# ANNUAL REPORT

To:
Horticultural Development Council
Bradbourne House
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Kent, ME19 6DZ

## Reducing losses from virus-induced storage disorders of processing cabbage

## FV 160b

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February 2007

Commercial - In Confidence

# Grower Summary

## FV 160b

## Reducing losses from virus-induced storage disorders of processing cabbage

**Annual Report 2007**

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| **Project Title** | Reducing losses from virus-induced storage disorders of processing cabbage |
| **Project number:** | FV 160b |
| **Project leader:** | John A. Walsh, Warwick HRI |
| **Report:** | Annual report, February 2007 |
| **Previous report** | |
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| **Location of project:** | Warwick HRI and Allium and Brassica Centre |
| **Project coordinator:** | Dick Evenden, H.L. Hutchinson Ltd., Boston, Lincolnshire. |
| **Date project commenced:** | February, 2006 |
| **Date completion due:** | 30 September, 2008 |
| **Key words:** | Processing cabbage, brassicas, storage, cultivars, internal disorders, viruses, tipburn, cigar burn, *Beet western yellows virus* (BWYV), *Turnip mosaic virus* (TuMV), time of infection, aphid, insecticide, Gaucho, imidaclopirid, Aphox, pirimicarb, Hallmark |

**Signed on behalf of: Warwick HRI**

***Signature***:..... … *Simon Bright* ..... Date: 1 October 2007

***Name:*** Professor Simon Bright
Director and Head of Department



The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and

the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

**AUTHENTICATION**

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

John A. Walsh
Project leader
Warwick HRI

Signature ..... Date .....

Andrew Richardson
Collaborator
Allium and Brassica Centre

Signature ..... Date .....

**Report authorised by:**

Professor S. Bright
Director and Head of Department
Warwick HRI

Signature ..... Date .....

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## Grower Summary

### Headline

- Examination of symptoms prior to harvest revealed that some varieties showed more severe Turnip Mosaic Virus (TuMV) symptoms than others. Serological testing of plants showed that some varieties contained more Beet Western Yellows Virus (BWYV) than other varieties. Weighing cabbage heads at harvest showed that the yields of some varieties were significantly reduced by virus infection.
- Monitoring of natural infection in Lincolnshire showed BWYV infection appearing soon after 13 July, 2006 and by 29th August, 2006, most plants were infected. Very little BWYV infection was detected after 24th August within two of the crops, whereas in the third crop, a further 25.5% of plants had become infected.
- The spread of the virus coincided with a rapid increase in the numbers of aphids (mostly *Myzus persicae* but also *Brevicoryne brassicae*).
- We successfully infected covered plots of cabbage plants in the field with BWYV in May, August, or October 2006. This will allow us to determine the effect of time of BWYV infection on symptom severity.

### Background and expected deliverables

Cabbage growers have experienced significant losses due to the internal disorders caused by viruses. In most years, losses of at least 3-5% are recorded, with much higher losses in some years, where some co-operatives and growers have recorded complete losses of stored material (up to 1200 tonnes in one store), with others suffering substantial losses in the range of 15-20%. In 2005, one grower alone recorded losses of £200,000.

The HortLink project carried out by John Walsh's group at HRI, Wellesbourne showed that *Beet western yellows virus* (BWYV) caused internal tipburn in processing cabbage and *Turnip mosaic virus* (TuMV) caused cigar burn. Both these viruses also significantly reduced the head weight of cabbage.

There were very big differences in the susceptibility of the 2 cabbage cultivars studied to tipburn and cigar burn. With the exception of these two cultivars, there is no reliable information on the relative susceptibilities of most current cabbage cultivars to these disorders

The HortLink project showed that later infection by TuMV (in June) increased the severity of cigar burn symptoms relative to earlier infection (during propagation). There is no information on the effect of time of infection by BWYV on the severity of tipburn symptoms.

In trials conducted by HRI, neither Gaucho (seed treatment) nor Aztec (3 sprays) were effective in controlling BWYV in cabbage, consequently alternative control measures are needed urgently. By identifying the cabbage cultivars that are most tolerant to tipburn and cigar burn, growers will be able to minimise losses caused by BWYV and TuMV. In the longer term, effective insecticides need to be identified and genetic resistance to both these viruses needs to be incorporated in to commercial brassica cultivars.

