Effects of beet western yellows virus on growth and yield of oilseed rape (*Brassica napus*)

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SUMMARY

Field trials were undertaken in Suffolk in commercial crops of autumn-sown oilseed rape cv. Capricorn during 1993/94, cv. Apex in 1994/95. Plots were artificially infected with beet western yellows virus (BWYV) using viruliferous *Myzus persicae*, giving 73 to 94 % infection. Control plots had natural infection ranging from 0 to 17·8 %. Destructive plant samples were taken from each of the infected and control plots throughout the seasons for growth analyses, and final yields were measured on 44 m² areas combine harvested from each plot. The seed yields of infected plots were 26 and 11 % lower than control plots in 1994 and 1995 respectively ($P < 0.001$).

Harvested seed yields were shown to be inversely proportional to the area of the plot that was inoculated with BWYV. Infection significantly lowered the oil content in 1995 from 47·9 to 46·8 % ($P < 0.001$), and increased glucosinolate levels from 16·12 to 18·37 µmol/g ($P < 0.01$). BWYV caused a significant reduction in plant height and in numbers of primary branches in the 1993/94 trial and had an effect on the dry weight of the leaves, stalks, racemes and pods at some sample dates in both seasons. Virus-testing of infected plants showed that BWYV was present in the pod wall, the septum and seed coat; two of 78 embryo samples also contained virus. It was concluded that BWYV can cause significant yield losses in those years in which there is a high incidence of virus in the overwintered crops.

INTRODUCTION

Approximately 400000 ha of autumn-sown oilseed rape (*Brassica napus* L.) are grown each year in the UK as a source of vegetable oil. The time at which the seedlings emerge coincides with the autumn migration of the peach-potato aphid, *Myzus persicae*, which colonizes, and overwinters on oilseed rape (Smith & Hinckes 1984). Beet western yellows virus (BWYV genus *Luteovirus*) is phloem-specific and is transmitted in a persistent manner by *M. persicae*. The virus is introduced into the oilseed rape crop by incoming aphids in the autumn, and a high percentage of infected plants have been found within crops both in the UK (Smith & Hinckes 1985) and in other parts of Europe (Schröder 1994; Maissoneuve *et al.* 1995) in some years. In the UK, the natural incidence of infection within a crop can range from as low as 4 up to 86 % (Lane & Walters 1993; Hardwick *et al.* 1994). Despite the potential risk of yield loss as a result of BWYV infection, little is known about the effect of the virus on the crop. Previous studies of the effects of the virus on yield have relied on natural infection of the crop, with control plots being sprayed with aphicides through the autumn to limit infection. Smith and Hinckes (1984) compared the yields of heavily infected plots with those of lightly infected plots and found a decrease of 13 % due to the effect on oil and seed yields. Further trials by Hill *et al.* (1989) proved inconclusive as only four out of 19 trials showed a significant yield decrease. These latter trials were carried out in years with a low incidence of natural infection. More recent work (Schröder 1994) showed yield decreases of 40 and 50 % for two out of the three oilseed rape cultivars tested, when individual plants in small experimental plots were infected with BWYV. This paper describes field trials to study the effects of BWYV on the growth and yield of winter oilseed rape, using artificial inoculation to control the infection.

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MATERIALS AND METHODS

Field trials were undertaken in commercial crops of autumn-sown oilseed rape at Wickhambrook, Suffolk during 1993/94, and 1994/95. In each season, a trial was conducted to study the effect of BWYV on the growth and yield of the crop, by taking destructive samples on subplots throughout the season for growth analyses, and by mechanically harvesting the main plots to determine the final yield. In the second season an additional trial was carried out to examine the effect of inoculation pressure on final yield.

