PROJECT REPORT No. 278

TOLERANCE OF WHEAT VARIETIES TO SOIL-BORNE WHEAT MOSAIC VIRUS (SBWMV)

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TOLERANCE OF WHEAT VARIETIES TO SOIL-BORNE WHEAT MOSAIC VIRUS (SBWMV)

by

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This is the final report of a twenty-five-month project, which started in October 1999. The work was funded by a grant of £13,264 from HGCA (project no. 2254).

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ABSTRACT

The discovery of soil-borne wheat mosaic virus (SBWMV) on a Wiltshire farm in 1999 triggered concern for the continuation of wheat production in the UK. Potential yield losses are high and the only practical method of control will be the use of resistant or partially resistant varieties. There was therefore an urgent need to:

- compare the severity of SBWMV symptoms (confirmed by ELISA) in plots of wheat varieties grown on infected sites
- identify UK varieties with resistance to SBWMV

Wheat varieties from the Recommended List (RL) and National List (NL) were sown on an infected site on the Wiltshire farm and assessed, both visually and by ELISA, to determine their susceptibility to the virus.

Five varieties from the RL and provisional RL were resistant in the first year of testing with 29 varieties from the NL also being resistant. Approximately a third of the varieties tested had low levels of infection whilst just under a half of varieties were very susceptible. Currently, there are three resistant varieties on the Recommended List for 2002. These are Charger, Claire and Hereward.

A further two infected sites were identified in Kent in 2000, but none was reported in 2001.

If SBWMV follows a similar pattern to the spread of BaYMV and BaMMV then we can expect the virus to be widespread throughout the UK by 2010.

The availability of resistant wheat varieties will not only maintain the viability of growing wheat on infected land but their use should also reduce the spread of infection. The evidence from this investigation and from countries already with widespread SBWMV would suggest that there is a sufficient gene pool to produce a number of resistant varieties suitable for the UK market. Routine testing as part of the Recommended List programme will keep levy payers abreast of new resistant varieties as they become available.

SUMMARY

ABSTRACT

The discovery of soil-borne wheat mosaic virus (SBWMV) on a farm in Wiltshire in 1999 was a matter for concern. Potential yield losses are high and the only practical method of control is the use of resistant varieties. A large number of varieties were sown on the infected site and assessed both visually and by ELISA to determine their resistance to SBWMV. Resistant varieties were identified, including Charger, Claire and Hereward. A further two infected sites were found in Kent in 2000. It is unclear how rapidly the virus will spread throughout the UK but if it were to follow a similar pattern to the barley mosaic viruses it could well be widespread by 2010. It is vital to encourage the use of resistant varieties to limit the establishment and spread of SBWMV.

INTRODUCTION

Winter wheat is the primary crop in the UK and any threat to its production is of concern. SBWMV can result in high yield losses in susceptible varieties and, without resistant varieties, lead to the removal of infected land from wheat production.

SBWMV occurs commonly in the USA, Egypt, China, Japan, Argentina, Brazil, Zambia, Italy, Germany and France. In France, it was first reported in 1978 and is now widely distributed in central and western regions and is rapidly spreading northwards and eastwards. The virus was identified in the UK for the first time in 1999 on a farm in Wiltshire.

Symptoms of SBWMV infection in wheat vary from pale green to prominent yellow streaks on the leaves and leaf sheaths, accompanied by moderate to sever stunting. Symptoms are prominent from spring onwards. As new leaves unfold they appear mottled and develop parallel dashes and streaks. Fields most often show a patchy incidence of the disease. A range of techniques is available for identifying the virus in infected plants, including electron microscopy, serological techniques (ELISA) and molecular techniques (PCR). Some of these techniques have been developed by CSL as part of an on-going HGCA project.

SBWMV is transmitted by the soil-borne fungus *Polymyxa graminis* and in this sense can be regarded as the wheat equivalent of the soil-borne viruses of barley, BaYMV and BaMMV. The virus survives in the absence of host plants in the resting spores of the fungus, which can remain viable in the soil for at least 15 years and can also survive in manure from animals fed with contaminated soil. Movement of the virus is thus by farm vehicles and machinery, footwear, livestock, wind blow and surface water. Most evidence suggests that SBWMV is not seed-borne. It is thought that its most likely route of entry into the UK would be as a contaminant of soil associated with seed potatoes, root vegetables, nursery stock and other transplants.