The expected deliverables from this project are:

- A database of relative susceptibilities of different processing cabbage to virus-induced tipburn and virus-induced cigar burn
- A database of the yield reduction of different processing cabbage cultivars due to infection by BWYV and TuMV
- These databases would allow growers to reduce losses from the internal disorders by selecting varieties that are less susceptible to such problems
- The time of infection of cabbage by BWYV will be determined in Lincolnshire in natural crop situations. This information will allow growers to target their control strategies more effectively. It will also allow future experiments on the efficacy of insecticide trials to be carried out in a more rational and informed way, targeting experimental treatments at the most important times.
- Any differences in the effect of time of infection by BWYV on tipburn severity will inform growers of the more important stages in crop growth for controlling BWYV and hence tipburn.

**Summary of the project and main conclusions**

- Plants of the 15 cultivars of processing cabbage growing in gauzehouses at Wellesbourne were successfully infected with TuMV, or BWYV and the uninfected plots were maintained uninfected.

- Testing the plants by enzyme-linked immunosorbent assay (ELISA) showed that some cultivars contained different amounts of BWYV to others.

- Visual assessment of the severity of external leaf symptoms induced by TuMV revealed that some cultivars showed less severe symptoms than others. Four cultivars showed no significant levels of symptoms. No clear symptoms of BWYV infection were seen in the gauzehouses, although some BWYV-infected plants were clearly smaller than uninfected plants of the same cultivar.

- Weighing heads at harvest showed that the yield of some cultivars was significantly reduced by virus infection. BWYV appeared to reduce yields more than TuMV.

- Monitoring natural infection of cabbage growing in plots within commercial crops at three different locations in Lincolnshire showed that infection started to spread in to the plots soon after 13 July and by 29th August, most plants were infected.

- Infection appeared to spread earlier / more rapidly at one of the sites than at the other two.

- Very little spread of infection was detected after 24th August within two of the crops, whereas in the third crop, a further 25.5% of plants were infected by 7th November.

- Covered plots of cabbage plants growing within a commercial crop in Lincolnshire were successfully infected with BWYV in May, August, or October 2006, or left uninfected in order to study the effect of time of infection on the severity of tipburn symptoms.

- All cabbage heads from all plots were successfully harvested in November and put in to a commercial store. These will be assessed later in the year after the store is opened.

**Financial benefits**

Until we have all the data and it has been fully analysed it is difficult to be specific about financial benefits, however, the results so far look very promising and it should be possible to provide growers with reliable information on the relative susceptibilities of current cabbage cultivars to tipburn and cigar burn and inform them of the most important times to target their insecticidal treatments in order to minimise losses from these two internal disorders.

**Action points for growers**

- Until we have data on the relative susceptibilities of cabbage cultivars (to tipburn, cigar burn and yield reduction) from two growing seasons, we do not wish to speculate on which are less susceptible than others.

- As BWYV infection seemed to appear soon after the aphid numbers caught in the suction trap in Lincolnshire peaked, if growers are concerned about virus infection and internal disorders, accessing data on aphid catches will give them an indication of when aphids are starting to fly and hence the most important time to spray crops for aphid control.

- Information on the effect of time of infection on the yield of cabbage and severity of tipburn and cigar burn will inform growers as to when the most important times for controlling aphids are in order to minimise losses from internal disorders.

Note:- Beet Western Yellows Virus (BWYV) has been renamed Turnip Yellow Virus (TuYV)

# Science Section

## Introduction

Cabbage growers have experienced significant losses due to the internal disorders caused by viruses. In most years, losses of at least 3-5% are recorded, with much higher losses in some years, where some co-operatives and growers have recorded complete losses of stored material (up to 1200 tons in one store), with others suffering substantial losses in the range of 15-20%. In 2005, one grower alone recorded losses of £200,000.

The HortLink project carried out by John Walsh's group at HRI, Wellesbourne showed that *Beet western yellows virus* (BWYV) caused internal tipburn in processing cabbage and *Turnip mosaic virus* (TuMV) caused cigar burn. Both these viruses also significantly reduced the head weight of cabbage.

There were very big differences in the susceptibility of the 2 cabbage cultivars studied to tipburn and cigar burn. With the exception of these two cultivars, there is no reliable information on the relative susceptibilities of most current cabbage cultivars to these disorders.

The HortLink project showed that later infection by TuMV (in June) increased the severity of cigar burn symptoms relative to earlier infection (during propagation). There is no information on the effect of time of infection by BWYV on the severity of tipburn symptoms.

