MOSAIC VIRUS SYMPTOMS IN POTATO CROPS AND THE OCCURRENCE OF GROWTH CRACKING IN TUBERS

M McCreath and S F Carnegie
Scottish Agricultural Science Agency, 1 Roddinglaw Road, Edinburgh, EH12 9FJ
E-mail: Maureen.McCreath@sasa.gsi.gov.uk

Summary: Infection of potato plants by viruses causing mosaic symptoms may result in a reduction in crop yield, depending on severity of symptoms and incidence. In 2004, an investigation was undertaken of the relationship between mosaic in plants and the occurrence of growth cracking in tubers. Samples of mosaic-affected and unaffected plants were collected from seven potato crops, of which five were cv. Estima, containing at least 20% virus. The incidence of cracking was much greater on plants of cv. Estima showing mosaic symptoms caused by *PVA* and *PVV* than on plants showing no symptoms. Cracking was more frequent on plants infected by both viruses than on plants infected by only one virus. The presence of virus in symptomless plants did not affect the incidence of tubers affected by cracking. In a crop of advanced selection Blue Tzar, plants with mosaic caused by PVY^N produced more tubers with cracking than plants with no symptoms. No cracking was found in samples of cv. Desiree.

INTRODUCTION

Viruses such as *potato virus A (PVA), potato virus V (PVV), potato virus X (PVX)* and *potato virus Y (PVY)* cause mosaic symptoms on the growing plant. Mild mosaic is a mottling of the leaflet but, with severe mosaic, the mottling is accompanied by a slight to severe distortion or reduction in size of the leaflet or plant. The severity of the symptom varies with virus and variety. The size of the reduction in tuber yield is related to symptom severity (Banttari *et al.*, 1993). These mosaic-causing viruses do not generally affect the quality of the tubers although misshapen tubers may be produced by plants produced from seed tubers infected by PVY^O (Logan, 1986). In addition, new variants of *PVY* have been recorded causing symptoms of Potato Tuber Necrotic Ring Disease (superficial necrotic rings on the tuber surface) in Europe (Beczner *et al.*, 1984) and North America (Piche *et al.*, 2004).

During July 2004, a complaint regarding plant distortion allegedly attributable to herbicide contamination of the seed tubers was investigated in two ware crops of cv. Estima. The grower was also concerned by a high incidence of growth cracking of tubers. The initial inspection of the crops revealed that the distortion of the leaflets was most likely related to a spray application of chemical to the crop rather than contamination of the seed tubers. However, in the course of the inspection, it became evident that there was a high incidence of plants with mosaic in the crop and this appeared to be associated with the growth cracking. A systematic investigation of the relationship between mosaic virus symptoms and the occurrence of growth cracking was, therefore, undertaken in a number of ware crops of cv. Estima and two seed crops of other cultivars containing relatively high amounts of mosaic affected plants.

MATERIALS AND METHODS

Five ware crops of cv. Estima and two seed crops, one of the advanced selection Blue Tzar and the other of cv. Desiree, containing mosaic-affected plants were identified for the investigation (Table 1). Paired plants comprising one plant affected by mosaic symptoms and one nearby symptomless plant were chosen. A sample of 4 leaflets was collected from each plant and tested by ELISA for *PVA*, *PVV*, *PVX*, *PVS*, *PVM*, PVY^O, PVY^N, *potato leaf roll virus (PLRV)*, *tomato black ring virus (TBRV)* and *potato mop top virus (PMTV)*. The tubers produced by each plant were harvested carefully by fork to ensure that harvested tubers were from the test plant. Replicates consisting of 10 pairs were sampled from 3 different areas in each crop. The number of tubers of each plant affected by cracking was counted. The data on the proportion of tubers affected by growth cracking was analysed by logistic regression for binomially distributed data, taking into account replicate effects.