Yield losses, due to the virus, are likely to be very variable, depending on variety, strain of the virus, level of infestation and climatic conditions. Yield losses of between 40-70% have been quoted for infected areas of susceptible wheat crops. Overall field losses will depend on the number and size of infected patches and can therefore be expected to be lower. The scale of losses in the UK as a whole will depend on how rapidly the virus spreads and on the susceptibility of UK wheat varieties.

Identifying varieties with resistance to SBWMV and suitability for UK conditions will have substantial benefits to the industry. Individual losses will be dramatically reduced, while, at the same time, the spread and build up of the virus will be slowed down. Perhaps most importantly, farmers will have the opportunity to continue to grow wheat on land which might otherwise have had to be taken out of wheat production indefinitely.

The only practical method of control is by using resistant or partially resistant varieties. Varieties with good levels of tolerance have been identified for use in France e.g. Fandango, Tremie, Taldor, but very little was known about the tolerance levels of UK varieties apart from suggestions from variety trials on infected sites in France that the varieties Charger and Cadenza show some tolerance.

Based on experience of SBWMV in other countries, and on our own UK experience of the soil-borne mosaic viruses of barley, it seems very likely that SBWMV will become more widespread in the UK, despite current hygiene measures. There will be an increasing demand for information on the susceptibility of UK wheat varieties under UK conditions, to enable farmers to continue to grow wheat on infected land without incurring major yield penalties. UK breeders have responded by starting the process of screening and selecting potential varieties with tolerance to SBWMV and entering resistant material into the official testing system. It is vital that all relevant variety information should be made widely available to HGCA levy payers through the Recommended List. Information is also required at an earlier stage in a variety’s career when the decision is made as to whether or not it has sufficient merit to be included in Recommended List trials.

There is a clear parallel here with the soil-borne mosaic viruses of barley. These viruses were first identified in the UK in 1981. Almost immediately, breeders began to screen their material on infected sites and NIAB initiated tests of varieties in Recommended and National List trials, with a view to identifying varieties with good resistance.

The main objective of this project was to provide information on the resistance / tolerance to SBWMV of a wide range of varieties at Recommended List and earlier stages. This was achieved by comparing the severity of SBWMV symptoms in plots of wheat varieties grown on infected sites. From the assessments it was possible to identify varieties with good resistance, to the virus, suitable for growing on infected land in the UK. This project has also provided the groundwork for a routine programme of monitoring winter wheat varieties for resistance to SBWMV.

MATERIALS AND METHODS

As there are many similarities between SBWMV and the barley mosaic viruses it was reasonable to adopt a similar method to the standard NIAB barley mosaic virus testing programme. The NIAB tests comprise small hand-sown plots (approx. 0.5m x 0.5 m) situated on sites known to be infected with BaMMV or one of the two UK strains of BaYMV. Symptom development is assessed during the late winter and spring, leading to an evaluation of the resistance of the variety. One of the main advantages of this approach is that a large number of varieties can be screened in a relatively small area, selected for uniformly severe infection in the previous season. This is important because of the typically patchy distribution of infection within a field. There is also an advantage in terms of hygiene as all operations are carried out by hand and there is no need to bring drills or other trials machinery onto the infected site.

Staff of the Central Science Laboratory (CSL) and the Plant Health and Seeds Inspectorate (PHSI), who have been monitoring the outbreak of SBWMV on the Wiltshire farm, helped NIAB to map patches of high infection suitable for small plot trials. Two areas uniformly infected with SBWMV were identified as test sites and permission was granted by PHSI for NIAB to conduct trials on these sites starting in Autumn 1999, one 12 x 24 m and the other 50 x 50 m.

Site 1 was sown on 8/10/99 and Site 2 on 7/10/99. The plots were each 0.5 x 0.5 m with the varieties randomised in a complete block design. Each trial contained two replicates of 149 varieties, including those currently recommended and in RL trials, together with candidate varieties in National List trials. The British Society of Plant Breeders had agreed to the inclusion of NL candidates in this way. A number of relevant control varieties were added, including a number of French varieties known to differ in their tolerance to the virus in France. A further set of late sown plots of seven varieties from the main trial were included on each site to see if late sowing could act as an escape mechanism (sown 23/11/99). Management of the site was according to local farm practice.

