment The chemical imidacloprid is widely used on sugar beet and appears to give excellent protection against aphid infestation and virus infection during the first few weeks of plant growth. It has also been quite widely available on cereals outside the UK and has recently been made available on winter barley and winter wheat in the UK.

Insecticidal Sprays Synthetic pyrethroids are the usual chemical of choice for controlling aphids potentially carrying virus into autumn-sown crops and have been used to control direct aphid damage on ears. However restrictions were imposed on this use in crops that had also been treated with a pyrethroid in the autumn to decrease the risk of resistance developing in the cereal aphid population. In these experiments a synthetic pyrethroid (Decis) was used either alone or in combination with the carbamate insecticide, Aphox.

Varietal Resistance Plant breeders have introduced into some spring barleys a character that decreases infection by BYDV in field crops. However, the basis of this effect is unclear, although real, and is not

obviously linked to previously known sources of tolerance in barley, e.g. Yd2. In these trials three varieties were used, two with the field resistance character and one without.

Sites Four trial locations in the UK were used. Three were provided by Arable Research Centres and one by New Farm Crops.

Virus Diagnosis Symptoms are usually readily visible in spring barley crops but can be masked by other diseases, especially brown rust, and yellowed infected plants also seem attractive to grazing animals possibly because of the larger concentrations of carbohydrates in these leaves compared with healthy ones. Definitive virus diagnosis was made using ELISA for the three principal BYDV isolates known to occur in the UK, the PAV-, MAV- and RPV- serotypes. Recent evidence suggests that the differences between RPV and PAV and MAV serotypes are sufficient to distinguish them as two distinct viruses.

The seed was kindly treated with imidacloprid each year by Bayer.

Linked Research Barley growers in New Zealand face many similar agronomic problems to those encountered in the UK and much early work on BYDV was done in New Zealand (Smith 1963. 1964). The Foundation for Arable Research (FAR) in New Zealand is a levy-based organisation which has developed a collaborative research agreement with ARC. FAR agreed to conduct identical trials with the seed treatments kindly provided by Bayer and antiserum and protocols for ELISA diagnosis were provided by IACR-Rothamsted. As the New Zealand season is six months later than that in the UK this trial series will be reported as a separate section to the main Research Report.

Trials locations and treatments

Each season the trials were conducted at four locations in the UK, three under the supervision of Arable Research Centres (ARC) and one of New Farm Crops (NFC).

ARC (Cirencester) - Gloucestershire
ARC (Caythorpe)- Lincolnshire
ARC (Andover) - Hampshire
NFC (Horncastle)- Lincolnshire

Experience of this type of experimentation necessitated a specific layout design provided by IACR Rothamsted. Interaction and interference between plots is a well documented problem in insect control trials so whilst each treatment plot was replicated three times there was also a system of buffer plots between treatment plots to restrict/minimise plot to plot influences.

In all three seasons, the same three spring barley varieties were evaluated. CORK and OPTIC (NIAB) are considered to be tolerant of BYDV infection whereas the third variety DERKADO (NIAB 3) was susceptible to BYDV.

The target drilling dates were planned to expose the emerging crops into two levels of risk from BYDV infection. Crops drilled during the early drilled window of mid February through to mid March are considered to be at low risk from BYDV infection as aphid activity is low during the early growth stages of the crop. The drilling dates that are more at risk from BYDV infection are those associated with higher temperatures (more aphid flight activity) and the second target drilling date was therefore approximately a month later in April.

The drilling dates over the three seasons are given in table 1.

Table 1 - Drilling dates at the four test sites

	Cirencester	Caythorpe	Andover	Horncastle
1996	5 March	8 March	14 March	21 March
	10 April	10 April	11 April	18 April
1997	5 March	5 February	10 March	5 March
	9 April	17 April	4 April	1 May
1998	17 February	18 February	20 February	23 March
	30 April	20 March	28 April	28 April

In 1996 and 1997 target drilling dates were achieved at all but one location. The exception, May 1st at Horncastle did establish satisfactorily but difficult harvest conditions led to excessive grain sprouting and the data from this drilling date was excluded from all analyses.

