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The relationship between common scab severity and reducing sugar contents in the peel of potato tubers

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Summary

Total sugar, reducing sugar, glucose, fructose, and sucrose of scabbed (*Streptomyces scabies*) and scab-free harvested tubers of several potato cultivars were analysed in four portions (peel and tuber flesh separately, from basal and apical halves), and also in small whole growing tubers.

The peel of scabby harvested tubers had higher reducing sugar (glucose and fructose) contents than that of corresponding scab-free tubers. The sugar contents in the flesh and in small growing tubers did not show significant difference between the scabbed and scab-free state.

Tubers of scab-susceptible cultivars had more scab and a higher reducing sugar content than those of resistant cultivars. The results indicate that the contents of reducing sugar (glucose and fructose) in tuber peel are positively correlated with scab severity.

Introduction

The infection process by *Streptomyces scabies* (common scab) in the potato tuber has been investigated morphologically. The results show that infection in the field takes place only on actively growing tubers or parts of tubers (Richardson, 1952; Lapwood & Hering, 1970) and not on mature potatoes (Fellows, 1926).

Although potato cultivars differ in susceptibility to common scab (Stevenson & Akeley, 1953), the reason for their differences in disease resistance remain largely obscure.

S. scabies, as a tuber parasite, may use after infection nutritive materials in the host for its growth or reproduction. It is, therefore, assumed that the chemical composition of tuber tissues may be closely related to the severity of scab lesions.

This investigation was initiated to clarify the relation between common scab severity and sugar content and composition in potato tubers.

Materials and methods

Experiment I: Comparison of the sugar content in scabbed and scab-free tubers
Potato tubers used in this study were grown at the Potato Research Branch of Nagasaki Agricultural & Forestry Experiment Station in Aino, during the 1977 spring growing season. The potatoes of six cultivars were planted in the two fields which were

Table 1. Some soil properties of the experimental fields.

	Scab-free soil	Scab-infested soil
pH H_2O	4.7	6.4
pH KCl	4.1	5.8
Total nitrogen (%)	0.23	0.17
Total carbon (%)	3.1	2.0
Carbon/nitrogen	13	12
Cation exchange capacity (meq)	20.5	17.8
Exchangeable base (meq/100 g)		
Ca	1.4	17.3
Mg	1.5	2.7
K	1.4	1.3
Base saturation (%)	7	97
Available P_2O_5 (mg/100 g)	14	61

close to each other; one was scab-infested and the other was scab-free. The fields had clay loam soils of volcanic ash origin and their water holding capacities were similar. The soil chemical properties are given in Table 1.

The scab-free soil had a lower content of exchangeable calcium and available phosphorus than scab-infested soil and its pH was below 5.0. *S. scabies* either fails to grow or has negligible activity below pH 5.0 (Alexander, 1961) and scabbed tubers were not found in this field.

The six cultivars planted were Saikai No 15, Tachibana, Dejima, Shimabara, Norin No 1, and Unzen.

At harvest the tubers were graded into saleable potatoes and small tubers (<20 g). Scabby tubers were collected from the scab-infested field and evaluated for scab, and scab-free tubers were collected from the scab-free field. All small tubers were free of scab. All these tuber samples were prepared for analysis of sugar content and composition.

Experiment II: Reducing sugar in potato peel of cultivars which differ in susceptibility Ten potato cultivars (Table 3), differing in susceptibility to common scab, were planted on 11 March 1977 in the scab-infested field (Table 1), and after harvest on 21 June the incidence of scab was evaluated. Tubers of all cultivars were analysed for sugar content and composition.

Scab evalutation. Tubers were washed and grouped into five classes: 0 = no scab; 1 = 25 % of surface scabbed; 2 = 25–50 %; 3 = 50–75 %; 4 = 75–100 %.

A 'scab index' was calculated as:

$$\text{Scab index} = \frac{n_0 \times 0 + n_1 \times 1 + n_2 \times 2 + n_3 \times 3 + n_4 \times 4}{4\,(n_0 + n_1 + n_2 + n_3 + n_4)}$$

where: n_0, n_1, n_2, n_3, n_4 = numbers of scabby tubers
0, 1, 2, 3, 4 = scab classes

Tuber tissue preparation and sugar analyses

Tubers were cut and separated into basal and apical halves and the periderm from a each half was thinly hand-peeled to separate the peel and flesh. The juice from each of the four tuber portions was separately analysed because the peel of the apical half is supposed to be the most actively growing portion of a tuber (Lapwood & Hering, 1970). In addition, juice samples from small growing tubers were analysed.