Experimental design and treatments

In the first season a growth analysis trial was carried out on a crop of winter oilseed rape cv. Capricorn, drilled on 17 August 1993, and in the second season on a crop of cv. Apex drilled on 3 September 1994, both at a seed rate of 7 kg/ha. The selection of the variety was at the discretion of the grower. Both trials consisted of four blocks each comprised of four main plots, 6×22 m, to give 16 plots in total. Two main plots in each block (eight plots in total) were inoculated with BWYV in early October, when the plants were at the 5–6 leaf stage in 1993, and the 2–3 leaf stage in 1994. Each main 6×22 m plot was divided into 3×22 m strips. One strip was marked into 1 m² subplots (with a 1 m guard between the subplots) which were destructively sampled through-out the season; the order of sampling these subplots was randomized. The second strip was combine-harvested to give final yield. To facilitate access into the plots after stem extension, the herbicide glyphosate was applied to the edges of the main plots in April.

Inoculation with BWYV

Inoculations were made using viruliferous *M. persicae* which had been raised on BWYV-infected oilseed rape plants in a glasshouse. Leaf pieces of these plants plus aphids were distributed among all plants in the field plots in October and left for up to 2 weeks, depending on the weather conditions. During this time the glasshouse-grown leaves wilted, and the viruliferous aphids moved onto and infected the young oilseed rape plants.

Aphid control

The 1993/94 trial was sprayed with pirimicarb (Aphox: Zeneca) at 140 g/ha to kill the aphids used to inoculate the plots; three further applications of insecticide (one of lambda-cyhalothrin [Hallmark: Zeneca] at 150 ml/ha and two of pirimicarb at 280 g/ha) were made during October and November to control incoming aphids. The 1994/95 trial was initially sprayed with lambda-cyhalothrin at 150 ml/ha with an additional application of pirimicarb at 140 g/ha.

Cultural practice

The trial areas received the grower's usual applications of fungicide and herbicide, but not insecticide. The insecticide cypermethrin (Ambush C: Zeneca) was applied to the surrounding areas at a rate of 250 ml/ha.

Growth analyses

Destructive harvests

One subplot (1 m²) was harvested from each main plot at eight growth stages (Table 1), giving eight samples from infected plots and eight from un-inoculated control plots on each sampling occasion. All plants within these 1 m² quadrats were harvested by cutting at the base of the plant; the plants were

Table 1. *Growth stage and date of sampling for growth analyses and mean incidence of BWYV infection in inoculated and control plots, 1993/94, 1994/95*

Growth stage*	Trial 1 Date sampled	1993/1994 % of BWYV in plots[+] Inoculated	Control	Trial 2 Date sampled	1994/1995 % BWYV in plots Inoculated	Control
1,7 – 1,8 (7 – 8 true leaves)	8 Nov	15·0	3·1	—		
1,9 – 1,10 (9 – 10 true leaves)	7 Dec	73·1	5·0	14 Dec	90·0	0
2,0 (rosette form)	8 Feb	94·3	17·8	16 Feb	88·7	0·6
3,3 (green bud)	31 Mar	91·2	9·3	3 Apr	86·0	1·0
4,5 (50 % flowering)	27 Apr	96·2	11·8	24 Apr	88·7	1·2
5,5 (early pod development)	23 May	91·8	10·6	24 May	89·4	1·2
6,3 (green seeds in pod)	20 Jun	89·4	6·2	22 Jun	—	—
6,9 (before final harvest)	20 Jul	—	—	20 Jul	—	—

* From Sylvester-Bradley & Makepeace (1984).
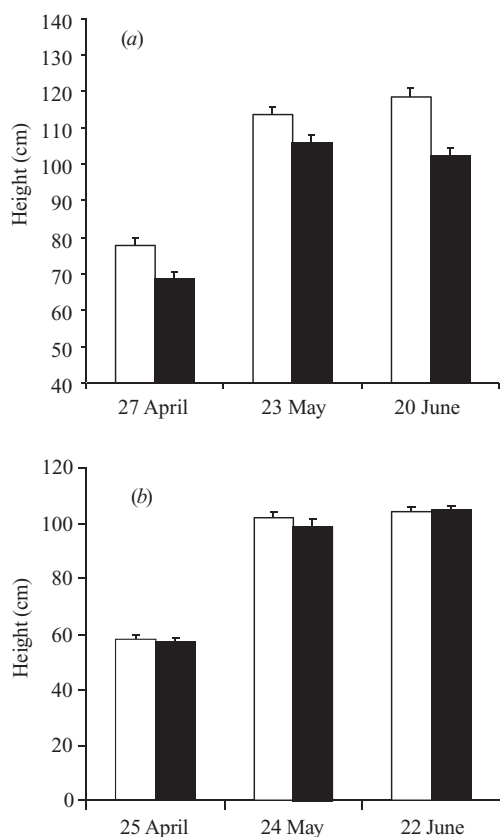[+] Mean for eight plots.
— Not sampled.