The 1998 spring was difficult with continued rainfall through much of April making drilling conditions difficult to achieve in some locations. However all trials were successfully implemented.

The individual seed treatments/foliar insecticide treatments conducted at each location are given in Table 2.

Table 2 - Seed Treatments and Insecticide Sprays

Seed Treatment	T_1	T_2
Raxil S	-	-
Raxil S		Decis (200 ml/ha)
Raxil S	Decis (200 ml/ha)	Aphox (280 g/ha)
Raxil S + Imidacloprid	-	-
Raxil S + Imidacloprid	-	Decis (200 ml/ha)

The T_1 timing ranged from late April to very early June over the three seasons of trials. The T_2 application was in mid to late June.

The Imidacloprid seed treatment was applied to seed already treated with Raxil S (tebuconazole plus triazoxide).

Assessments

All sites were monitored regularly for the presence of aphids and BYDV. Other factors that could influence yield and hence the interpretation of results were also recorded. These observations included the presence of fungus diseases, especially brown rust in 1998, grazing mainly by rabbits and usually worst on the later-sown plots, erosion, in 1996. No systematic counts were made.

On all occasions visual symptoms of BYDV were recorded either by direct counts of the number of infected plants per plot, or when infection was more extensive by an estimate of the percentage of plot infected. In most years these results were consistent between treatments although rarely was infection widespread.

On each sampling occasion collections of leaves were made at random from plants believed to be showing symptoms of BYDV infection and of leaves from plants not showing symptoms. Each of these samples, more than 2000 in total, were analysed by ELISA using standard methods and protocols. Internal positive standards were provided from the IACR-Rothamstead isolate collection. The antibodies for all tests were from AGDEN, Auchincruive so that the results from year to year were directly comparable. The three isolates for which tests were done were:-

PAV - Transmissible by both grain *(Sitobion avenae)* and bird cherry *Rhopalosiphum padi)* aphids

MAV - transmissible by the grain aphid

RPV - transmissible by the bird cherry aphid

These three isolates constitute more than 99% of all isolates previously recorded in the UK. The only other isolate that could occur is the RMV isolate which is entirely associated with the maize aphid *Rhopalosiphum maidis* which, despite its name has only ever been found on barley in the UK. In the three years of experiments *R.maidis* was only seen in 1997 at the Horncastle site and then it was not seen on trial plots.

Results

Aphids While it was not possible to record aphid populations in detail at each site observations of presence or absence of each of the species, *Sitobion avenae, Rhopalosiphum padi,* and the leaf-feeding species *Metopolophium dirhodium* were noted.

In no year at no site and on no sampling occasion were aphids numerous. There were always more apparent aphids present later in the season, on the second virus sampling occasion, than earlier. Also later in the season parasitised aphids were present but in small numbers. The site with the most aphids was Andover in 1997. The only aphids frequently seen were *S.avenae* and *M.dirliodium*. This is partly because these two species feed on leaves and/or ears whereas *R.padi* is more often found feeding on stems, or pseudostems, close to ground level. However, close inspection of plants rarely found *R. padi.*

Aphid populations can be very volatile and it is possible that populations were greater at times other than when sampling was done. However , previous experience suggests that this was unlikely as barley is not a favoured host for aphids and at the outset of ripening populations of aphids rapidly decline.

BYDV Infection Levels

The three seasons of trials produced different levels of BYDV infections. In both 1996 and 1997 visual levels of BYDV infection were low and this was confirmed by the recovery of only a low number of isolates from tissue samples.

In 1998 both visual and ELISA assessments of virus infection levels were higher than in previous seasons.

1996

The 1996 trials gave the lowest infection levels with a few BYDV symptoms being recorded at Caythorpe but not at the other three locations. However ELISA tests did indicate slightly higher infection levels predominantly in the later drilled plots. Averaged across the four locations the number of isolates detected were.