In trials conducted by HRI, neither Gaucho (seed treatment) nor Aztec (3 sprays) were effective in controlling BWYV in cabbage, consequently alternative control measures are needed urgently. By identifying the cabbage cultivars that are most tolerant to tipburn and cigar burn, growers will be able to minimise losses caused by BWYV and TuMV. In the longer term, effective insecticides need to be identified and genetic resistance to both these viruses needs to be incorporated in to commercial brassica cultivars.

Prior to this project there was no reliable comparative data on the relative susceptibilities of different cabbage cultivars to tipburn and cigar burn. If the industry has this information, they will be able to make informed choices of cultivars in order to reduce or minimise risk from tipburn and cigar burn.

Although information has been obtained from the earlier HortLINK project on the effect of time of TuMV infection on the severity of cigar burn symptoms, nothing is known about the effect of time of infection by BWYV on the severity of tipburn symptoms. Providing this information will allow aphid control treatments to be targeted/timed more effectively.

Information on cultivar susceptibility will provide options for growers to reduce losses from tipburn and cigar burn and minimise the chances of rejection of produce by processors

**Materials and Methods**

*Virus isolates used in experiments at Warwick HRI and in Lincolnshire.*

The UK isolate of *Beet western yellows virus* (BWYV) found to cause tipburn by Hunter *et al*. (2002) was used in those experiments where we deliberately infected plants for experimental purposes. BWYV is not mechanically transmissible, so aphids have to be used to infect plants with this virus. The UK 2 isolate of TuMV (Walsh, 1989) shown to cause cigar burn of cabbage (Hunter *et al.* 2002) was also used in these experiments. TuMV is mechanically transmissible so can be inoculated to plants by rubbing inoculum on to leaves and aphids don't have to be used.

*Cabbage cultivars used in experiments at Warwick HRI and in Lincolnshire.*

The 15 cultivars of cabbage that were tested for susceptibility to BWYV (tipburn) and TuMV (cigar burn) in gauzehouses at Warwick HRI, Wellesbourne were as follows:

Bartolo (Elsoms)
Brigadier (Clause)
Caid (Clause)
Cilion (Syngenta)
Colmar (Elsoms)
Counter (Elsoms)
Impala (Elsoms, known to be susceptible to tipburn from previous experiments)
Kilaton (Syngenta)
Kingston (Syngenta)
Kronas (Seminis)
Lennox (Elsoms)
Lion (Nickersons)

Polinius (Elsoms, known to be susceptible to cigar burn from previous experiments)
Shelton (Elsoms)
Zerlina (Elsoms)

For experiments carried out in Lincolnshire only cabbage cultivar Impala was grown.

*Gauzehouse experiment at Warwick HRI.*

The 15 cabbage cultivars were planted into Hassey 308 trays on 20th April, 2006. A tray containing all cultivars was infected with BWYV on 23rd May, 2006. This was done by transferring aphids (*Myzus persicae*) from virus-infected oilseed rape plants to the plants growing in the trays. The plants were subsequently sprayed with Decis to kill the aphids on 30th May and this was followed by a Dursban drench on 9th June, 2006. A different tray was infected (mechanical inoculation) with TuMV on 5th June, 2006 by rubbing the leaves with macerated mustard leaves infected with the TuMV isolate. One tray containing all cultivars was kept virus free. The soil in the gauzehouses was fertilised prior to planting and top-dressed in August, 2006 in line with the Cabbage (crop ID-58), Crop Specific Protocol produced by Assured Produce Ltd. The cabbages were transplanted in to four gauzehouses with a spacing of 60cm on 12th June, 2006. Three plants of each cultivar per treatment (BWYV, TuMV and uninfected) were transplanted in to each of the four gauzehouses in plots of 3 plants following an alpha randomised design for each gauzehouse; a total of 135 cabbage per gauzehouse and a total of 540 cabbage for the experiment. One of the gauzehouses is shown in Fig. 1.

*Figure 1. Gauzehouse no. 1 with cabbages growing in photographed on 1st August, 2006.*

Following transplanting the gauzehouses were sprayed with the fungicide Bravo. Every two weeks they were also given insecticide sprays alternating between Dovetail and Toppel in order to ensure no aphids infested the cabbage and compromised the different treatments. The plants previously inoculated with TuMV received a second mechanical inoculation with TuMV on 5th September, 2006. The plants were monitored regularly for any problems. Following the discovery of one plant infected by *Botrytis*, the cabbage in all gauzehouses were sprayed with Rovral on 11th and 13th October, 2006. On 16th November, all cabbages were visually assessed for virus symptoms and scored for the severity of any symptoms seen on a scale of 0-5, where 0 was no symptoms and 5 was very severe symptoms. On 21st November, the cabbage plants in all four gauzehouses were harvested, with the cutting knives sterilised in alcohol between cutting each head. Each cabbage head was weighed, recorded and numbered in order to be able identify them when they are assessed following storage and the three heads from each plot were put in onion bags and the bags labeled. The heads from each gauzehouse were put in to separate wooden bins, transported to Lincolnshire, drenched with SL567a (Metalaxyl-m; 104ml per 1000L) and Rovral WP (Iprodione; 1kg per 1000L) at a rate of 20L spray mixture per tonne on 22nd November and stored in a CA store running at ~0°C.