Fig. 1. The effect of BWYV on the height of oilseed rape in (*a*) 1994 and (*b*) 1995. Vertical bars represent the standard error of the means with 11 D.F.

counted, and fresh weights of the whole sample, and fresh and dry weights (72 h at 80 °C) of a subsample of 20 plants were measured. Detailed growth analyses of the sampled plants included measurements of leaf area, dry weights of the leaves, stalks, flowers, pods and branches, and numbers of branches, pods and seeds. The heights of 20 plants from each subplot were measured in the April, May and June samples. In July of each season, before final harvest, subsamples of five plants in 1994 and 10 in 1995 were taken for pod measurements. In 1994, counts were made of the total number of pods produced by each of these five plants; the numbers of seeds per pod were counted for 10 pods from each plant, selected at regular height intervals up the raceme. In the 1995 season 10 plants were sampled and the pod numbers on the branches and racemes were counted. These pods were then hand threshed for the branch and raceme components separately to obtain seed numbers and the 1000-seed weight (TSW).

The remainder of the 1 m² sample was threshed and winnowed to obtain the seed yield. The TSW was

measured for each of the 16 plots in both seasons and in 1994 the seed samples were also size graded using a series of sieves.

All growth analyses data were analysed using the Genstat statistical package for analysis of variance (Payne *et al.* 1987) with 11 degrees of freedom. The 1994 data for the seed number per pod were analysed separately for each height category.

Final yield

The final harvests were made on 4 August 1994 and 28 July 1995 using a SAMPO Rosenlew 2010 combine harvester with a 2 m swath to give a total harvested area of 44 m² per plot. The total seed yield per plot was weighed using a weighing bucket inside the seed tank. Moisture and oil content of 20 g seed samples from each plot were assessed by ADAS Laboratory Services, Wolverhampton, using the nuclear magnetic resonance (NMR) method (Tomassetti *et al.* 1991), and seed yield adjusted to 91% dry matter. Glucosinolate levels were also measured in the 1995 season using the X-ray fluorescence method with 10 g of milled sample (Schnug & Haneklaus 1988). All data were analysed using analysis of variance with 11 degrees of freedom.

BWYV infection

During the sequential harvests, the oldest non-senescent leaves from 20 plants per plot were checked for BWYV using an indirect ELISA protocol, based on that described by D'Arcy *et al.* (1989), to determine the proportion of infected plants per plot (Table 1). If the leaves had dropped, the pods were tested for BWYV. Twenty samples from the strips to be combine harvested were also tested for virus on 11 March 1994 and 4 April 1995, for the 1993/94 and 1994/95 seasons, respectively.

Virus content of pod and seed components

In June 1994, two pods from each of 78 BWYV-infected plants were dissected and separated into pod walls, septa, seed coats and embryos. For one sample the seed coat was also separated into the outer and inner coat. The pod components were tested for BWYV using ELISA (Clark & Adams 1977).

