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FURTHER SOURCES OF RESISTANCE TO *HETERODERA ROSTOCHIENSIS WOLL.* IN THE ANDIGENA POTATOES

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SUMMARY

The Andigena potatoes (*Solanum tuberosum* ssp. *andigena*) of the Commonwealth Potato Collection (C.P.C.) were screened for resistance to 'non-pathotype A' populations of *Heterodera rostochiensis*. Three populations were used: Duddingston (pathotype B), Nocton (pathotype C) and Changed Little Ouse (pathotype C). Resistance was found in C.P.C. 2775, 2802 and 2805. C.P.C. 2775 also had resistance to pathotype A (Feltwell population) and appeared to have two dominant genes, H_1 giving resistance to pathotype A and H_3 giving resistance to pathotypes B and C. C.P.C. 2802 was susceptible to pathotype A and appeared to have only an H_3-type gene. C.P.C. 2805, which has not been investigated thoroughly because the plants lacked vigour, may also have an H_1 and an H_3 gene. The value of C.P.C. 2775, 2802 and 2805 for breeding nematode-resistant potatoes will only be known when they have been tested with further non-pathotype A populations and when the genetics of resistance have been investigated thoroughly.

INTRODUCTION

The breeding of potatoes for resistance to potato cyst-nematode (*Heterodera rostochiensis* WOLL.) was made possible by the work of ELLENBY (1952, 1954). He screened the Commonwealth Potato Collection (C.P.C.) and found resistance in the wild, diploid species, *Solanum vernei* (C.P.C. 105, 2413.1 and 2414.3), in a single triploid clone with affinities to Andigena (C.P.C. 1647) and in five Andigena clones (C.P.C. 1595, 1673, 1685, 1690 and 1692). Resistance in the Andigena clones C.P.C. 1673 and 1685 was shown by TOXOPEUS and HUIJSMAN (1952, 1953) to be due to a single, dominant gene, H_1, and COLE and HOWARD (1957) found C.P.C. 1690 also to have a single dominant gene for resistance. No further data on C.P.C. 1595 are given in literature, so it has apparently been lost from the collection. The resistance of C.P.C. 1692 has been suggested to be due to polygenes but has not been investigated to any extent because C.P.C. 1673 proved to be a good source of resistance.

The discovery by DUNNETT (1957) of a nematode population at Duddingston, near Edinburgh, which produced about as many cysts on the roots of potatoes with gene H_1 as on the roots of standard susceptible varieties, initiated a new phase in breeding for nematode resistance. Surveys (e.g. JONES, 1957, 1958) showed that there were many nematode populations in the United Kingdom which were similar

to the Duddingston population in that they could produce many cysts on the roots of potatoes with gene H_1. DUNNETT (1961) found that the wild, diploid species, *S. multidissectum*, had a dominant gene, H_2, which gave resistance to the Duddingston population (pathotype B) but no resistance to the Boghall population (pathotype A). Potatoes with both genes H_1 and H_2 have been bred, but tests (e.g. JONES and PAWELSKA, 1963; JONES and PARROTT, 1965; GUILE, 1966, 1967) have shown that most populations which were not predominantly pathotype A (no cysts on potatoes with gene H_1) were not pathotype B (no cysts on potatoes with gene H_2) but pathotype C (many cysts on potatoes with both genes H_1 and H_2). Similarly ROSS and HUIJSMAN (1969) have found that there are populations in Germany, The Netherlands and Switzerland which produce many cysts on potatoes with genes H_1 and H_2.

Because genes H_1 and H_2 are not effective against many nematode populations, there has been a renewed and increased interest in the resistance of wild species. Much effort has been put into breeding for resistance using wild species such as *S. vernei*, *S. oplocense* and *S. spegazzinii* (ROSS, 1966 a, b; ROSS and HUIJSMAN, 1969) and some progress has been made. It would be much easier, however, to use a cultivated Andigena source of resistance than that of a wild species. There is also no reason why the Andigena potatoes should have resistance to pathotype A only. Accordingly, we decided that it was worthwhile to screen the Andigena potatoes of the Commonwealth Potato Collection for resistance to pathotypes other than A.

MATERIAL

True seed of the Andigena potatoes in the Commonwealth Potato Collection was obtained. This consisted of some 310 selfs or sib-crosses and some 370 crosses between clones. The families raised from this seed at Cambridge were renumbered AND 1–680. Tubers from five plants of each AND line were used wherever possible in the tests for resistance. Many lines were found to be extreme short-day types for tuberization and, although tubers were obtained, they were produced very late in the season and were often very small. Many tubers also sprouted late and tended to produce slow-growing plants with rather poor root-systems which did not always appear to be adequate for cyst production. This made testing difficult and led to the following statement of HOWARD (1967): "There still remain five lines which have not been shown to be susceptible but it is possible that they have escaped infection in the tests and are not resistant."

