CONTROLLING COLUMBIA ROOT-KNOT NEMATODE THROUGH GENETIC RESISTANCE

by
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INTRODUCTION

The Columbia root-knot nematode (Meloidogyne chitwoodi) is a serious pest of potatoes, causing exterior and interior blemishes which can result in dockage of price or outright rejection of shipments at the point of purchase of the raw commodity from the grower. Chemical control is the most common means to counteract this nematode. Costs due to attempts to control the nematode and dockage penalties may be as high as $400 to $500 per acre. Since 1977, the use of three soil fumigants (DBCP, EDB, and DD) has been lost. Presently, potato growers have only two soil fumigants (Telone II and metham sodium) available for use. Telone II has been banned in California.

Preliminary studies show that two Mexican wild potato species, Solanum bulbocastanum and S. hougasii, have substantial resistance to the Columbia root-knot nematode (Brown et al., 1989, 1991). Research to determine the genetic control of resistance is being conducted by the USDA-Agricultural Research Service in collaboration with nematologists of Washington State University to achieve a better understanding of inheritance, nature of resistance, and to introduce this resistance into new varieties.

MATERIALS AND METHODS

Work was initiated with screening of Plant Introduction accessions maintained at the IR-1 Potato Introduction Station in Sturgeon Bay, Wisconsin. True seed of the accessions was germinated and seedlings were inoculated with the nematode. Plants that showed resistance to multiplication by the nematode were propagated clonally and inoculated with races 1 and 2 in replicated tests. Cuttings of each clone were separated into two groups of five plants. The cuttings in one group were inoculated with 5000 eggs of race 1 and the cuttings of the other group were inoculated with race 2. The plants were allowed to grow for 55 days at approximately 21 C. The results are shown in Table 1, expressed as reproductive efficiency (R_f), the ratio of the final number to the initial number of eggs.

This Presentation is part of the Proceedings of the 1991 Washington State Potato Conference & Trade Fair.

If R_f is greater than 1 the plant genotype is a "good host," if R_f is between 1.0 and 0.1 this denotes a "poor host," and plants having an R_f less than 0.1 are termed "non-hosts." Only one species, Solanum hougasii, showed consistently low R_f values, i.e., high levels of resistance to races 1 and 2. Consequently, further research was focused on the utilization of S. hougasii as a source of resistance.

RESULTS AND DISCUSSION

This species has 72 chromosomes compared to the 48 of the potato familiar to us, but, fortunately, crosses between the two resulted in F_1 hybrids. The cultivated parent was a long russet french fry quality breeding line, A8341.5, provided by J. Pavek, USDA/ARS, Aberdeen. Some of these hybrids possessed resistance to both races of the nematode. The results of resistance screening are shown in Figure 2. The encouraging aspect here is that very strong resistance, i.e. virtually no reproduction by the nematode, was found for race 1. Resistance to race 2 in the wild parent, 161726.2 (Table 1), and in the hybrids (Table 2) was not as high as evidenced by more reproduction. The hybrids showed relatively little pollen fertility but could be crossed as female parents with A8341.5 again and resulted in the production of backcross 1 (BC_1) progeny. The BC_1 progenies were multiplied by cutting and inoculated as described above. Analysis of resistance in these progeny allowed us to infer the number of genes involved in the expression of resistance.

The co-segregation of resistance to races 1 and 2 among 105 BC_1 progeny is presented in Table 2. Each progeny was classified as resistant if all three replications individually yielded less than 5000 eggs; i.e., the reproductive factor, R_f, was less than 1.0. If a single replication yielded more than 5000 eggs, the progeny was classified as susceptible, even if the mean of the three replications was less than 5000 eggs. Of the 105 progenies, 45% were resistant to race 1 while 13% were resistant to race 2. This is consistent with a single dominant gene inheritance for race 1 and multiple gene resistance to race 2. In the case of resistance to race 2, one would expect about 12% of the progeny to have resistance to race 2 if three unlinked genes were involved in expression. It is possible to apply other interpretations of mode of inheritance as well, but these will have to await further progeny tests to interpret.

Resistances to the two races is consistent with independence as tested in a 2 x 2 contingency table (chi-square = 0.018, not significant), i.e., the genetic control of resistance to one race is not influencing the other.

These results are very encouraging. It would appear to be a relatively simple task to incorporate resistance to race 1 into the cultivated gene pool. Although more of a challenge, resistance to race 2 can also be incorporated. It would be no more difficult than a large number of traits having complex inheritance which have been successfully incorporated into varieties.

REFERENCES

Brown, C.R., Mojtahedi, H. and G. S. Santo. 1989. Comparison of reproductive efficiency of Meloidogyne chitwoodi on Solanum bulbocastanum in soil and in vitro tests. Plant Dis. 73:957-959.