Effect of different inoculum levels on seed yield, 1994/95

A trial was set up in a commercial crop of winter rape drilled on 4 September 1994 with the cv. Capricorn at a seed rate of 8 kg/ha, and consisted of four blocks, each containing six plots 24 m long and 3 m wide. The treatments within the blocks were randomized. Two plots in each block were left uninoculated; two were inoculated as described previously, and two received a reduced intensity of inoculation, achieved by applying infected aphids to alternate strips 2 m long

and 2 m apart. Prior to inoculation, ten plants per plot were checked for aphids and tested for virus. Plots were inoculated on 19 October 1994 when the oilseed rape plants were at the 2–3 leaf stage. The plots were subsequently sprayed with pirimicarb at a rate of 140 g/ha on 2 and 29 November. As with the previous trials the plots received the farmer's usual spray programme, apart from insecticides; the insecticide cypermethrin was applied to the surrounding area. In April 1995, 54 plants per plot were tested for the presence of BWYV. The trial was harvested on 28 July 1995. Yield data were analysed using analysis of variance with 18 degrees of freedom.

RESULTS

BWYV infection

The virus incidence in the sequentially harvested plots averaged 89 % in both 1994 and 1995 for the inoculated plots, while the virus incidence in the control plots averaged 10 % in 1994 and 1 % in 1995 (the incidence of virus in November 1993 was not included in the mean value as it was unrepresentative) (Table 1). The virus incidence in the harvested plots had a mean value of 92·5 % in 1994 and 80 % in 1995 for the inoculated plots, with an incidence of 3·1 % in 1994 and zero infection in 1995 for the control plots.

Growth analyses

The height of BWYV-infected plants was significantly lower than that of control plants in 1994. In April, infected plants had an average height of 68·5 cm (12 % less than controls) ($P < 0·01$, LSD = 6·25, 11 D.F.), in May 105·9 cm (7 % less) ($P < 0·05$, LSD = 6·77, 11 D.F.) and in June 102·2 cm (14 % less) ($P < 0·001$, LSD = 7·28, 11 D.F.) (Fig. 1a). However, there was no clear effect of BWYV on height in 1995 (Fig. 1b). BWYV-infected plants had significantly less leaf area per plant ($P < 0·05$) and lower dry weights for both the leaves ($P < 0·05$) and stalks ($P < 0·01$) in March 1994. There was also a decrease in stem plus raceme weight ($P < 0·01$) and main raceme pod weight ($P < 0·001$) in June 1994 (Table 2). In 1995, infection

Table 2. *The dry weight (g) of leaf, stalk and pod components and leaf area (cm²) of the sub-sampled plants with and without BWYV, 1993/94 and 1994/95 (data are per plant)*

	Dry weight of components, leaf area	1993/94			1994/95		
		Uninfected	BWYV-infected	S.E. 11 D.F.	Uninfected	BWYV-infected	S.E. 11 D.F.
Nov	Leaf area	137·0	124·4	10·49	—	—	—
Dec	Leaf	—	—	—	0·51	0·53	0·066
	Stalk	—	—	—	0·35	0·33	0·032
	Leaf area	117·3	114·0	8·40	—	—	—
Feb	Leaf	1·08	1·01	0·091	0·64	0·62	0·054
	Stalk	0·50	0·51	0·039	0·45	0·44	0·025
	Leaf area	125·0	117·0	9·04	—	—	—
Mar	Leaf	2·03	1·78	0·094	0·94	0·85	0·098
	Stalk	1·60	1·29	0·734	0·82	0·66	0·077
	Leaf area	346·7	298·6	16·06	—	—	—
Apr	Leaf	2·36	2·63	0·246	1·17	1·26	0·162
	Stalk	5·14	4·54	0·494	2·50	2·34	0·307
	Flower heads	—	—	—	0·31	0·28	0·031
	Leaf area	465·0	446·0	47·60	—	—	—
May	Leaf	1·07	1·39	0·198	0·91	1·02	0·131
	Stem and raceme	4·99	5·03	0·567	3·58	3·20	0·349
	Pods on raceme	1·35	1·28	0·121	1·05	0·66	0·060
	Primary branches and pods	1·75	1·78	0·440	1·29	1·02	0·219
	Leaf area	210·0	238·0	31·40	—	—	—
Jun	Leaf	0·50	0·54	0·076	0·39	0·51	0·037
	Stem and raceme	6·24	4·70	0·370	3·42	3·74	0·235
	Pods on raceme	5·00	4·00	0·194	3·34	2·93	0·137
	Primary branches	1·79	1·39	0·263	0·88	1·08	0·118
	Pods on Primary branches	3·44	2·70	0·556	1·74	2·35	0·295
	Secondary branches and pods	0·06	0·01	0·033	0·09	0·03	0·051