Optic - 16 (all in later drilled plots)
Cork - 8 (7 in later drilled and 1 an early drilled plots)
Derkado - 17 (15 in later drilled and 2 in early drilled plots)

As both Optic and Cork are considered resistant to BYDV infection and Derkado very susceptible the differences were not as marked as had been anticipated.

1997

The levels of infection detected in plant samples using ELISA techniques in 1997 were higher than 1996 but a key feature was the difference between locations (Table 3). The infection levels at the four locations were

Table 3 BYDV Infection (plants/plot) - 1997

	Total	Early Drilled	Later Drilled
Andover	240	54	186
Caythorpe	47	1	46
Cirencester	42	18	24
Horncastle	46	0	46

An interesting feature of the Andover location was that 94% of the isolates were MAV (transmitted by the grain aphid) whereas at the other three locations RPV isolates were dominant, Caythorpe (89%), Cirencester (100%) and Horncastle (96%). RPV is only transmitted by the bird cherry aphid.

The influence of variety and drilling date (Table 4) on the levels of isolates identified were as follows

Table 4 BYDV Infection (plants/plot) - 1997

	Optic	Cork	Derkado
Early Drilled	25	12	36
Late Drilled	87	76	139
Total	**112**	**88**	**175**

The key features from isolate detection were that later drilling encountered more BYDV infection and that the most susceptible variety (Derkado) clearly exhibited the highest levels of infection.

1998

The high BYDV infection levels in 1998 emphasised the drilling date and variety influences that had previously been noted. However there did not appear to be any consistent differences in infection levels between the different treatments applied to a specific variety (Table 5)

Table 5 BYDV Infection (plants/plot) - 1998

	Total	Early Drilled	Late Drilled	
		Assessed 12/6	Assessed 12/6	Assessed 16/7
Andover		347	190	1346
Caythorpe		454	790	2940
Cirencester		462	241	3208*
Horncastle		505	887	3082

*Cork not included in this figure as unable to assess.

Two of the locations initially indicated higher levels of BYDV infection from the early rather than later drillings. However, when a later assessment was made on the later drillings the levels were very much higher than the earlier assessments.

Using the data from the June 12th assessment the influences of variety on BYDV infection level can be determined (Table 6)

Table 6 BYDV Infection (plants/plot) - 1998

	Optic	Cork	Derkado
Early Drilled	620	493	655
Late Drilled	675	604	829
Total	**1295**	**1097**	**1484**

The variety considered most susceptible to BYDV infection was marginally worse, by ELISA diagnosis, than the two BYDV resistant varieties. By contrast with 1997 MAV and PAV isolates predominated at all sites (Table 7)

Table 7 **Percentage of BYDV isolates in 1998**

RPV		PAV	MAV	
Andover	June	30.7	68.0	1.3
	July	29.2	66.6	4.2
Caythorpe	June	33.4	65.4	<1
	July	38.5	65.4	2.0
Cirencester	June	13.3	86.3	<1
	July	7.1	90.2	2.5
Horncastle	June	17.2	81.1	<1
	July	41.0	54.0	4.9

While there were small differences between sites, Cirencester for example had an especially high proportion of MAV isolates, the only consistent trend was for RPV isolates to be more common in July than in June. This may reflect the generally later invasion of the crop by this species. It might have been expected that this pattern of RPV occurrence would also be reflected in the different drilling dates. However, at two sites Andover and Caythorpe no RPV isolates were found on the early-drilled crop whereas at Cirencester and Horncastle most RPV infection was on crops sown late (Table 8). There was no clear pattern in the occurrence of MAV PAV isolates although at three sites Caythorpe, Cirencester and Horncastle there was proportionately more MAV on the late than on the early-sown plots.