Symptoms of SBWMV infection were to be assessed visually throughout the season from first appearance, however manganese deficiency had been a problem delaying the first assessment until 12 April 2000. Plots were assessed as the percentage of plots showing symptoms. Site one was abandoned due to excessive rabbit damage. Site two was assessed twice more 16 May and 6 June, on the later date an assessment of stunting was done. There was also an assessment of vigour on 17 May.

Although it was expected that symptoms should be quite distinctive and easy to quantify visually, the range of symptom expression under UK conditions was unknown. Whole plant samples were taken at the first and last assessment dates from selected plots for ELISA testing by CSL. These samples were taken to confirm the visual assessments and to detect infected varieties not showing classic symptoms.

An additional two areas of infection were mapped, in Kent, in April 2000 giving a potential site for additional plots.

The sites were cleared after the final assessment to prevent the risk of volunteers in 2001 and as part of the weed control.

Site 1 was sown to farm crop in autumn 2000 to help control a growing black grass problem. Site 2 sowing was delayed until 10 November 2000 by the extreme weather conditions. Only one replicate was sown on this date with the second replicate being sown on 15 December 2000. Visual assessments were recorded on 6 June 2001 and 3 July. Whole plant samples were taken on 3 July from selected plots for ELISA testing. 110 varieties were tested in 2001.

RESULTS

There were a number of varieties with no visual symptoms, which have been classified as being resistant (varieties with < 5% have been classified as resistant to account for volunteer plants within the plots). Resistant varieties were confirmed by ELISA testing of both roots and leaves. Those with less than 10% of the plants showing symptoms fall into the intermediate category whilst those with greater than 10% being susceptible.

Table 1. RL and RL candidate variety results for SBWMV.

Variety	Rating 2000	Rating 2001
Consort	susceptible	susceptible*
Hereward	resistant	resistant
Madrigal	susceptible	susceptible*
Rialto	intermediate	susceptible
Savannah	susceptible	susceptible*
Riband	susceptible	susceptible*
Equinox	susceptible	susceptible*
Charger	resistant	resistant
Claire	resistant	resistant
Malacca	susceptible	susceptible*
Shamrock	intermediate	susceptible
Buchan	susceptible	susceptible*
Reaper	intermediate	#*
Buster	susceptible	#*
Soissons	susceptible	susceptible*
Aardvark	resistant	resistant #
Cockpit	resistant	resistant #
Genghis	intermediate	intermediate
Napier	susceptible	susceptible*
Eclipse	intermediate	#*
Biscay	intermediate	intermediate
Option	susceptible	susceptible*
Oxbow	susceptible	susceptible*
Deben	intermediate	susceptible
Tanker	intermediate	susceptible
Macro	intermediate	intermediate
Access	intermediate	susceptible
Phlebas	resistant	resistant
Solstice	intermediate	intermediate
Xi19.	resistant	intermediate
Chatsworth	resistant (?)	intermediate
Fender	susceptible	susceptible*
Richmond	intermediate	intermediate

* varieties not tested in 2001; # varieties not in 2001 RL tests

A study of the parentage of varieties revealed Cadenza as a common parent, occurring in seven of the resistant varieties. Based on the earmarking of Cadenza as a potential source of resistance genes it was included as a control in 2000/1 where it proved to be resistant.

The late sown varieties (Table 4, Appendix) gave the same results as their earlier sown counterparts but with a slight delay in the expression of symptoms.

In July 2000 a sample was received at NIAB from a Crop Consultant in Kent. This may have been prompted by coverage of the HGCA project in the farming press. Visual symptoms were still discernible even though the crop was at an advanced stage. Samples were then sent to CSL for confirmation by ELISA test. Two infected farms were identified in Kent. One of the farms had two areas of infection large enough to be mapped for use in future small plot trials.

DISCUSSION

The discovery of SBWMV in the UK in 1999 threatened the heart of arable farming. This project provides the first, extensive, screening of the susceptibility of UK varieties to the virus.

The persistence of the virus in the soil, viable in excess of ten years, makes control of SBWMV impractical by any means other than growing resistant varieties. Sterilization of the soil is likely to be prohibitively expensive and the potentially large yield losses makes growing susceptible wheat varieties uneconomical.