*Serological testing of plants for virus infection.*

On 27th June, 2006, leaf samples were taken from those cabbage plants infected with BWYV. The leaves were macerated between electric rollers and the sap collected for testing for the presence of BWYV by Enzyme-linked Immunosorbent Assay (ELISA). A triple antibody sandwich (TAS)-ELISA format was used for the BWYV testing as described by Walsh *et al.* (1989) using the same antisera as in the experiments carried out in 1999-2000 and described by Hunter *et al*. (2002).

On 11th July, 2006, leaf samples were collected from cabbage plants inoculated with TuMV, macerated as described above and tested for the presence of TuMV by TAS-ELISA as described by Walsh *et al.* (2002).

*Determining the time of infection by BWYV and the effect of this on tipburn symptom severity*.

Cabbage cultivar Impala seed was planted into Hassey 308 trays on 31st March, 2006 at Warwick HRI. On 21st April, the trays containing the young plants were moved to an aphid proof screenhouse to harden off. The plants were transported to Lincolnshire on 1st June, 2006 and transplanted into the middle of commercial cabbage crops the following day (2nd June, 2006) at three different locations. One hundred Impala plants were transplanted at each site and half of the plants at each site (50 plants per site) were covered with mesh, to exclude aphids and hence virus infection. The plants at one of the sites were eaten by pigeons and hence this site was replanted on 20th June, 2006. The cabbage plots received the same treatments as the surrounding crop.

Leaves from each of the 50 uncovered plants at each site were sampled every two weeks from 26th June to 24th August, 2006 and sent to Warwick HRI where they were tested for BWYV by ELISA as described above.

On 24th August, 2006, the plants that had been covered with mesh at each of the three sites were uncovered and the mesh was used to cover the 50 plants that had not been covered. From then on, the newly uncovered 50 plants were sampled and tested for BWYV infection by ELISA every two weeks from 11th September to 6th November, 2006.

The cabbage from two sites (B and C) were harvested on 14th November, 2006 and the third site (A) on 15th November. Each head was labeled, placed in wooden bins, drenched with SL567a (Metalaxyl-m; 104ml per 1000L) and Rovral WP (Iprodione; 1kg per 1000L) at a rate of 20L spray mixture per tonne on and stored in a CA store running at ~0°C in Lincolnshire.

*Determining the effect of the time of infection by BWYV on tipburn symptom severity*.
Cabbage cultivar Impala seed was planted into Hassey 308 trays on 31st March, 2006 at Warwick HRI. On 21st April, the trays containing the young plants were moved to an aphid proof screenhouse to harden off. On 9th May, some of the cabbage seedlings (>54) were infected with BWYV by transferring aphids (*M. persicae*) from virus-infected oilseed rape plants to the cabbage plants. Further aphids from BWYV-infected oilseed rape were put on to these plants in May. The plants were then sprayed on 31st May with Decis to kill the aphids.

The plants were transported to Lincolnshire on 1st June, 2006 and transplanted into the middle of a commercial cabbage crop at site A on 2nd June, 2006. The plants were planted in 20 plots of 18 plants (3 rows of 6). Each of the four treatments (infected with BWYV pre-transplanting in May, infected in August, infected in late September and uninfected) was replicated five times. The plants were covered with mesh stretched over plastic hoops (Fig. 2). The plants did not receive any insecticide sprays applied to the surrounding commercial crop, but otherwise received the same treatments as the surrounding crop. BWYV-infected oilseed rape plants with aphids (*M. persicae*) feeding on them were taken to Lincolnshire on 2nd August and 2nd October and on each occasion five plots were partially uncovered, BWYV-infected leaves with aphids feeding on them put on to each of the 18 plants in each plot and then the plots were covered with the mesh again. On 14th August, those plots infected with BWYV on 2nd August were sprayed with Aphox and Hallmark (420g Aphox + 75ml Hallmark in 300L/ha using a knapsack sprayer) to kill the aphids and on 9th October, the plots infected on 2nd October were sprayed with Aphox and Hallmark at the same rate as above to kill the aphids. The cabbage were harvested on 15th November, 2006, each head labeled, placed in wooden bins, drenched with SL567a (Metalaxyl-m; 104ml per 1000L) and Rovral WP (Iprodione; 1kg per 1000L) on the day of harvest at a rate of 20L spray mixture per tonne and stored in a CA store running at ~0°C.