Table 1. Details of crops sampled in 2004

Crop No.	Cultivar / selection	Location	Intended crop use	Date of sampling
1	Estima	Borders	Ware	20 July
2	Estima	Borders	Ware	20 July
3	Estima	Aberdeenshire	Ware	5 August
4	Estima	Borders	Ware	17 August
5	Estima	Morayshire	Ware	20 August
6	Blue Tzar	Inverness-shire	Seed	4 August
7	Desiree	Kincardineshire	Seed	29 July

RESULTS

In the crops of cv. Estima, the main viruses causing mosaic symptoms were *PVA* and *PVV* (Table 2); the other viruses consisted of *PVX*, *PVS* and PVY^N. For mosaic-affected plants, the frequency of plant infection by *PVA* and *PVV* together was greatest in crops 3, 4 and 5 and was at least twice as large as that for plants infected with *PVA* or *PVV* alone. The incidence of infection by *PVA* and *PVV* together was less than that for *PVA* or *PVV* alone only in crop 1. The incidence of virus infection in symptomless plants in crops of cv. Estima tended to increase the later the date of sampling (Table 2). By contrast with mosaic-affected plants, the incidence of infection by *PVA* and *PVV* together in symptomless plants was less than that for infection by one of the viruses alone, except for crop 5. In the crop of advanced selection Blue Tzar (crop 6), the virus causing mosaic symptoms was PVY^N and in cv. Desiree (crop 7), the main virus was *PVA* followed by *PVX* which infected 20% of plants. No virus was detected in symptomless plants in crops 6 and 7.

Table 2. The incidence of viruses detected in symptomless and mosaic-affected plants sampled from seven potato crops

Crop No.	Cultivar / selection	Symptom	% plants infected by *PVA*	*PVV*	*PVA+PVV*	Other
1	Estima	Mosaic	36.7	40.0	13.3	10.0
2	Estima	Mosaic	20.0	16.7	53.3	10.0
3	Estima	Mosaic	0	24.1	69.0	6.9
4	Estima	Mosaic	6.9	20.7	62.1	10.3
5	Estima	Mosaic	0	13.3	80.0	6.7
6	Blue Tzar	Mosaic	0	0	0	100
7	Desiree	Mosaic	80.0	0	0	20.0
1	Estima	None	0	6.7	0	3.3
2	Estima	None	10.0	6.7	0	0
3	Estima	None	37.9	10.3	6.9	3.4
4	Estima	None	51.7	0	3.4	0
5	Estima	None	20.0	16.7	46.7	0
6	Blue Tzar	None	0	0	0	0
7	Desiree	None	0	0	0	0

No growth cracking was found on the tubers sampled from the crop of cv. Desiree, crop 7. On the other samples, most of the growth cracks, characteristically, ran from rose to heel end. The incidence of tuber cracking was much greater on plants showing mosaic symptoms than on plants showing no symptoms (Table 3). For cv. Estima crops 2, 3, 5 and 6, more than 35% of tubers produced by mosaic-affected plants developed growth cracking compared with less than 3% for symptomless plants. With selection Blue Tzar, the difference was even greater, with 47.6% tuber cracking on produce of plants affected by PVY^N mosaic compared with 0.8% for symptomless plants. The logistic regression analysis calculated that the predicted proportions of cracked tubers were 32.5% for mosaic-affected plants of cv. Estima and 1.2% for symptomless plants [LSD ($p<0.05$) 3.6%]. The proportion of symptomless plants producing cracked tubers tended to increase the later the date of sampling but this trend was less evident with the proportion of tubers affected by cracking.

Table 3. Association between mosaic symptoms in potato plants and growth cracking in tubers

Crop No.	% plants with cracked tubers		% tubers affected by cracking	
	Symptomless	Mosaic	Symptomless	Mosaic
1	0	43.3	0 (328)*	7.0 (257)
2	6.7	80.0	0.7 (287)	50.0 (224)
3	10.3	75.9	0.7 (401)	37.0 (335)
4	13.8	62.1	1.4 (346)	19.5 (318)
5	23.3	83.3	2.9 (349)	48.4 (343)
6	14.3	92.9	0.8 (512)	47.6 (456)
7	0	0	0 (247)	0 (194)