Table 8 **Percentages of BYDV isolates on crops sown early or late**

RPV		PAV	MAV	
Andover	Early Drilled	31.3	68.1	0
	Late Drilled	30.1	67.8	1.3
Caythorpe	Early Drilled	44.0	48.5	0
	Late Drilled	23.6	59.5	<1
Cirencester	Early Drilled	24.0	71.4	3.1
	Late Drilled	5.5	94.5	0
Horncastle	Early Drilled	25.4	71.4	2.3
	Late Drilled	10.4	89.2	<1

Influence of drilling date on yield

Whilst the influence of drilling date on BYDV infection levels was anticipated the influence upon yield was greater than expected.

A comparison of conventionally treated seed (Raxil S) with no foliar insecticide applications at the different drilling dates over the three seasons gave the following results (Table 9)

Table 9 - Yield and yield loss (t/ha and %) due to later drilling (Raxil S treatments)

	Cork			Optic			Derkado		
1996	**ED**	**LD**	**% Loss**	**ED**	**LD**	**% Loss**	**ED**	**LD**	**% Loss**
ARC (Caythorpe)	6.39	6.01	-5.9	6.79	5.99	-11.8	6.60	5.68	-13.9
ARC (Andover)	7.61	5.94	-21.9	8.03	6.22	-22.5	7.43	5.87	-21.0
ARC (Cirencester)	5.17	5.80	+12.2	5.10	4.40	-13.7	3.73	4.16	+11.5
NFC (Horncastle)	8.84	4.95	-44.0	8.60	5.00	-41.9	7.44	4.51	-39.4
			-14.9%			**-22.5%**			**-15.7%**

The average loss of yield due to later drilling was -17.7%, but there was considerable variation between locations. At Cirencester both Cork and Derkado actually gave higher yields from the later drillings and in both cases the responses were significant.

In 1997 the most severely infected location was Andover but the greatest yield losses due to later drilling were consistently recorded at Caythorpe (Table 10)

Table 10 - Yield and yield Losses (t/ha and %) due to later drilling (Raxil S treatment)

	Cork			Optic			Derkado		
1997	**ED**	**LD**	**% Loss**	**ED**	**LD**	**% Loss**	**ED**	**LD**	**% Loss**
ARC (Caythorpe)	6.39	2.34	-60.4	5.41	2.53	-53.3	5.76	3.47	-39.8
ARC (Andover)	4.16	3.53	-15.1	4.31	3.50	-18.8	4.81	3.82	-20.6
ARC (Cirencester)	7.05	5.98	-15.2	6.86	5.29	-22.9	6.79	6.07	-10.6
NFC (Horncastle)									
			-30.2			**-31.7**			**-23.7**

The second drilling date at the Horncastle location was unsuccessful, but the overall loss of yield resulting from late drilling was -28.5% from the remaining three locations.

The BYDV infection levels in 1998 were the highest in the three seasons in trial and the yield depressions resulting from later drilling were also highest in this season (Table 11)

Table 11 - **Yield and yield loss (t/ha and %) due to later drilling (Raxil S treatment)**

	Cork			Optic			Derkado		
1998	**ED**	**LD**	**% Loss**	**ED**	**LD**	**% Loss**	**ED**	**LD**	**% Loss**
ARC (Caythorpe)	6.41	6.05	-5.6	6.37	5.99	-6.0	5.46	5.87	+7.5
ARC (Andover)	5.09	1.38	-72.9	5.28	2.06	-61.0	4.96	1.60	-67.7
ARC (Cirencester)	6.21	3.39	-45.4	4.53	2.42	-46.6	3.73	1.98	-46.9
NFC (Horncastle)	8.58	6.30	-26.6	6.93	6.25	-9.2	7.88	5.23	-33.6
			-37.6			**-30.7**			**-35.2**

The 1998 season produced greater yield losses than previous seasons, particularly at two locations Cirencester and Andover. The overall loss of yield through delayed drilling was -34.5%

Averaged across the three seasons the loss of yield resulting from later drilling was -26.9%.

