PROGRESS IN BREEDING FOR RESISTANCE TO COLUMBIA ROOT-KNOT NEMATODE

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The Columbia root-knot nematode (Meloidogne chitwoodi Gold) is a major pest of potato in the Columbia Basin and certain other regions. It is the primary reason that fields are fumigated, operations that can cost up to 300 dollars per acre. When this work was initiated there was no potato clone known that was not a suitable host for Columbia root-knot nematode. The nematode colonizes potato roots in the spring. Root damage is almost imperceptible, but newly hatched nematode juveniles penetrate tubers early in the growing season. Tuber invasion continues during the whole season. The nematodes in the tubers cause the surface to appear bumpy and create brown spots in the flesh near the surface which are apparent on peeled product. Affected tubers are unusable for fresh market or processing. The damage is proportional to the length of time the crop is allowed to grow or the time period tubers are kept in storage. Therefore, the late maturing varieties which are stored for several months to supply the processors throughout the year are most at risk of severe economic loss.

The objectives of this work were the following: 1) identification of sources of resistance to Columbia root-knot nematode and northern root-knot nematode, 2) determination of inheritance of resistance, 3) incorporation of resistance into cultivated gene pool, and 4) characterization of resistance in roots and tubers.

Our first strategy was to find any kind of potato germplasm that retarded colonization of roots. Relatively quickly we were able to identify wild species of potato that had resistance to reproduction by both races of the nematode. We discovered that Solanum bulbocastanum, a wild species from Mexico, demonstrated good resistance to both races of the nematode and we selected clones that had practically negligible reproduction. All the results in the following tables are expressed as the ratio of nematode eggs extracted to those inoculated, after exposure for 55 days. This ratio, R_f, is the "Reproductive Factor." A selected group of resistant S. bulbocastanum clones is shown in Table 1. (Brown et al., 1988). In addition, in a survey of other wild species, another Mexican species, Solanum hougasii, was found to be resistant to both races (Brown et al., 1991). Results are shown in Table 2.

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Utilization of these two species was most easily initiated with S. hougasii which was directly crossable with cultivated tetraploid potato. It was found in a number of hybrids with a long russet French Frying clone that resistance to reproduction could be obtained (Table 3). Crosses of the F_1 hybrids involving S. hougasii with cultivated breeding clones indicated that the inheritance of resistance to race 1 was most probably controlled by a single dominant gene, while resistance to race 2 was more complexly inherited. Also, it was possible to determine in the BC_2 generation that resistance to races 1 and 2 was independently controlled genetically (Brown et al., 1994).

In the meantime there was considerable interest in S. bulbocastanum, but this species is not crossable with cultivated potato. A contract was set up between USDA/ARS and the University of Wisconsin. Dr. Austin was able to obtain hybrids of S. bulbocastanum with cultivated potato through protoplast fusion (Austin et al., 1993).

Somatic hybrids including S. bulbocastanum were found to be resistant to both races. Since the resistance to race 2 appeared to be greater it was decided to invest breeding effort in this rather than the S. hougasii source of resistance. Backcross 1 (BC_1) progenies derived from the S. bulbocastanum source showed, however, no resistance to race 2 amongst those that have been tested to date (Table 4). However it appears that resistance to Meloidogyne hapla does occur at a low frequency.

It is particulary important to predict how the resistance to race 1 would be inherited in future crossing cycles. We have carefully screened 51 BC_2 progenies arising from a backcross to A84118.3 of DG17. We have found that 20 out of 51, or 39%, are resistant (virtually immune). Within this progeny we have identified molecular markers that tag the S. bulbocastanum chromosomes that are being sorted out in the backcross generation. Evidence to date indicates that chromosome 11 the one bearing the genetic resistance that must be passed on to a future potato variety. We have found five DNA markers that are linked to the resistance, and have been able to determine that it is located at the far end of the upper arm of this chromosome.

We have looked at the resistance to tuber damage that these hybrids possess. Even with extraordinarily high numbers of eggs added to the soil, or with several later inoculations of fresh eggs, tuber damage does not occur.