METHODS

Tests for resistance were made by planting tubers in small pots of nematode-infested soil. The first tests were made using sterilized soil to which cysts of the Duddingston population (pathotype B) had been added. Later tests were made using a soil from Nocton, Lincs., which appears to contain a mixture of pathotypes B and C (GUILE, 1966, 1967) and the Changed Little Ouse population (COLE and HOWARD, 1966) which also appears to contain a mixture of pathotypes B and C. Root balls were examined for cysts at about 14-day intervals. Susceptible controls had usually 200 or more cysts per root ball.

RESULTS

Resistance to pathotypes other than A has probably been found in five lines. These are: AND 229 (C.P.C. 2775 self), AND 237 (C.P.C. 2802 self), AND 238 (C.P.C. 2805 self), AND 586 (C.P.C. 2774 × C.P.C. 2775), and AND 595 (C.P.C. 2793 × C.P.C. 2775). Three of these lines, AND 229, 586 and 595, involve C.P.C. 2775 and it is this source of resistance for which we have the most information.

C.P.C. 2775

Line AND 229 from C.P.C. 2775 selfed had three plants out of four tested which were apparently resistant to the Duddingston population. The tubers from only two plants, 229/2 and 229/4, were available for testing against the Nocton and Changed Little Ouse populations. They were resistant to both. One seedling, 229/2, was also resistant to the Feltwell population (pathotype A), see Table 1; the other was susceptible.

Line AND 586 from the cross C.P.C. 2774 × C.P.C. 2775 had three out of five seedlings tested resistant to the Duddingston population. Only two seedlings were tested against the Nocton population; both were resistant. Only one seedling, 586/1, was tested against the Changed Little Ouse and Feltwell populations; it was resistant to both (Table 1).

Line AND 595 from the cross C.P.C. 2793 × C.P.C. 2775 had two out of five seedlings resistant to the Duddingston population. One of these seedlings was found to be resistant to the Nocton population, but both seedlings were lost before they could be tested with the Changed Little Ouse and Feltwell populations.

A further family, K81, was grown from the cross C.P.C. 2774 × C.P.C. 2775. Tested with Changed Little Ouse population, 15 seedlings were found to be resistant and 24 susceptible. Eleven of these resistant seedlings were tested in the following year with the Feltwell population (pathotype A); six were resistant and five susceptible. It is probable, therefore, that C.P.C. 2775 has two genes for resistance, a gene identical with or similar to H_1 giving resistance to pathotype A and another gene, H_3, giving resistance to pathotypes B and C.

Table 1. Test with Feltwell (pathotype A) and Changed Little Ouse (pathotypes B and C) populations.

Seedling	Number of cysts per root ball	
	Feltwell	Changed Little Ouse
AND 229/2	4	3
AND 229/4	51	4
AND 237/3	114	6
AND 238/3	3	6
AND 586/1	5	2
Maris Page (control)	460	202

C.P.C. 2802

Line AND 237 from C.P.C. 2802 selfed had two out of four plants tested apparently resistant to the Duddingston population. Only one of these plants, 237/3, was tested with the Nocton and Changed Little Ouse populations; it was resistant to both. AND 237/3 was found to be susceptible to the Feltwell population (Table 1).

A further family, K78, was raised from C.P.C. 2802 selfed. Of the 12 seedlings tested against the Changed Little Ouse population, 8 were found to be resistant and 4 susceptible. The eight seedlings resistant to the Changed Little Ouse population were all found to be susceptible to the Feltwell population. C.P.C. 2802, thus, appears to have a single H_3 type gene.

C.P.C. 2805

Line AND 238 from C.P.C. 2805 selfed had 4 out of 4 plants tested apparently resistant to the Duddingston population. The plants of this line were very weak growing, had rather poor root systems and produced very small tubers; accordingly there must be considerable doubts as to the validity of the nematode tests. The one seedling, 238/3, which has been maintained, appeared to be resistant to the Nocton, Changed Little Ouse and Feltwell populations. Tests of further progenies from C.P.C. 2805 are necessary, however, to confirm its resistance.

DISCUSSION

The value of the Andigena potatoes

The potato breeder has four types of parents he can use: Tuberosum, Andigena, cultivated diploids and wild species (HOWARD, 1970). New varieties continue to be bred from intervarietal crosses within Tuberosum but there is becoming to be more or less general agreement that such crosses are of limited value. The Andigena potatoes, being the ancestors of the Tuberosum group, are very easy to use as parents. They may contain valuable genes for pest and disease resistance and in addition there is the possiblity of heterotic effects for higher yields (GLENDINNING, 1969). It must be pointed out, however, that the resistance genes may be very rare. For example, ELLENBY (1952, 1954), found only five clones with resistance to *Heterodera rostochiensis* pathotype A and in the present work only three sources of resistance to pathotypes B and C were found. Similarly BAERECKE (1967) only found a single clone with field-immunity to virus S in the Andigena potatoes of the Erwin Baur Sortiment (E.B.S.). Although genes for resistance may be very rare in Andigena, the authors hold that potatoes of the Andigena group should always be screened first for possible resistance because they are very much easier to use in a breeding programme than are wild species. The diploid cultivated potatoes should be the next source of resistance to be investigated and resource should only be made to the wild species when no resistance has been found in the other groups.