Influence of seed/foliar treatment

The BYDV infection levels observed in the different treatments and measured by ELISA techniques did not indicate consistent differences between treatments. This was also supported by the yield data which indicated few consistent differences between treatments.

The % yield responses from the five different treatments applied to the three varieties, at the four locations have been averaged across the three seasons and are presented in Table 12.

Table 12 - Percentage Yield Responses to insecticide treatments - (4 locations x 3 Years)

	Early Drilled	Later Drilled
Cork		
Raxil S	0	0
Raxil S + insecticide	+3.4	-0.5%
Raxil S + insecticide (x2)	+3.9	+3.8%
Imidacloprid	+2.4	+1.7%
Imidacloprid + insecticide	+2.9	+2.9%
Optic		
Raxil S	0	0
Raxil S + insecticide	+0.8	+3.8
Raxil S + insecticide (x2)	+0.8	+2.1
Imidacloprid	+0.6	+0.3
Imidacloprid +insecticide	+4.0	+0.4
Derkado		
Raxil S	0	0
Raxil S + insecticide	+0.5	+2.7
Raxil S + insecticide (x2)	+4.1	+8.9
Imidacloprid	+2.0	+6.1
Imidacloprid +insecticide	+2.6	+6.5

The highest responses to treatment were recorded in the most BYDV susceptible variety Derkado at the latest drilling date. This was the anticipated result but the highest averaged response was only +8.9% which was a result of the twice applied foliar insecticide treatment.

However these relatively small changes in performance when averaged across several locations and seasons conceal substantial variations between varieties, treatments and seasons.

Optic Thirty of the 92 treatments that were compared to Raxil S seed treatment produced significant yield responses (Table 13)

Table 13 Significant yield responses compared to Raxil S

	Yield Increase	Yield Decrease
Raxil S + insecticide	4	3
Raxil S + insecticide (x2)	6	2
Imidacloprid	2	3
Imidacloprid +insecticide	6	4

The highest number of significant positive yield responses came from the sequential treatments of either Imidacloprid followed by foliar insecticide or sequential insecticide treatments. However 12 treatments did result in significant yield penalties.

Cork - Twenty six of the 92 treatments that were compared to Raxil S seed treatment produced significant yield responses (Table 10). However 7 of those 26 significant responses were lower yielding than Raxil S

Table 14 - **Significant Yield Responses Compared to Raxil S**

	Yield Increase	Yield Decrease
Raxil S + Insecticide	6	2
Raxil S + Insecticide (x2)	5	1
Imidacloprid	4	2
Imidacloprid + Insecticide	4	2

Derkado - In comparison to Raxil S treated seed, 19 treatments gave significant increases in yield over the standard seed testament and three treatments gave significantly lower yields (Table 15)

The actual number of significant responses produced over the three seasons to the different individual treatments were

Table 15 **Significant yield responses compared to Raxil S**

	Yield Increase	Yield Decrease
Raxil S + insecticide	4	1
Raxil S + insecticide (x2)	9	1
Imidacloprid	2	0
Imidacloprid +insecticide	3	1

The sequential application of two foliar insecticides was clearly the most effective treatment on this variety.

The individual results from each variety at each location over the three year trial programme are presented in the Tables 16 to 18.

In each case the yield data is expressed as a % of the seed treated with Raxil S only and not receiving a foliar insecticide treatment. The yield of this control treatment is also presented.

An asterisk (*) indicates that the designated yield figure was significantly different from the control treatment.

Cork

This variety is considered to have field resistance to BYDV infection.