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Table 1. Reproductive efficiency of Meloidogyne chitwoodi, races 1 and 2, on various Solanum species standards and differentials. $R_f=P_f/P_i$. Initial inoculum, P_i=5,000 eggs. Incubated 55 days.

Species Code (cv or P.I.)	Rf Race 1		Rf Race 2	
Tomato (cv. Columbia)	7.9	abcdef[1]	15.1	abcd
Potato (cv. Russet Burbank)	30.4	ab	25.4	ab
S. andreanum 498148.4	3.0	cdefg	0.9	fghij
S. andreanum 498148.6	8.8	abcdef	2.0	defghi
S. andreanum 498148.7	25.9	abc	7.4	abcde
S. berthaultii 310927.3	35.6	a	21.8	ab
S. berthaultii 310927.5	48.6	a	5.6	abcdef
S. berthaultii 310927.8	43.5	a	15.7	abc
S. boliviense 265861.1	1.4	fghi	0.2	jk
S. boliviense 265861.9	10.3	abcdef	4.4	abcdef
S. boliviense 310974.8	22.71	abcd	0.8	fghijk
S. boliviense 310974.10	42.22	a	27.5	a
S. boliviense 310975.1	3.20	cdefg	1.6	efghi
S. boliviense 310975.4	2.0	efgh	0.1	jk
S. boliviense 310975.6	2.7	defg	0.4	hijk
S. boliviense 310975.10	7.4	abcdef	1.72	efghi
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
S. acaule 208874.2	1.4	fghi	3.4	bcdefg
S. acaule 208874.5	0.8	ghij	2.4	cdefgh
S. canasense 265865.2	16.3	abcde	8.8	abcde

[1] Means not sharing a letter are significantly different at 5% level, Duncan's Multiple Range Test. Separation test was performed on means of ln (x + 1) or the geometric mean. The $R_f=P_f/P_i$=[antilog(geometric mean)]/5000 is presented in the table.

Table 2. Reproductive efficiency (R_f) of standards, S. hougasii (hgs) x S. tuberosum ssp. tuberosum (tbr) hybrids and parents of hybrids.

Genotypes	R_f=Pf/P_i Race 1	Race 2
Standards	R	R
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
C008014.1 (tbr)	5.5 ab	13.0 ab
161726.2 (hgs)	< 0.01 g	0.13 e
S. hougasii x *S. tuberosum* ssp. *tuberosum* hybrids		
(161726.2 x A8341.5).2[1]	0.01 def	0.66 bcde
(161726.2 x A8341.5).3	< 0.01 fg	0.08 ef[2]
(161726.2 x A8341.5).4	< 0.01 efg	0.37 de
(161726.2 x A8341.5).5	< 0.01 defg	0.52 cde
(161726.2 x A8341.5).6	0.04 cde	12.0 ab
(161726.2 x A8341.5).7	0.02 def	9.4 abcde
(161726.2 x A8341.5).9	< 0.01 defg	4.4 abcd
(161726.2 x A8341.5).10	< 0.01 fg	0.8 bcde
(161726.2 x A8341.5).11	8.7 a	5.4 abcd
(161726.2 x A8341.5).13	9.05 a	3.1 abcd
(161726.2 x A8341.5).14	6.0 ab	3.6 abcd
(161726.2 x A8341.5).15	0.5 bc	< 0.01 f[2]
(161726.2 x A8341.5).16	< 0.01 fg	12.1 ab
(161726.2 x C008014.1).1	0.06 cd	6.5 abcd

1 The cross (161726.2 x A8341.5) was coded as 89G11 and is used in table 2. Reproductive factor R_f values represent geometric means of P_f divided by 5,000, the initial egg population (P_i). Means not sharing a letter are significantly different ($P < 0.05$) according to Duncan's Multiple Range Test. Separation test was performed on means of ln(x + 1) or the geometric mean. The $R_f=P_f/P_i$=[antilog(geometric mean)]/5000 is presented in the table.

2 Geometric means are misleadingly low because several replications were zero values. These progeny are considered to be poor hosts.

Table 3. Segregation of resistance to races 1 and 2 of Meloidogyne chitwoodi in 105 BC_1 progeny of [(S. hougasii x S. tuberosum ssp. tuberosum) x S. tuberosum ssp. tuberosum].

	SS	SR	RS	RR	
89G11.2 x A8341.5	9	1	4	0	
89G11.3 x A8341.5	2	0	3	1	
89G11.4 x A8341.5	16	5	12	3	
89G11.5 x A8341.5	23	2	22	2	
TOTAL	50	8	41	6	105

A8341.5 Long russet, frying-quality breeding clone from J. Pavek, USDA/ARS-Aberdeen

89G11.2, .3, .4, .5 F_1 hybrids of *S. hougasii* (161726.2) x A8341.5

SS - susceptible to race 1, susceptible to race 2

SR - susceptible to race 1, resistant to race 2

RS - resistant to race 1, susceptible to race 2

RR - resistant to race 1, resistant to race 2