*Figure 2. Covered plots used to investigate the effect of the time of infection by BWYV on tipburn symptom severity at site A in Lincolnshire.*

*Statistical analyses*

The ELISA data on the amount of BWYV detected in the cabbage plants, the symptom scores and yield data for the Warwick HRI experiment on the 15 cabbage cultivars was analysed using Residual Maximum Likelihood (REML). The ELISA data was transformed as described previously by Hunter *et al.* (2002), (except 0.065 was not added to each value) prior to analysis.

**Results and Discussion**

As the first experiment runs from March 2006 to the summer of 2007 when the cabbage heads are due to be taken out of store and cut open to assess the amount of internal disorder (tipburn and cigar burn) present, the results at 31st January 2007, are limited to:

- ELISA data on the amount of BWYV detected in the 15 cabbage cultivars tested at Warwick HRI
- the severity of external symptoms in these plants
- the weight yield at harvest of these plants

- the dates that natural infection of cabbage plants growing at three sites in Lincolnshire occurred

*Gauzehouse experiment at Warwick HRI.*

The mean values (optical densities [ODs] following back-transformation) for each cultivar are given below. As the experiment was designed for data from the year 1 experiment to be analysed together with the data from year 2, no indications of significant differences are given at this stage. However, the analysis of the results suggested that there are significant differences in the amount of BWYV detected in the different cultivars.

*The mean OD from the ELISA carried out on 27th June, 2006 to investigate the amounts of virus in the different cabbage cultivars:*

| **Cultivar** | **Mean OD** |
|---|---|
| Bartolo | 1.821 |
| Brigadier | 1.873 |
| Caid | 1.463 |
| Cilion | 1.938 |
| Colmar | 2.215 |
| Counter | 1.450 |
| Impala | 1.370 |
| Kilaton | 1.598 |
| Kingston | 1.293 |
| Kronas | 1.463 |
| Lennox | 1.337 |
| Lion | 1.338 |
| Polinius | 1.465 |
| Shelton | 1.507 |
| Zerlina | 1.434 |

None of the uninfected cabbage plants showed any symptoms of virus infection.

None of the cabbage plants infected by BWYV showed any external leaf symptoms, consistent with previous experiments (Hunter *et al.* 2002). However, where uninfected plants and BWYV-infected plants were growing close, or adjacent to each other, it was clear that in many instances, the BWYV-infected plants were visibly smaller than the uninfected plants.

Many plants infected by TuMV showed necrotic symptoms in the outer leaves, mostly necrotic spots and ringspots typical of infection of cabbage by this virus (Fig. 3).

*Figure 3. Typical necrotic symptoms seen in some TuMV-infected cabbage cultivars growing in the gauzehouses.*

The mean symptom scores for the different cultivars are given below.

*Mean symptom scores for the external leaves of TuMV-infected and uninfected cabbage plants on 16th November, 2006 for the different cultivars:*

| **Cultivar** | **Mean symptom score for TuMV-infected plants** | **Mean symptom score for uninfected plants** |
|---|---|---|
| Bartolo | 3.9167 | 0 |
| Brigadier | 0.7314 | 0 |
| Caid | 4.3333 | 0 |
| Cilion | 1.1667 | 0 |
| Colmar | 2.2500 | 0 |
| Counter | 1.5000 | 0 |
| Impala | 0.0833 | 0 |
| Kilaton | 0.8333 | 0 |
| Kingston | 2.2500 | 0 |
| Kronas | 0.4167 | 0 |
| Lennox | 2.3333 | 0 |
| Lion | 2.0000 | 0 |
| Polinius | 1.3333 | 0 |
| Shelton | 2.2500 | 0 |
| Zerlina | 1.6667 | 0 |

As for the ELISA results, as the experiment was designed for data from the year 1 experiment to be analysed together with the data from year 2, no indications of significant differences between individual cultivars are given at this stage. However, again, the analysis of the data suggested that there were significant differences in the symptoms between cultivars (a significant interaction between TuMV and cultivar). The mean symptom score for TuMV-infected plants of some cultivars wasn't significantly different to that of the mean symptom score of uninfected plants.