The method employed for the preparation of potato juice was essentially that of Shaw (1969) and sugars were analysed by gas chromatography as described by Brobst & Lott (1966).

Results

Experiment I: Comparison of the sugar contents in scabbed and scab-free tubers

Table 2 summarizes the results for the average of sugar contents in potato tubers of six cultivars comparing scabbed and scab-free tubers.

The basal and apical peel samples of scabbed tuber and higher reducing sugar (glucose and fructose) contents than those from scab-free tubers. Sucrose contents in the apical portions of scab-free tubers were higher than in those from scabbed tubers. The total sugar content did not differ significantly between scabbed and scab-free tubers.

The flesh had more sucrose and less reducing sugar than peel from both half tuber

Table 2. Average contents of sugars in tubers of 6 cultivars.

Tuber portion	Tuber	Sugar content of tubers (mg/ml juice)				
		glucose	fructose	reducing sugars	sucrose	total sugars
Peel						
Basal	Scabby	2.2	1.6	3.8	3.1	6.9
	Scab-free	0.8	0.5	1.3	4.6	6.0
		**	*	**		
Apical	Scabby	3.2	1.4	4.6	3.3	7.9
	Scab-free	1.3	0.7	2.1	4.7	6.8
		*	**	*	**	
Flesh						
Basal	Scabby	0.5	0.7	1.2	5.5	6.6
	Scab-free	0.6	0.4	1.0	6.2	7.2
Apical	Scabby	0.8	0.8	1.6	6.1	7.7
	Scab-free	0.6	0.4	1.0	6.8	7.8
Small tuber	Scabby	1.7	1.9	3.6	6.3	9.9
	Scab-free	1.2	0.6	1.7	5.8	7.5
			*			

* $P < 0.05$; ** $P < 0.01$.

Table 3. Scab index of ten cultivars and the reducing sugar content in peel.

Cultivar	Scab index	Sugar content of peel (mg/ml juice)		
		reducing sugar	glucose	fructose
Dejima	75	4.0	2.5	1.5
Tachibana	58	5.9	3.5	2.4
Saikai No 15	56	3.0	1.9	1.1
Norin No 1	47	5.3	4.0	1.3
Saikai No 14	46	3.2	2.9	0.3
Menominee	46	2.8	1.0	1.8
Unzen	45	4.3	2.3	2.0
Shimabara	32	2.9	2.0	0.9
Urtica	19	0.8	0	0.8
Jubel	16	0.9	0.3	0.6
LSD (5 %)	21	2.3	NS	NS

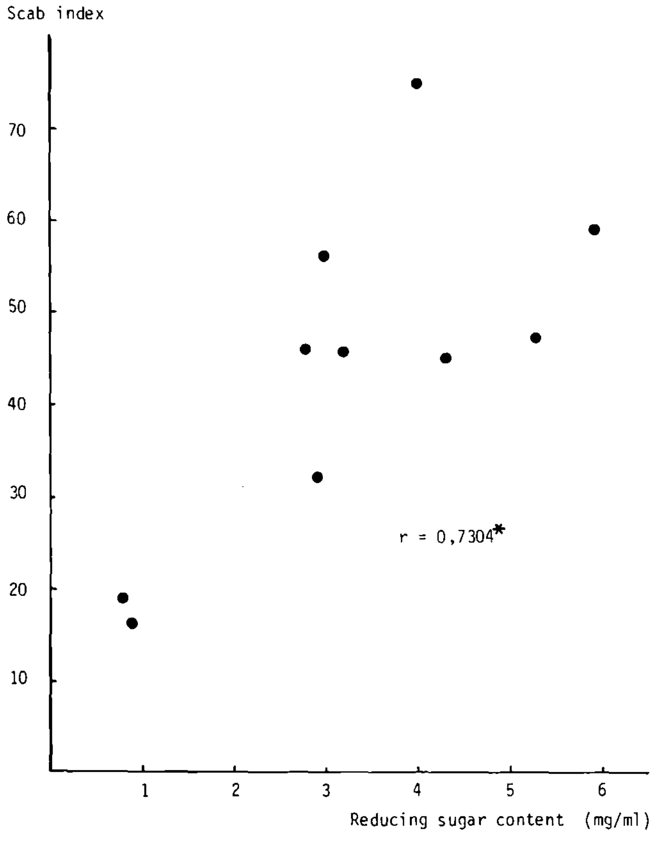

Fig. 1. Relationship between scab index and content of reducing sugar in peel.

samples but the contents of different sugar fractions did not differ insignificantly between scabbed and scab-free tubers.

Small tubers harvested from scab-infested field had higher fructose content than those from scab-free field. Glucose, reducing sugar, sucrose, and total sugar contents were not significantly different between the tubers from the scab-infested and scab-free field.