* Figure in parenthesis is number of tubers assessed

Table 4 shows the proportions of tubers affected by growth cracking for all five crops of cv. Estima in relation to symptoms and virus. With mosaic-affected plants infected by *PVA* and *PVV* together, the incidence of cracked tubers was at least twice as great as that for plants infected by either virus alone. Predicted proportions, from the logistic regression analysis accounting for location, for *PVA* only, *PVV* only and for both viruses were 21.1%, 12.0% and 41.1% respectively. The incidence of cracking with both viruses thus differed significantly from that for *PVA* and *PVV* alone [LSD ($p<0.05$) 16.1% and 10.0% respectively]. The incidence of growth cracking did not differ significantly between mosaic-affected plants infected by *PVA* or *PVV* alone [LSD ($p<0.05$) 15.7%]. The frequency of growth cracking for symptomless plants was not affected by the virus infecting the plant.

Table 4. Occurrence of growth cracking in relation to symptoms and virus in five crops of cv. Estima

Symptom	Virus	No. of plants	No. of tubers	% cracked tubers
Mosaic	*PVA*	25	199	16.6
Mosaic	*PVV*	35	355	8.7
Mosaic	*PVA + PVV*	87	916	45.5
None	None	83	933	0.8
None	*PVA*	36	451	1.1
None	*PVV*	12	130	4.6
None	*PVA + PVV*	17	197	1.0

DISCUSSION

Viruses causing mosaic are widely recognised as affecting crop vigour and yield, depending on the interaction of virus and variety and its effect on plant growth (Burton, 1966). The yield of an infected plant is generally reduced in proportion to the severity of the symptom. However, in a crop, adjacent healthy plants can compensate, to some extent, for the reduced yield of virus-affected plants, provided that the incidence of infection is not too great. In certification schemes e.g. United Nations Economic Commission for Europe Standard for Seed Potatoes (www.unece.org/trade/agr/standard/potatoes/pot_e.htm), the minimum tolerance for virus in the direct progeny (succeeding crop) of certified seed potatoes is no more than 10% severe virus, above which crop yield will be increasingly affected. Our results are, however, the first report to indicate that infection by the mosaic causing viruses *PVA*, *PVV* and PVY^N may, in some circumstances, affect tuber quality by rendering tubers unmarketable because of growth cracking. Growth cracking was much more prevalent on plants showing mosaic symptoms than on those symptomlessly infected or free of virus. The data also indicates that, in cv. Estima, growth cracking was more frequent when *PVA* and *PVV* were both present in a symptomatic plant than when they were present alone. Infection by more than one virus is likely to result in more severe symptoms of mosaic than infection by a single virus, possibly resulting in a greater effect on tuber growth. The association of growth cracking with mosaic symptoms did not seem to depend on any specific virus because it occurred with three viruses, *PVA*, *PVV* and PVY^N. Nevertheless, these findings must be treated with some caution as the investigation was conducted only over one season and was confined to only three varieties.

The infection detected in apparently healthy plants of cv. Estima was probably the result of primary infection occurring within the crops in 2004. The incidence of mosaic-affected plants in the sampled crops was very high, at least 20%, so there were numerous sources of virus within each growing crop for aphids to acquire and transmit virus. This conclusion is supported by the increased amount of infection detected in symptomless plants at the later dates of sampling when a longer period will have been available for virus transmission from aphids carrying virus. Such infection seemed to be more common in the ware crops than in the two seed crops. This could be attributable to more effective aphid control measures in seed crops than in ware crops. Our results show that the incidence of growth cracking on tubers from apparently healthy plants was similar for infected and uninfected plants. Primary infection by these viruses did not, therefore, appear to enhance growth cracking of tubers.

The finding of an association between mosaic symptoms and the development of tuber growth cracking clearly has potentially important implications for seed and ware producers. If mosaic-affected plants in a crop produced more tubers with growth cracks than symptomless plants then the incidence of such virus infection would have an effect on marketable yield and thus relatively low levels of virus could have a financial impact on the profitability of a crop.

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