The main objective was achieved in the identification of several resistant varieties. Of the 35 resistant varieties (some of which are only provisional due to limited data) only six got as far as the Recommended List testing programme. In 2001/2 seven varieties out of thirty-five in RL tests had previously been classified as resistant to SBWMV. With only four varieties in National List year 2 tests that are potentially resistant any increase in the incidence of SBWMV would require more resistant varieties to be available to provide a broader choice to growers. Currently testing for SBWMV is not standard test in either the RL or NL protocols so the availability of independent data will become restricted without further screening programmes.

The use of late sowing as an escape mechanism had the effect of delaying the expression of symptom but did not seem to reduce the peak level of infection. There was no comparison of yields between early and late sown plots, however as susceptible varieties suffer large yield penalties any benefit would be unlikely to significantly offset any losses.

A brief study of the parentage of the resistant varieties highlighted a few common parents of which Cadenza and Moulin were tested in 2001. Both proved to be resistant, confirming the evidence from France that Cadenza was resistant. The study was not large enough to tell how broad an original gene-pool of resistance exists.

Genetic sequencing of the UK SBWMV isolates has shown them to be the same as the European strains rather than the American, Chinese and Japanese strains (Clover *et al*., 2001). This implies that infected material has been transported from the European mainland into the UK, which supports the theory that the incidence of SBWMV is likely to be far more widespread than currently documented. The dominance of Claire in the market may be limiting the spread of SBWMV or merely masking its occurrence.

Agenda 2000 is up for review in 2005 but it is unlikely that there will be a major shift away from wheat production. Currently weak wheat prices are predicted to rise as increases in world population out-strip production. However a global view ignores high UK farm inputs which threatens the competitiveness of UK wheat. Any increase in the incidence of SBWMV will be detrimental to UK wheat production so it is important to have a choice of resistant varieties available and to encourage there usage in at risk areas.

ACKNOWLEDGEMENTS

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SCIENTIFIC REPORT

INTRODUCTION

Winter wheat is the primary crop in the UK and any threat to its production is of concern. Soil-borne wheat mosaic virus (SBWMV) can result in high yield losses in susceptible varieties and, without resistant varieties, lead to the removal of infected land from wheat production.

SBWMV occurs commonly in the USA, Egypt, China, Japan, Argentina, Brazil, Zambia, Italy, Germany and France. In France, it was first reported in 1978 and is now widely distributed in central and western regions and is rapidly spreading northwards and eastwards. The virus was identified in the UK for the first time in 1999 on a farm in Wiltshire.

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Identifying varieties with resistance to SBWMV and suitability for UK conditions will have substantial benefits to the industry. Individual losses will be dramatically reduced, while, at the same time, the spread and build up of the virus will be slowed down. Perhaps most importantly, farmers will have the opportunity to continue to grow wheat on land which might otherwise have had to be taken out of wheat production indefinitely. This is bound to be particularly significant in the current climate of Agenda 2000 and increased dependence on the wheat crop.

The only practical method of control is by using resistant or partially resistant varieties. A number of experimental breeding lines with both root and shoot resistance have been reported in France and may lead to improved varieties in the future. Varieties with good levels of tolerance have been identified for use in France e.g. Fandango, Tremie, Taldor, but very little was known about the tolerance levels of UK varieties apart from suggestions from variety trials on infected sites in France that the varieties Charger and Cadenza show some tolerance.

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Table 2. RL and RL candidate variety results for SBWMV.

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Buchan	susceptible	susceptible*
Reaper	intermediate	#*
Buster	susceptible	#*
Soissons	susceptible	susceptible*
Aardvark	resistant	resistant #
Cockpit	resistant	resistant #
Genghis	intermediate	intermediate
Napier	susceptible	susceptible*
Eclipse	intermediate	#*
Biscay	intermediate	intermediate
Option	susceptible	susceptible*
Oxbow	susceptible	susceptible*
Deben	intermediate	susceptible
Tanker	intermediate	susceptible
Macro	intermediate	intermediate
Access	intermediate	susceptible
Phlebas	resistant	resistant
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Agenda 2000 is up for review in 2005 but it is unlikely that there will be a major shift away from wheat production. Currently weak wheat prices are predicted to rise as increases in world population out-strip production. However a global view ignores high UK farm inputs which threatens the competitiveness of UK wheat. Any increase in the incidence of SBWMV will be detrimental to UK wheat production so it is important to have a choice of resistant varieties available and to encourage there usage in at risk areas.