The mean weights for the different cultivars of cabbage at harvest are given below.

*The mean weight (kg) of cabbage heads at harvest on 21st November, 2006 for the different cultivars:*

| **Cultivar** | **Mean head weight for TuMV-infected heads** | **Mean head weight for BWYV-infected heads** | **Mean head weight for uninfected heads** |
|---|---|---|---|
| Bartolo | 2.329 | 2.395 | 2.388 |
| Brigadier | 4.590 | 4.065 | 5.147 |
| Caid | 3.309 | 3.186 | 4.019 |
| Cilion | 2.926 | 2.848 | 3.929 |
| Colmar | 2.724 | 2.411 | 3.090 |
| Counter | 3.629 | 4.307 | 4.429 |
| Impala | 3.244 | 2.768 | 3.066 |
| Kilaton | 3.004 | 2.687 | 3.756 |
| Kingston | 3.668 | 3.622 | 3.532 |
| Kronas | 4.370 | 3.325 | 4.540 |
| Lennox | 3.145 | 2.860 | 3.031 |
| Lion | 2.662 | 2.892 | 3.615 |
| Polinius | 2.767 | 2.360 | 2.783 |
| Shelton | 3.046 | 3.480 | 3.872 |
| Zerlina | 3.177 | 3.335 | 3.633 |
| All | 3.250 | 3.102 | 3.657 |

Again, as the experiment was designed for data from the year 1 experiment to be analysed together with the data from year 2, no indications of significant differences between the yields of individual cultivars are given at this stage. The analysis of the data showed that the virus infections significantly reduced the yield. The data also suggested significant differences between cultivars, where several cultivars showed little or no reduction in mean head weight following virus infection. Some cultivars appear to be affected by one virus but not the other.

*Determining the time of natural virus infection of cabbage in the field*

Following the transplanting of the cabbage in to the commercial crops in Lincolnshire on 2nd June, 2006, it was a few weeks before infection was first detected (almost 8 weeks, first infection detected 27th July, 2006). The incidence of virus infection detected at the different sampling points in the three plots of 50 plants left uncovered following transplanting is shown below.

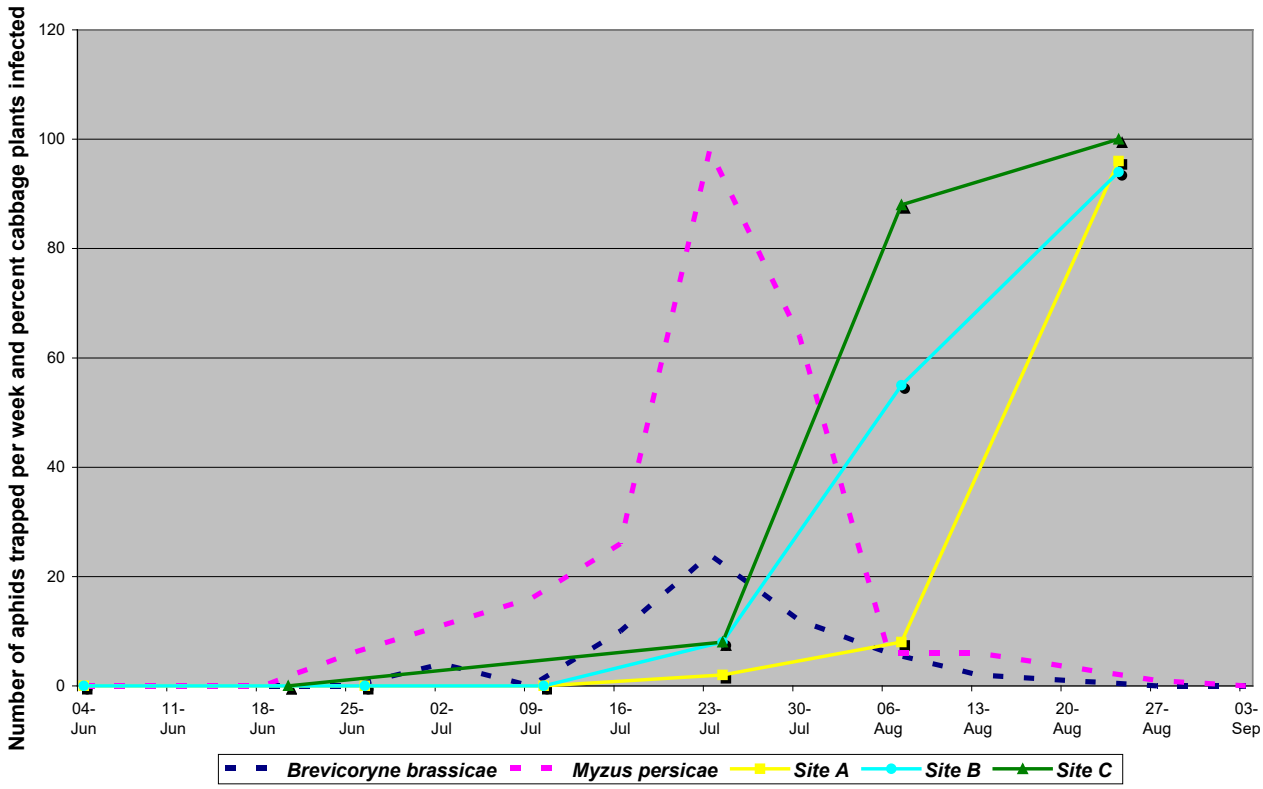
*The incidence of BWYV detected in cabbage plots growing in commercial crops at three sites in Lincolnshire between 2nd June and 24th August 2006:*