Table 16 - The influence of drilling date, seed treatment and foliar insecticide on the yield of Cork

ARC Caythorpe

	Early Drilled				Late Drilled			
	8.3.96	5.2.97	18.2.98	Mean	10.4.96	17.4.97	20.3.98	Mean
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	109.4*	105.4	103.7	**106.2**	97.8	116.7*	99.3	**104.6**
Raxil S + insecticide (X2)	103.4	104.0	104.4	**103.9**	101.3	125.2*	102.6	**109.7**
Imidachloprid	103.8	100.3	102.8	**102.3**	96.2	126.1*	97.0	**106.4**
Imidachloprid + insecticide	106.6*	102.0	102.5	**103.7**	94.0*	142.3*	90.7*	**109.0**
Control Yield (t/ha)	(6.39)	(5.94)	(6.41)		(6.01)	(2.34)	(6.05)	

ARC (Andover)

	Early Drilled				Late Drilled			
	14.3.96	10.3.97	20.2.98	Mean	11.4.96	4.4.97	28.4.98	Mean
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	102.1	114.9	102.9	**106.6**	105.7*	89.0	95.7	**96.8**
Raxil S + insecticide (X2)	100.3	108.7	102.3	**103.8**	104.2	107.9	115.2	**109.1**
Imidachloprid	97.2	122.8*	98.6	**106.2**	103.4	65.7*	127.5*	**98.9**
Imidachloprid + insecticide	96.8	118.5*	99.0	**104.8**	105.2	94.1	118.1	**105.8**
Control Yield (t/ha)	(7.61)	(4.16)	(5.09)		(5.94)	(3.53)	(1.38)	

ARC (Cirencester)

	Early Drilled				Late Drilled			
	5.3.96	5.3.97	17.2.98	**Mean**	10.4.96	9.4.97	30.4.98	**Mean**
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	83.0*	105.0*	107.1*	**98.4**	83.3*	104.0	98.2	**95.2**
Raxil S + insecticide (X2)	96.7	106.0*	111.3*	**104.7**	85.2*	96.0	112.7*	**98.0**
Imidachloprid	89.6*	102.0	106.1*	**98.6**	86.0	97.0	102.7	**95.2**
Imidachloprid + insecticide	93.2	100	103.1	**98.8**	97.4	99.0	98.2	**98.2**
Control Yield (t/ha)	(5.17)	(7.05)	(6.21)		(5.80)	(5.98)	(3.39)	

NFC (Horncastle)

	Early Drilled				Late Drilled		
	21.3.96	15.3.97	23.3.98	**Mean**	18.4.96	28.4.98	**Mean**
Raxil S	100	100	100	**100**	100	100	**100**
Raxil S + insecticide	101.7	108.6*	96.6	**102.3**	106.5	98.4	**102.4**
Raxil S + insecticide (X2)	103.2	107.5*	99.1	**103.3**	88.5	103.3	**95.9**
Imidachloprid	101.4	103.7	100.9	**102.0**	112.9	103.7	**108.3**
Imidachloprid + insecticide	102.9	112.5*	97.9	**104.4**	90.9	101.9	**96.4**
Control Yield (t/ha)	(8.84)	(6.25)	(8.58)		(4.95)	(6.30)	

OPTIC

This variety like Cork has field resistance to BYDV

Table 17 - **The influence of drilling date, seed treatment and foliar insecticide on the yield of Optic**

ARC (Caythorpe)

	Early Drilled				Late Drilled			
	8.3.96	5.2.97	18.2.98	**Mean**	10.4.96	17.4.97	20.3.98	**Mean**
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	106.6*	104.4	99.7	**103.6**	106.0*	102.4	97.2	**101.9**
Raxil S + insecticide (X2)	101.0	103.5	103.0	**102.5**	98.0	115.8*	91.3*	**101.7**
Imidachloprid	103.4	100.7	102.4	**102.2**	104.8	119.0*	94.0	**105.9**
Imidachloprid + insecticide	101.6	98.5	100.8	**100.3**	87.2*	121.3*	91.2	**99.9**
Control Yield (t/ha)	(6.79)	(5.41)	(6.37)		(5.99)	(2.53)	(5.99)	

ARC (Andover)