Table 3. *Effect of BWYV on numbers of primary branches, pods, seeds per pod and 1000 seed weight (TSW) of oilseed rape, 1994 and 1995*

Yield component	Month	Uninfected	BWYV-infected	S.E. (11 D.F.)
Primary branches	Jun 1994 (10)*	4·76	4·06	0·253
	Jun 1995 (10)	3·78	3·65	0·233
	Jul 1995 (10)	4·42	4·65	0·410
Pods on main raceme	Jun 1994 (10)	46·7	48·5	1·64
	Jul 1994 (5)	53·3	50·8	2·68
	Jul 1995 (10)	43·6	41·4	1·73
Aborted pods on raceme	Jun 1994 (10)	6·36	4·11	0·480
	Jul 1995 (10)	10·31	11·10	0·685
Pods on branches	Jun 1994 (10)	47·4	46·3	7·90
	Jul 1995 (10)	45·8	58·1	10·94
Seeds per raceme pod	Jul 1994 (5, 10 pods/plant)	14·1	8·4	0·88
	Jul 1995 (10)	15·1	11·4	0·77
Seeds per branch pod	Jul 1995 (10)	13·7	8·2	0·77
TSW of m² sample (g)	Jul 1994	6·24	6·99	0·135
	Jul 1995	5·03	5·67	0·145
TSW of seeds from raceme pods (g)	Jul 1995 (10)	4·94	5·47	2·420
TSW of seeds from branch pods (g)	Jul 1995 (10)	4·85	5·54	0·184

* Numbers of plants sampled shown in parentheses.

caused lower pod weight in both May ($P < 0.001$) and June ($P < 0.05$), and leaf dry weight in June ($P < 0.01$). There was no effect on leaf area, or on dry weights at any other sample dates. BWYV-infection was associated with significantly fewer numbers of primary branches in 1994 ($P < 0.05$), although this effect was not seen in 1995 (Table 3).

Numbers of pods and seeds per pod

Infection had no significant effect on the numbers of pods produced on the main raceme or on the branches. There were significantly fewer aborted pods ($P < 0.001$) in June 1994 on the infected plants, however this effect was not seen in 1995. The BWYV-infected plants produced fewer seed per pod (Table 3) but these seed were heavier than those produced by uninfected plants, and therefore they gave a significantly higher TSW ($P < 0.001$). Seed size data also showed that the infected plants had larger size seeds which were more closely centred on the mean, i.e. the spread between the size categories was smaller. In the 1995 trial the TSW was higher by 10·5 and 14% on the raceme and branches of the infected plots respectively. The higher TSW on the branches correlates with the greater decrease in seed numbers per pod. The threshed metre squared sample was a mixture of racemes and branches, and the TSW of the infected seeds was 12·7% more than the control seeds ($P < 0.001$), in between the values for the raceme or branches alone. However, because there were fewer seeds per pod, this resulted in an overall reduction in

seed yield. In 1994 the lower numbers of seed were apparent at all pod positions on the raceme, although the difference was most noticeable at the lower positions (Fig. 2).

BWYV in pod components

Virus testing of the components showed that BWYV was present in the pod wall, the septum and the seed coat (Table 4): two of 78 embryo samples gave absorbance values in ELISA of 0·22 and 0·24, indicating the presence of virus. One seed coat that was dissected into the inner and outer coat showed ELISA absorbance readings of 0·22 for the outer coat indicating the presence of virus, but only 0·07 for the inner coat.

Final seed yields

Seed yields of 4·14 and 3·04 t/ha were obtained at final harvest in 1994 for control and inoculated plots respectively, with 26% less yield as a result of BWYV infection ($P < 0.001$, LSD = 0·1, 11 D.F.) (Fig. 3a). In 1995, control and inoculated plots gave mean yields of 4·78 and 4·26 t/ha respectively, a significant difference of 11% ($P < 0.001$, LSD = 0·09, 11 D.F.) (Fig. 3b).