| **Event** | **Percentage incidence of BWYV detected by ELISA** | | |
|---|---|---|---|
| | **Site A** | **Site B** | **Site C** |
| Transplanting date | 2.6.06 | 2.6.06 | 20.6.06 |
| Covered | 24.8.06 | 24.8.06 | 24.8.06 |
| Sampling 1, 26.6.06 | 0 | 0 | - |
| Sampling 2, 10.7.06 | 0 | 0 | - |
| Sampling 3, 24.7.06 | 2 | 8 | 8 |
| Sampling 4, 7.8.06 | 8 | 55 | 88 |
| Sampling 5, 24.8.06 | 96 | 94 | 100 |

BWYV infection was first detected on 24th July, 2006, with incidences ranging from 2% at one site, to 8% at the other two sites. At site C, infection progressed rapidly with 88% of plants infected by 7th August and 100% infection by 24th August 2006. At site A, infection progressed slower, with only 8% infection by 7th August, but then increasing rapidly to 96% infection by 24th August, 2006. The rate of infection at site B was intermediate to that of sites A and C (Fig. 4).

The spread of BWYV in to the plots appeared to be related to the numbers of winged aphids (peach potato aphid [*M. persicae*] and woolly cabbage aphid [*Brevicoryne brassicae*]) caught in the Rothamsted suction trap in Kirton, Lincolnshire (Fig. 4).

*Figure 4. The numbers of aphids (peach potato aphid* [M. persicae] *and woolly cabbage aphid* [B. brassicae]*) caught in the Rothamsted suction trap at Kirton and the incidence of* Beet western yellows virus *(BWYV) at the three sites.*




The incidence of virus infection detected at the different sampling times in the plots of 50 cabbage plants that were uncovered at the three sites on 24th August is shown below.

*The incidence of BWYV detected in cabbage plots growing in commercial crops at three sites in Lincolnshire between 24th August and 6th November 2006:*

| **Event** | **Percentage incidence of BWYV detected by ELISA** | | |
|---|---|---|---|
| | **Site A** | **Site B** | **Site C** |
| Transplanting date | 2.6.06 | 2.6.06 | 20.6.06 |
| Uncovered | 24.8.06 | 24.8.06 | 24.8.06 |
| Sampling 6, 11.9.06 | 0 | 0 | 4 |
| Sampling 7, 21.9.06 | 2 | 0 | 14 |
| Sampling 8, 9.10.06 | 2 | 0 | 14.2 |
| Sampling 9, 23.10.06 | 2 | 0 | 22.4 |
| Sampling 10, 6.11.06 | 2 | 0 | 25.5 |

Following the uncovering of the plots of 50 plants at two of the sites (A and B), very little infection occurred (2% at site A and no infection at site B). However, at site C, where infection had previously occurred most rapidly, infection levels rose steadily, reaching 25.5% by the 6th of November, 2006.

*Determining the effect of the time of infection by BWYV on tipburn symptom severity*.
ELISA testing of leaf samples from the covered plots of 18 cabbage plants that we infected with BWYV prior to transplanting, on the 2nd of August, 2006 and on 2nd of October confirmed that most plants were infected. All of the plants in most plots were infected; the lowest incidence detected in any plot was 16 out of 18 plants.

**Conclusions**

The experiments have gone very well so far and look set to provide very useful information once completed.