	Early Drilled				Late Drilled			
	14.3.96	10.3.97	20.2.98	**Mean**	11.4.96	4.4.97	28.4.98	**Mean**
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	92.5*	102.6	95.8	**97.0**	100	106.0	86.9*	**97.6**
Raxil S + insecticide (X2)	95.6*	96.3	97.3	**96.4**	100.3	83.1	94.2	**92.5**
Imidachloprid	90.0*	96.8	93.2*	**93.3**	102.4	98.3	80.6*	**93.8**
Imidachloprid + insecticide	98.4	118.6*	101.5	**106.2**	104.2	75.1*	86.4*	**88.6**
Control Yield (t/ha)	(8.03)	(4.31)	(5.28)		(6.22)	(3.50)	(2.06)	

ARC (Cirencester)

	Early Drilled				Late Drilled			
	5.3.96	5.3.97	17.2.98	**Mean**	10.4.96	9.4.97	30.4.98	**Mean**
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	89.2*	102.0	111.5*	**100.9**	105.4	102.8	130.2*	**112.8**
Raxil S + insecticide (X2)	95.5	100	107.9*	**101.1**	109.8*	102.1	113.2*	**108.4**
Imidachloprid	96.7	102.0	109.1*	**102.6**	104.8	97.9	107.4	**103.4**
Imidachloprid + insecticide	95.5	104.9*	109.9*	**103.4**	105.2	104.9	109.9*	**106.7**
Control Yield (t/ha)	(5.10)	(6.86)	(4.53)		(4.40)	(5.29)	(2.42)	

NFC (Horncastle)

	Early Drilled				Late Drilled		
	21.3.96	15.3.97	23.3.98	**Mean**	18.4.96	28.4.98	**Mean**
Raxil S	100	100	100	**100**	100	100	**100**
Raxil S + insecticide	97.7	104.9	102.7	**101.8**	103.8	101.6	**102.7**
Raxil S + insecticide (X2)	99.2	109.0*	101.2	**103.1**	123.4*	93.6	**108.5**
Imidachloprid	105.1	102.5	105.3	**104.3**	103.6	90.6	**97.1**
Imidachloprid + insecticide	104.3	110.9*	102.7	**106.0**	103.6	97.1	**100.4**
Control Yield (t/ha)	(8.60)	(5.67)	(6.93)		(5.00)	(6.25)	

DERKADO

This variety is considered susceptible to BYDV infection

Table 18 - The influence of drilling date, seed treatment and foliar insecticide on the yield of Derkado

ARC (Caythorpe)

	Early Drilled				Late Drilled			
	8.3.96	5.2.97	18.2.98	**Mean**	10.4.96	17.4.97	20.3.98	**Mean**
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	102.4	100.2	104.6	**102.4**	109.9*	94.8	108.5*	**104.4**
Raxil S + insecticide (X2)	100.9	98.1	98.7	**99.2**	98.6	97.1	108.3*	**101.3**
Imidachloprid	100.1	96.4	102.9	**99.8**	97.5	90.8	105.4	**97.9**
Imidachloprid + insecticide	105.9*	105.0	101.5	**104.1**	93.7*	104.6	104.6	**101.0**
Control Yield (t/ha)	(6.60)	(5.76)	(5.46)		(5.68)	(3.47)	(5.87)	

ARC (Andover)

	Early Drilled				Late Drilled			
	14.3.96	10.3.97	20.2.98	**Mean**	11.4.96	4.4.97	28.4.98	**Mean**
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	105.8	96.0	99.2	**100.3**	100.7	97.6	115.6	**104.6**
Raxil S + insecticide (X2)	106.5*	115.6	106.7	**109.6**	103.2	103.4	132.5*	**113.0**
Imidachloprid	97.6	110.8	105.2	**104.5**	102.6	108.9	116.2	**109.2**
Imidachloprid + insecticide	102.6	101.2	99.0	**100.9**	101.9	105.5	128.7*	**112.0**
Control Yield (t/ha)	(7.43)	(4.81)	(4.96)		(5.87)	(3.82)	(1.60)	

ARC (Cirencester)