There was no significant effect of virus infection on oil content of the samples in 1994, the mean contents being 45·97 and 45·99% for the control and inoculated plots respectively (S.E. = 0·496, 11 D.F.). However, in 1995, the oil content was 47·91% in the control plots compared with 46·81% in the BWYV-infected plots,
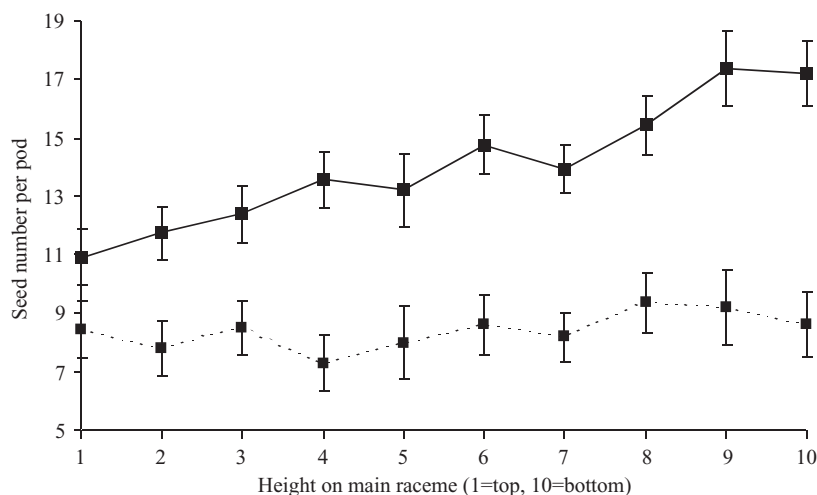
Fig. 2. The effect of BWYV on the number of seeds per pod at differing height on the main raceme, unbroken lines = control, broken lines = infected. Vertical bars represent the standard error of the means with 11 D.F.

Table 4. *Detection of BWYV in oilseed rape pod components*

Pod component	Number of samples positive for BWYV	A_{405} value mean $\pm$ SD
Pod wall + septa	59/59	1·27 ± 0·451
Pod wall	19/19	1·32 ± 0·407
Septa	19/19	1·14 ± 0·491
Seed coat	77/78	0·79 ± 0·342
Embryo	2/78	0·09 ± 0·032

Mean A_{405} readings ± S.D. for uninfected controls = 0·072 ± 0·014.

a significant difference at $P < 0.001$ (LSD = 0·49, 11 D.F.). Conversely, BWYV-infection gave a significant increase in the glucosinolate concentration, from 16·12 μmol/g in the control plots to 18·37 μmol/g in the inoculated plots ($P < 0.001$) (LSD = 1·01, 11 D.F.) (Figs. 4a and 4b).

Effect of inoculation pressure on yield

The mean BWYV incidence in March was 13·38 % for the control plots, 44·75 % for the 50 % inoculated plots and 75·25 % for the 100 % inoculated plots. The incidence in the plots for each of the 0, 50 and 100 % inoculations varied about the mean, providing a range of values between 2–35 %, 33–63 % and
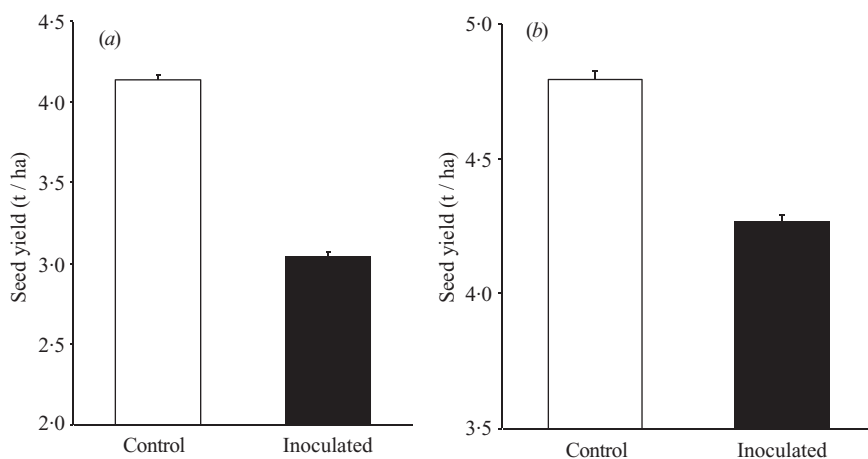