Clear differences in the amount of BWYV detected in the different cabbage cultivars were found. These differences were confirmed by the statistical analysis of the ELISA data for the different cultivars. Until data is available later in the year on the severity of internal tipburn symptoms (when the heads are taken out of store and assessed), it isn't possible to draw any conclusions as to whether there is a relationship between the amount of BWYV detected in plants in the field and the severity of tipburn after storage. No clear symptoms of BWYV infection were seen in the leaves of any of the cabbage cultivars, however, where uninfected plants and BWYV-infected plants were growing close, or adjacent to each other, it was clear that in many instances, the BWYV-infected plants were visibly smaller than the uninfected plants.

Big differences in the severity of external TuMV symptoms in different cabbage cultivars were seen. These differences are reflected in the mean symptom scores for the different cultivars. Plants of cultivars Bartolo and Caid infected by TuMV showed particularly severe external necrotic symptoms (mean severity scores of 3.9167 and 4.3333, respectively) and plants of cultivars Impala and Kronas infected by TuMV showed very little in the way of symptoms (mean severity scores of 0.08333 and 0.4167, respectively). This suggests that there may be differences in the severity of internal cigar burn symptoms after storage. At this stage, it is not possible to conclude whether there is any correlation between the severity of external symptoms prior to harvest and the severity of internal symptoms.

Both viruses caused a big reduction in the weight yield of some cabbage cultivars at harvest. Cultivars Cilion and Lion were worst affected by TuMV with their weight yields being reduced by 26%. Cultivars Cilion and Kilaton were worst affected by BWYV with their weight yields being reduced by 28%. Other cultivars appeared not to be greatly affected, suggesting some tolerance / partial resistance to BWYV and TuMV in these cultivars. The weight yields of cultivars (Bartolo, Impala, Kingston, Lennox and Polinius) were not affected by TuMV infection and the weight yields of Bartolo, Counter and Kingston were not affected by BWYV. The lack of effect of the viruses on the weight yield does not appear to be a good indicator of susceptibility to virus infection or storage disorders. For example, although the weight of cultivar Bartolo wasn't affected by either virus, it developed very severe TuMV symptoms prior to harvest. Also Impala's weight yield wasn't affected by TuMV, but we know from previous studies (Hunter *et al*. 2002) that it is susceptible to tipburn and Polinius' head weight wasn't affected by TuMV, but again from earlier work (Hunter *et al*. 2002) we know it is susceptible to cigar burn.

When we have data from the year 2 experiment, it will be possible to rank the different cultivars for their susceptibility to tipburn and cigar burn and vulnerability to weight yield loss from infection by both viruses.

Testing our cabbage plants growing in the commercial crops of cabbage in Lincolnshire showed that there is high infection pressure from BWYV in cabbage fields in Lincolnshire; infection levels reached 94%, 96% and 100% at the three sites by 24th August. After the 24th August, very little BWYV infection occurred at two of the sites, whereas at the third site 25.5% of plants became infected between 24th August and 6th November, 2006. This result along with differences between the sites in terms of how quickly the cabbage became infected in July / August suggest that it may be possible to delay infection by BWYV with good crop husbandry / well timed insecticidal sprays. The date on which we first detected BWYV infection in the field (24th July, 2006), was just over 4 weeks after the first aphids were caught in the Rothamsted suction trap at Kirton. This might suggest that there is a window of opportunity to control aphids in order to prevent BWYV infection of brassicas, however, we do not know at this time, how long it takes from a cabbage plant being infected in the field by BWYV, to the time when BWYV reaches detectable levels in the cabbage (i.e. the latent period between infection and detectability).

Successful infection of the cabbage plants in the covered plots pre-transplanting and at the different times during the growing season (2nd August and 2nd October, 2006) means that we will be able to determine whether early or late infections affect the severity of tipburn

symptoms after storage. This will then inform growers as to when the most important times to protect crops from virus infection are in order to reduce losses from tipburn.

**Technology transfer**

- John Walsh gave a presentation at the Brassica Growers' Association meeting, White Hart Hotel, Boston, Lincs., 9th January 2007 on the progress of the project.
- John Walsh gave a presentation to the Vegetable Consultants Association, Charlecote Pheasant, Charelcote, Warks., on 31st July, 2007 on the progress of the project. The attendees were also given a guided tour of part of the year 2 experiment at Warwick HRI, Wellesbourne.

**Glossary**

BWYV; *Beet western yellows virus*
DAS-ELISA; double antibody sandwich, enzyme-linked immunosorbent assay
ELISA; enzyme-linked immunosorbent assay
TuMV; *Turnip mosaic virus*

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