	Early Drilled				Late Drilled			
	5.3.96	5.3.97	17.2.98	**Mean**	10.4.96	9.4.97	30.4.98	**Mean**
Raxil S	100	100	100	**100**	100	100	100	**100**
Raxil S + insecticide	111.0*	100	81.2*	**97.4**	97.1	104.0	90.4	**97.2**
Raxil S + insecticide (X2)	112.1*	94.0*	94.6	**100.2**	116.1*	104.9*	112.6*	**111.2**
Imidachloprid	104.3	105.0*	94.4	**101.2**	123.6*	102.0	108.1	**111.2**
Imidachloprid + insecticide	109.7	101.0	98.1	**102.9**	109.1*	104.0	97.5	**103.5**
Control Yield (t/ha)	(3.73)	(6.79)	(3.73)		(4.16)	(6.07)	(1.98)	

NFC (Horncastle)

	Early Drilled				Late Drilled		
	21.3.96	15.3.97	23.3.98	**Mean**	18.4.96	28.4.98	**Mean**

Raxil S	100	100	100	**100**	100	100	**100**
Raxil S + insecticide	101.2	104.6	99.9	**101.9**	97.3	114.1	**105.7**
Raxil S + insecticide (X2)	105.9	110.5*	105.8	**107.4**	98.9	122.6*	**110.7**
Imidachloprid	103.4	101.7	102.4	**102.5**	103.3	109.0	**106.2**
Imidachloprid + insecticide	100.7	105.1	101.9	**102.6**	107.8	114.5	**111.2**
Control Yield (t/ha)	(7.44)	(5.89)	(7.88)		(4.51)	(5.23)	

Conclusions

One of the key features of this series of seed treatment and foliar insecticide treatments on the spring barley varieties was the unpredictability of the response patterns. The largest significant yield response that was recorded in the three seasons of trials was +42.3% comparing Imidacloprid + one insecticide with a Raxil S seed treatment. This was generated at the Caythorpe location in the 1997 season on the variety Cork. However in the two seasons each side of this 1996 and 1998 the same late drilled treatment on Cork gave significant yield reductions of -6.0% and -8.8% respectively.

Another illustration of this inconsistency again occurs with Cork a variety considered as resistant to BYDV. The straight Imidacloprid seed treatment at a later drilling date in 1997 gave a yield significantly lower than Raxil S by 34.3% at the Andover location. However the same treatment in 1998 produced a significant yield advantage over Raxil S from a later drilling of +27.5%.

It has been very difficult to relate any of the yield responses to the infection patterns of BYDV other than to indicate that the largest negative responses overall to late drilling were in the 1998 season when the highest levels of BYDV infection were recorded.

The visual observations and ELISA analysis techniques confirmed that generally BYDV infection levels are higher at later drilling dates.

Cork was the variety that overall had the lowest BYDV infection levels, followed by Optic and Derkado. This generally follows the pattern anticipated by the ratings for the individual varieties susceptibility to BYDV.

The application of an aphicide by either a seed treatment (Imidacloprid) or a foliar insecticide had little influence on the incidence of the virus although untreated plots did have slightly more cases of virus infection. This would suggest that the majority of infections were a result of primary infections (infected aphids flying into crops) and there was little secondary infection (movement of an infected aphid within a crop). As levels of infection were high in some cases it would suggest that none of the treatments, seed or foliar, successfully controlled primary infections.

The use of earlier drilling dates and variety resistance would appear to be the most effective ways of reducing BYDV infection levels in spring barley. Responses from seed treatment and foliar insecticides appeared to be too inconsistent to justify their use alone or in combination to reduce BYDV infections of spring barley.

The results do not support the use of insecticides either as seed treatments or sprays on spring barley.

Usual agronomic practice, i.e. drilling as early as practicable is the best method of virus control.

BYDV 'field resistance' is a useful character but is rarely the difference between a good or bad yield and should not be the main criterion for choosing a cultivar.

There was no suggestion that BYDV on spring barley is a serious problem other than in relatively unusual circumstances, especially those that delay drilling.