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REFERENCES

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APPENDIX 1

Table 3. Visual and ELISA results 2000

VARIETY	VISUAL		ELIS	
	max % infection	stunting	leaf	root
CONSORT	15		+	+
HEREWARD	5		-	-
MADRIGAL	15	severely stunted	+	
RIALTO	10		+	
SAVANNAH	20		+	
RIBAND	20		+	
EQUINOX	20	severely stunted	+	
CHARGER	1		-	-
CLAIRE	1		-	-
MALACCA	15		+	
SHAMROCK	10		+	
BUCHAN	30	severely stunted	+	
REAPER	5		+	
BUSTER	15		+	
SOISSONS	15		+	
AARDVARK	1		-	-
COCKPIT	1		-	-
GENGHIS	5		+	
NAPIER	25		+	
ECLIPSE	10		-	
BISCAY	5		+	+
CWW 97/4	50	severely stunted	+	
CWW 97/22	15		+	
NSL WW-27	10		+	
TANKER	8		+	
CWW 97/45	10			
ISENGRAIN	5		+	+
CPBT W59	10			
NFC 19706	10			
NFC 19808	8		+	
NFC 19812	25			
ELS 98.17	10			
CEB 96087	10		+	
CEB 96136	10			
CEB 96151	1		-	-
CEB 96169	15			
CPBT W63	5		+	
CPBT W64	15	severely stunted		
CPBT W65	15			
CPBT W66	15			
CPBT W67	10		+	
CPBT W68	10			
CPBT W69	10			
CWW 98/167	20			
CWW 98/95	10			
CWW 98/54	25			
CWW 98/51	1		-	-
CWW 98/49	10			
CWW 98/25	20	severely stunted		
CWW 98/6	5		-	
FRELON	20			
CPBT W70	5		-	-
A19-98	1		+	+
A18-98	8		+	
A16-98	3		-	-
A14-98	40			
SWUW 98-6	1		+	-
11957WT1	15		+	
97-F-26	40			
96-37B	15			
DI-403	3		-	-
NSL WW-33	1		-	-

VARIETY	VISUAL		ELIS	
	max % infection	stunting	leaf	root
NSL WW-32	25	severely stunted		
NSL WW-28	35	severely stunted		
WINDSOR	8		+	
GAIE59	10			
HYNO-ESTA	8			
MAGNUS	1			
KORSAR	25			
F1205	7			
BR3167D1	5			
HS14-89-2	20			
21R40	5			
21R41	8			
21R60	10			
NORD 99/239	1			
NORD 99/158	25			
SUR 204-11	5			
A20-99	10			
CPBT W74	10			
CBPT W75	5			
CPBT W76	30	severely stunted		
CPBT W77	10			
CPBT W78	15			
CPBT W79	15			
CPBT W80	10			
CPBT W81	15			
A26-99	10			
A25-99	1			
A24-99	10			
A23-99	5			
A21-99	20			
A22-99	10			
DSV 90112	40			
DSV 90107	15			
DSV 90212	12			
ELSOMS 99.20	10	severely stunted		
FD 97052	10			
ELSOMS 99.19	5			
98 E 42	5			
D96/464 YT	30			
13905 YT1	30			
CEB 97004	20			
CEB 97036	15			
CEB 97046	10			
CEB 97047	15			
CEB 97171	5			
PR 9027-115	15			
LW 91W89-11	35			
BPZ 88.017	1			
BR3218D7	3			
CWW 99/16	15			
CWW 99/8	10			
CWW 99/15	15			
CWW 99/17	10			
CWW 99/43	15			
CWW 99/45	8			
CWW 99/48	30	severely stunted		
CWW 99/51	10			
HYB 96.130	1			
CWW 99/19	30			
NFC 19926	20			
NFC 19925	25			
NFC 19924	30			
NFC 19923	15			
NFC 19916	20	severely stunted		