From these results it was clear that the presence of scab on tubers is associated with increased amounts of reducing sugar in the peel.

Experiment II: Reducing sugar content in potato peel of cultivars which differ in susceptibility

Table 3 shows scab index and reducing sugar contents (average of apical and basal halves) in the peel of various cultivars.

Among the ten cultivars, scab indices of Jubel and Urtica were lower than those of the Japanese cultivars among which Shimabara had the lowest incidence.

The peel of scab-resistant cultivars (e.g. Urtica and Jubel) had lower reducing sugar contents than that of the susceptible cultivars.

The sugar composition, i.e. glucose and fructose content, did not differ significantly between the ten cultivars.

A summary of the relationship between scab index and the content of reducing sugar in peel is presented in Fig. 1. The reducing sugar contents in the peels were positively correlated with scab indices.

Discussion

Disease resistance of plants is of two kinds: structural or functional resistance to penetration by the pathogen, or biochemical resistance of the tissues to infection. There have been some studies concerned with the interactions between susceptibility to potato scab and chemical composition of tuber tissues. These studies have dealt almost exclusively with mineral nutrients (Davis et al., 1974a, 1976a, b), such as calcium (Horsfall et al., 1954; Davis et al., 1974b) and manganese (McGregor & Wilson, 1964, 1966). However, mineral nutrients in potato tuber are merely reflections of soil fertility and do not account clearly for these relations.

Biochemical research about the severity of potato scab may be based on the hypothesis that nutritive substances in tubers, such as the sugars, may play an important role. The results of this study indicated that the presence of scab on a tuber was associated with an increased amount of reducing sugar in the peel; the greater the severity of scab on a tuber the greater the amount of reducing sugar present.

However, the results were unable to show whether the relationship was the result of infection or of a predisposing factor and to elucidate the relationship requires further investigations. These would include clarifying the relationship between scab severity and changes of sugar content in the growing tuber, and investigations of sugar contents in tubers from plants grown under soil conditions favourable and unfavourable for scab infections. Furthermore, research on the influence of fertilizers and soil moisture on the sugar content of tubers may suggest methods for control of potato scab.

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References

Alexander, M., 1961. Introduction to soil microbiology. John Wiley, New York. pp. 381.

Brobst, K. M. & C. E. Lott, Jr., 1966. Determination of some components in corn syrup by gas-liquid chromatography of the trimethylsilyl derivatives. *Cereal Chem.* 43: 35–43.

Davis, J. R., G. M. McMaster, R. H. Callihan, J. G. Garner & R. E. McDole, 1974a. The relationship of irrigation timing and soil treatments to control potato scab. *Phytopathology* 64: 1404–1410.

Davis, J. R., J. G. Garner & R. H. Callihan, 1974b. Effects of gypsum, sulfur, Terraclor and Terraclor Super-X for potato scab control. *Am. Potato J.* 51: 35–43.

Davis, J. R., G. M. McMaster, R. H. Callihan, F. H. Nissley & J. J. Pavek, 1976a. Influence of soil moisture and fungicide treatments on common scab and mineral content of potatoes. *Phytopathology* 66: 228–233.

Davis, J. R., R. E. McDole & R. H. Calliham, 1976b. Fertilizer effects on common scab of potato and the relation of calcium and phosphate-phosphorus. *Phytopathology* 66: 1236–1241.

Fellows, H., 1926. Relation of growth in the potato tuber to the potato-scab disease. *J. Agric. Res.* 32: 757–781.

Horsfall, J. G., J. P. Hollis & H. G. M. Jacobson, 1954. Calcium and potato scab. *Phytopathology* 44: 19–24.

Lapwood, D. H. & T. F. Hering, 1970. Soil moisture and the infection of young potato tubers by *Streptomyces scabies* (common scab). *Potato Res.* 13: 296–304.

McGregor, A. J. & G. C. S. Wilson, 1964. The effect of applications of manganese sulphate to a neutral soil upon the yield of tubers and the incidence of common scab in potatoes. *Plant Soil.* 20: 59–64.

McGregor, A. J. & G. C. S. Wilson, 1966. The influence of manganese on the development of potato scab. *Plant Soil.* 25: 3–16.

Richardson, J. K., 1952. The influence of tuber development on scab infection in Katahdin potatoes. *Phytopathology* 42: 297–298.

Shaw, R., 1969. Analysis of potato sugars by gas chromatography. *Am. Potato J.* 36: 201–213.

Stevenson, F. J. & R. V. Akeley, 1953. Control of potato diseases by disease resistance. *Phytopathology* 43: 245–253.