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Table 1. Reproductive efficiency ($R=P_f/P_i$) of races 1 and 2 of Meloidogyne chitwoodi on Solanum bulbocastanum.

Identity	R-factor/race 1		R-factor/race 2	
243505.6	0.00	m[a]	0.13	hi
243505.7	<0.01	j-m	0.02	ij
255518.5	<0.01	lm	0.36	e-i
255518.7	0.00	m	0.23	f-i
55518.9	<0.01	j-m	0.40	e-i
275184.6	<0.01	j-m	0.16	g-i
275187.8	<0.01	lm	0.15	g-i
275187.10	0.00	m	<0.01	j-l

[a]Values are means of five replicates, data in each column followed by different letters differ significantly ($P < 0.05$) according to Duncan's multiple range test.

Table 2. Reproductive efficiency ($R_f=P_f/P_i$) of Meloidogyne chitwoodi, races 1 and 2, on various Solanum species 55 days after inoculating 5,000 eggs.

Species Code (cv or P.I.)	R_f Race 1		R_f Race 2	
Potato (cv. Russet Burbank)	30.4	ab	25.4	ab
S. hougasii 161726.1	< 0.01	n	0.3	ijk
S. hougasii 161726.2	0.04	kl	0.5	ghijk
S. hougasii 161726.5	< 0.01	mn	< 0.01	l
S. hougasii 161726.7	0.01	lm	< 0.01	l

Table 3. Reproductive efficiency (R_f) of standards, S. hougasii (hgs) x S. tuberosum ssp. tuberosum (tbr) hybrids and parents of hybrids.

Genotypes	Race 1 R_f	Race 2 R_f
Standards		
Tomato (cv. Columbia)	12.8 a	32.2 a
Potato (cv. Russet Burbank)	29.5 a	23.6 a
Parents		
A8341.5 (tbr)	21.2 a	14.2 ab
161726.2 (hgs)	0.0002 g	0.13 e
***S. hougasii* x *S. tuberosum* ssp. *tuberosum* hybrids**		
(161726.2 x A8341.5).2	0.01 def	0.66 bcde
(161726.2 x A8341.5).3	0.001 fg	0.08 ef
(161726.2 x A8341.5).4	0.003 efg	0.37 de
(161726.2 x A8341.5).5	0.006 defg	0.52 cde
(161726.2 x A8341.5).6	0.04 cde	12.0 ab

Table 4. Resistance to reproduction of three nematode types on BC_1 progenies (DG's) deriving resistance from S. bulbocastanum and resistant and susceptible parents.

Clone	Rf-Mc1	Rf-Mc2	Rf-Mh
BC_1 Progenies			
DG1	3.20 abcd	2.23 abcde	0.62 efg
DG3	0.00 g	7.34 abcd	5.02 abcde
DG4	3.52 abcd	1.65 bcdef	0.17 fgh
DG5	7.34 abcd	6.64 abcde	0.02 h
DG6	3.01 bcd	6.25 abcde	1.27 cdefg
DG7	0.00 f	0.55 ef	3.27 abcde
DG8	10.73 abc	2.00 abcdef	1.25 cdefg
DG9	1.52 cd	4.08 abcde	2.19 abcdef
DG10	9.23 abcd	3.57 abcde	4.08 abcde
DG11	3.77 abcd	23.17 a	9.51 abcde
DG12	4.10 abcd	2.95 abcde	1.75 bcdefg
DG14	4.12 abcd	0.71 def	0.94 defg
DG15	0.03 e	10.94 abc	10.94 abcd
DG16	3.01 bcd	1.14 cdef	18.41 abc
DG17	0.00 fg	10.41 abc	10.00 abcde
DG18	4.54 abcd	1.97 abcdef	0.70 defg
DG19	0.65 d	5.27 abcde	0.75 defg
DG21	10.62 abc	6.38 abcde	0.78 defg
Resistant Parents			
SB22	0.00 fg	0.18 f	0.14 gh
CBP233	0.03 e	0.57 ef	1.33 cdefg
Susceptible Parents			
R4	28.30 ab	20.96 a	32.23 a
A84118.3	45.73 a	15.22 ab	24.85 ab