VARIETY	VISUAL max % infection	stunting	ELIS leaf	root
NFC 19911	15			
NFC 19910	20			
NSL WW36	15			
NSL WW41	30			
NSL WW42	1			
NSL WW40	15			
NSL WW39	15			
NSL WW35	5			
NSL WW38	1			
NSL WW37	30			
SHANGO *	10			
APACHE	5		+	
AZTEC (NSA)	40		+	
TREMIE	1		-	-
Unknown 1	15			
Unknown 2	10			
Unknown 3	30			
Unknown 4	1			
Unknown 5	20			
Unknown 6	7			
Unknown 7	1		-	-
Unknown 8	3			
Unknown 9	8			

Table 4. Visual and ELISA results 2000: late sown plots

VARIETY	VISUAL max % infection					
	13 April		16 May		6 June	
Sown	November	*October*	November	*October*	November	*October*
CONSORT	1	*15*	2	*15*	5	*8*
RIALTO	1	*10*	1	*8*	20	*8*
SAVANNAH	5	*20*	8	*20*	3	*5*
EQUINOX	5	*20*	15	*20*	40	*7*
CHARGER	0	*1*	0	*0*	0	*0*
CLAIRE	0	*1*	0	*0*	0	*0*
SHAMROCK	5	*10*	5	*8*	7	*7*

Table 5. Visual and ELISA results 2001

VARIETY	VISUAL max % infection	ELISA leaf	root
CLAIRE	2	-	-
RIALTO	30	+	
HEREWARD	2	-	-
CHARGER	2	-	-
SHAMROCK	24	+	
GENGHIS	10	+	
BISCAY	4	+	
DEBEN	14	+	
TANKER	24	+	
MACRO	10	+	
ACCESS	24	+	
PHLEBAS	1	-	-
SOLSTICE *	11	+	
XI19.	4	+	+
CHATSWORTH	8	+	
RICHMOND	16	+	
AARDVARK	2	-	-
HA 6AB	20		

VARIETY	VISUAL	ELISA	
	max % infection	leaf	root
BR3167D1	2	-	
21R60	24		
CBPT W75	25		
CPBT W80	2	-	
A25-99	0	-	
A24-99	6		
A22-99	12		
ELSOMS 99.20	14		
CEB 97171	1	-	
CWW 99/8	14		
CWW 99/17	5		
CWW 99/45	4		
CWW 99/51	10		
HYB 96.130	4		
NFC 19923	6		
NSL WW35	2		
CPBT W83	2		
CPBT W84	20		
CPBT W85	0	-	
CPBT W86	14		
CPBT W87	8		
CPBT W88	8		
CPBT W89	14		
CPBT W90	9		
CPBT W91	24		
21R15	8		
21R42	1		
21R61	16		
NFC 10006	40		
NFC 10016	10		
NFC 10018	12		
NFC 10020	6		
NFC 10034	8		
H 97265	2		
DSV 90306/292	16		
DSV 90425/353	2		
LW92W49-1	4		
1EB 98020	10		
CEB 98057	30		
CEB 98178	30		
CEB 98179	12		
A28-00	14		
A29-00	17		
A30-00	6		
A31-00	6		
A32-00	10		
A33-00	8		
A34-00	24		
A35-00	0	-	
NORD 00/318	30		
SUR.HD.199/5	8		
NSL WW50	8		
NSL WW49	20		
NSL WW48	50		
NSL WW47	16		
NSL WW46	20		
NSL WW45	60		
NSL WW44	10		
NSL WW43	12		
WW 98-5	2		
2799 2T2	30		
SWUW 00-7	12		
SWUW 00-8	8		
HADM.21502-94	6		

VARIETY	VISUAL	ELISA	
	max % infection	leaf	root
SEMC 29	14		
SEMC 34	8		
98ST125	20		
CWW 00/47	20		
CWW 00/40	9		
CWW 00/36	20		
CWW 00/33	6		
CWW 00/22	1	-	
CWW 00/7	14		
CWW 00/4	22		
CWW 00/2	5		
FD99130	9		
ELS 00.23	10		
ELS 00.22	14		
ELS 00.21	24		
COCKPIT	4	-	-
CADENZA	1	-	
APACHE	1		
AUTAN	6		
TREMIE	4	-	-
MOULIN	2	-	
Unknown 10	24		
Unknown 11	12		
Unknown 12	4		
Unknown 13	24		
Unknown 14	30		
Unknown 15	14		
Unknown 16	5		