The C.P.C. nematode-resistant Andigenas

The nematode-resistant Andigena clones in the C.P.C. are listed in Table 2. They were all collected by Professor M. Cárdenas of the Departamento Botánica Aplicada, Universidad Mayor de San Simón, Cochabamba, Bolivia, and come from a limited

Table 2. Andigena potatoes in the Commonwealth Potato Collection which have been found to be resistant to *Heterodera rostochiensis*.

C.P.C. No.	Cárdenas No.	Locality	Vernacular Name	Genes
1595	9	Oruro, Bolivia	Kellu sonko	?
1673	165	La Paz, Bolivia	Polo	H_1
1685	192	Puno, Peru	Pocoya	H_1
1690	211	Puno, Peru	—	H_1
1692	214	Cochabamba, Bolivia	Azul Runa	polygenes?
2775	11	Potosi, Bolivia	Sipankachi	$H_1 + H_3$
2802	56	Oruro, Bolivia	Siquinchilla	H_3
2805	88	Oruro, Bolivia	Papa isuli	?

area of Peru and Bolivia, Puno in south Peru being very close to the border with Bolivia. This suggests that Andigena potatoes from this area should be investigated thoroughly for resistance to *H. rostochiensis* rather than the wild species of northern Argentina as suggested by BRÜCHER and ROSS (1953), BRÜCHER (1959, 1963) and HAWKES and HJERTING (1969).

Pathotypes of H. rostochiensis

There is as yet no agreed scheme for identifying pathotypes of *H. rostochiensis* although several schemes have been suggested (ANON, 1959; HUIJSMAN, 1962; COLE and HOWARD, 1966; ROSS and HUIJSMAN, 1969). Several difficulties stand in the way at present and it may be premature to suggest a scheme. First *H. rostochiensis* appears to be a species which is typically out-breeding (HOWARD, 1968) and it may be that many populations are not pure for any one pathotype. Secondly the use of wild species for identifying pathotypes is in many cases unsatisfactory because these wild species very often have an underground system of massive stolons and relatively few roots which makes cyst counting very difficult. The wild species may also contain several genes for resistance (ROSS, 1966b). In many cases F_1 hybrids from wild species are also not satisfactory and it is not until short-stolon derivatives with more or less cultivated root-systems have been obtained that the plants are satisfactory for cyst counts.

In at least the United Kingdom one major division appears to be satisfactory. This is based on colour changes undergone by the cysts during their development (GUILE, 1966, 1967). Pathotype A (no cysts on potatoes with gene H_1) is the golden nematode, having a long golden-yellow stage during cyst development, whereas pathotypes B and C (many cysts on potatoes with gene H_1) are the cream nematode, having a long cream stage during cyst development. So far it appears that gene H_3 also distinguishes between the golden and the cream nematodes.

The value of C.P.C. 2775, 2802 and 2805

Until further work has been done, it is premature to suggest that C.P.C. 2775, 2802 and 2805 will be as valuable sources of resistance to non-pathotype A nematodes as

C.P.C. 1673 has been for pathotype A. It is necessary to obtain F_1 or B_1 hybrids of these Andigena clones from crosses with Tuberosum varieties so that satisfactory tests for resistance to a wide range of nematode populations can be made. Although the present indications are that C.P.C. 2775 and C.P.C. 2802 have a single major gene, H_3, for resistance to non-pathotype A populations, this needs checking and it is not yet established that there are no minor genes affecting the action of H_3. On the other hand there is no doubt that it will be very much easier to obtain seedlings with good commercial qualities from C.P.C. 2775 or C.P.C. 2802 than it is from *S. vernei* and other wild species. It will be easy also to combine genes H_1 and H_3 because there now exists a number of good varieties with gene H_1 which can be used as parents. As was found in breeding from C.P.C. 1673, a major difficulty will probably be to obtain adequate resistance to blight, *Phytophthora infestans*.

There is, however, another source of resistance to non-pathotype A nematodes which might be more valuable than the Andigena clones. This is a Tuberosum clone from Chile, E.B.S. 2084, which Ross an HUIJSMAN (1969) found to be resistant to and six nematode populations. The genetics of its resistance have not yet been reported but it is presumably due to one or two major genes as in the Andigena clones.

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