Fig. 3. The effect of BWYV on the final seed yield of oilseed rape in (a) 1994 and (b) 1995. Vertical bars represent the standard error of the means with 11 D.F.
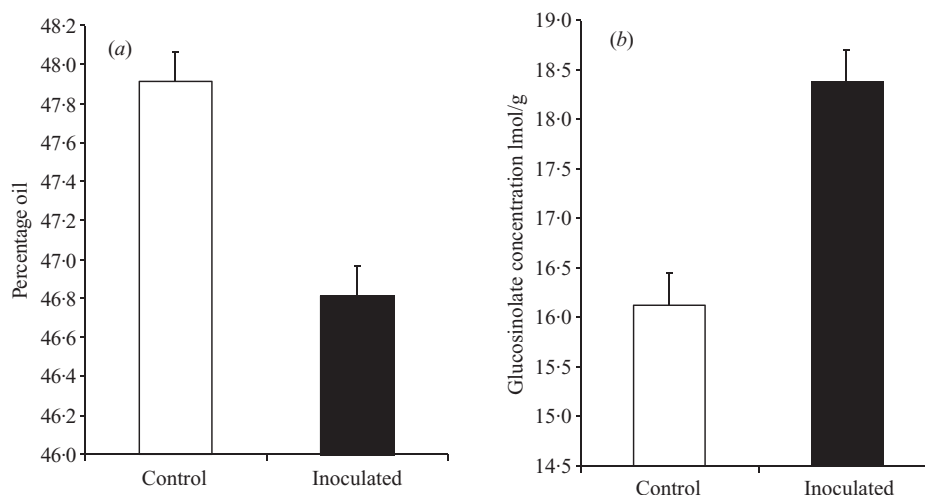
Fig. 4. The effect of BWYV on the (*a*) percentage oil and (*b*) glucosinolate concentration in oilseed rape seeds in 1995. Vertical bars represent the standard error of the means with 11 D.F.

61–85% respectively. The final combine-harvested seed yields were inversely proportional to the area of the plot that was inoculated with BWYV. Final seed yields of 4·51, 4·41 and 4·11 t/ha were obtained for the 0, 50 and 100% inoculated plots respectively, with a strong effect of treatment on seed yield ($P < 0.001$, LSD = 0·17, 18 D.F.). A strong linear effect could be seen which was significant at $P < 0.001$. *T*-tests were carried out to compare virus incidence, although these were not significant as there was a strong block effect. A regression was fitted with the percentage infection per plot against the seed yield (t/ha) per plot to form the equation $y = -0.0085x + 4.7145$, where y = yield and x = incidence of infection with BWYV, which was significant at $P < 0.05$ ($r = -0.492$). There was a general decrease in the seed yield with increasing infection levels, with a wide scatter due to the block effect.

DISCUSSION

A high incidence of BWYV was achieved in the inoculated plots in both seasons, whereas the un-inoculated plots remained relatively virus-free throughout the growing season. The effects of BWYV on growth of oilseed rape were not consistent between years, possibly because of varietal effect, also because environmental conditions varied.

Numbers of pods and seeds per pod and TSW

BWYV infection resulted in lower pod weight and a lower number of seeds per pod. This effect on seed number may have been due to the presence of BWYV in the phloem. Assimilate supply is an important factor in determining pod formation and seed set (Mendham *et al.* 1981). There has been little research into the physiological effects of BWYV, however studies on barley yellow dwarf luteovirus have shown that the disruption of the phloem leads to reduced translocation and therefore carbohydrate accumulation, with an increase in dry weight and respiration, but with a reduction in chlorophyll content and photosynthesis (Jensen & D'Arcy 1995). Sugar content has been found to increase in the leaves of BYDV-infected winter wheat, but decline in the grain. Grain-fill in wheat seems to be determined by the photosynthetic production of the flag leaf, head and awns (Stoy 1963), which would be reduced in an infected plant. If this pattern is similar for oilseed rape, it would be expected that reduced photosynthesis and translocation of photosynthates in infected leaves would decrease the assimilate availability which would affect seed set.

The TSW was increased in BWYV-infected plants. The growth rate of seeds is determined either by assimilate availability during seed filling and the number of competing seeds, or by the maximum growth rate of the seeds (Mendham *et al.* 1981). The increased TSW is likely to be as a direct consequence of having fewer seeds per pod, with less competition for available assimilates. The lower seed number per pod was the main contributing factor in the lower seed yields of the infected plots.

BWYV in pod components

The results indicated that virus particles can occasionally reach the embryo, which suggests that seed transmission of BWYV should not be discounted, and requires further investigation. For a virus to be truly seed transmitted it must infect the embryonic tissue, such as lettuce mosaic virus (LMV). LMV has been

found throughout the ovular tissues, but not in the embryo sac (Hunter & Bowyer 1993). For one sample which was tested, BWYV was detected in the outer seed coat, but not the inner coat, supporting the idea that there may be some point in the seed coat at which virus movement generally stops, however as only one sample was tested this result is preliminary. The results in this experiment were in agreement with those of Maisonneuve *et al.* (1995) who found BWYV in pod walls and in immature seeds. They did not, however, separate the seeds into the seed coat and embryo, and the positive readings for the embryos that they obtained may have been due to virus in the seed coat. Seed transmission, even at very low incidence, could have a marked effect on the epidemiology of BWYV. Final incidence of LMV in lettuce crops is dependent on the initial rate of seed transmission and on both the subsequent activity and population density of aphid vectors (Zink *et al.* 1956).

Final seed yields

Compared to the controls, the final seed yields were lower in the infected plots by 26 % in 1994 and 11 % in 1995. These losses occurred when infection was high, although the second 1995 trial showed that the yield was inversely proportional to virus incidence. With the cost of spraying insecticides at *c.* £10–20 per hectare all of the yield losses shown in the field trials would have made spraying economically viable.

The loss was shown to be enhanced in 1995 by a decrease in the oil content in the infected seeds from 47·9 to 46·8 % and an increase in the glucosinolate level of the infected seeds from 16·12 to 18·37 µmol/g. High amounts of glucosinolate are of concern when the meal is used for animal feed, and current breeding aims to decrease the glucosinolates. Glucosinolate in the seed is also important if the next crop is to be grown from farm-saved seed. In order for the crop to qualify for area payment, the quantity of glucosinolate in the farm-saved seed must be < 18·0 µmol/g (Anon 1995). Infection with BWYV can increase the quantity of glucosinolate to above this figure, which could potentially prevent growers from using farm-saved seed for their next crop. Higher glucosinolate values may be the result of bigger seeds; both Milford & Evans (1991) and Merrien (1989) have reported a positive correlation between seed weight and glucosinolate content.

These studies have shown that BWYV can cause economic losses in oilseed rape and therefore control measures may in some years be warranted. Advice on control must be based on a forecasting scheme, since unnecessary or prophylactic spraying could lead to an increase in the numbers of resistant aphids, which could adversely affect their control in other crops in oilseed rape growing areas, such as sugar beet. Sugar beet is a host of a closely related virus, beet mild yellowing virus (BMYV), also transmitted by *M. persicae*. BWYV does not infect sugar beet in Europe, and may even represent an isolate of turnip yellows virus (Graichen & Rabenstein 1996), however, both BWYV and BMYV share a number of common weed hosts. An increase in aphids that contain both strains of virus may increase the incidence of yellowing in sugar beet. An integrated approach to disease control is needed, which should also include the use of resistant varieties in conjunction with chemical control.

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