Short Communication

DIFFERENCES IN TUBER ROT DEVELOPMENT FOR NORTH AMERICAN CLONES OF *PHYTOPHTHORA INFESTANS*

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Abstract

The relative aggressiveness of *Phytophthora infestans* clones in potato tubers was compared in three trials using 7 to 24 isolates of 2 to 4 clones. Visible rot developed slowly at 13C with isolates of the US-1 genotype, the only significant clone found in North America prior to 1979, but substantially faster with most isolates of the newer clonal genotypes US-6, US-7 and US-8. Certain US-7 isolates were similar to US-1, and US-6 isolates also had a broad range of aggressiveness. Secondary infection by *Fusarium* sp. increased rot development in many instances, but this effect was not clone-related. Differences in rot development may affect potato storage or late blight disease transmission.

Introduction

Since the 1970's, the population of the late blight pathogen, *Phytophthora infestans*, has become more diverse and difficult to manage. North American isolates are categorized into clones of common origin characterized by mating type (A1 or A2), metalaxyl sensitivity, allozyme patterns, and DNA restriction fragment sizes (Goodwin *et al.*, 1994: Goodwin *et al.*, 1995). In addition to several types from British Columbia and another (US/G-11) recently active in the Far West, the most common clones in North America have been US-1 (the A1, metalaxyl-sensitive, original population), US-6 (A1, metalaxyl-resistant, present in California since 1979), US-7 (A2, resistant, often associated with tomato epidemics), and US-8 (A2, resistant, currently the most widespread). Foliage studies indicate shorter latent period and increased sporula-

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Maine Agricultural and Forestry Research Station external publication 2040.
Accepted for publication December 21, 1996.
ADDITIONAL KEY WORDS: Fitness, late blight, potato, storage diseases.

tion for strains of these "new" clones (Kato and Fry, 1995a; Kato and Fry, 1995b; Miller *et al.*, 1995). In Israel and Northern Ireland, similar differences have been described for strains characterized as metalaxyl-resistant (Bashan *et al.*, 1989; Kadish *et al.*, 1990; Walker and Cooke, 1990). Metalaxyl-resistant strains may also cause more rapid rotting of tubers under certain circumstances (Grinberger *et al.*, 1995; Kadish and Cohen, 1992) with increased severity of secondary bacterial rot (Walker and Cooke, 1990). In Maine, growers comment that storage rot development in potatoes infected with US-8 is more rapid than it was when *P. infestans* US-1 was the dominant clonal type. The present study compares the ability of small subpopulations of the clones listed above to cause rapid tuber breakdown at moderate storage temperatures.

Methods

Phytophthora infestans strains used were obtained by K. Deahl, W. Fry, and D. Lambert from diverse sources, and include **US-1**: McCotter, VW, DIL (KD); HF-8, WI-93-13 (WF); ND4 (DHL); **US-6**: BIN 16 (KD); BIN 16, LI, MV92-6, MV92-10a, MV92-13, FP-4 (WF); **US-7**: DI-Hal {KD); 17, 96, 104, Ca Home 2-4, Fl Manitee 2, FL Hastings 12B, 78, 79 (WF); **US-8**: ME-93-2a (WF); ND-2, ND-3, ME1, ME-2, ME-3 (DHL). These strains were identified to clone by, at least, gpi allozyme testing (Goodwin *et al.*, 1995)

In the each of the first three experiments, tubers were washed, punctured at the bud end, and each injected with 50 µl of water (control) or blendor-homogenized suspensions (one V-8 plate in 100 ml sterile water) of individual *Phytophthora infestans* strains. The wounds were covered with parafilm, and the tubers were incubated in paper bags at 13C in a potato storage with ambient RH of 87-92%. After 7 days, half of the tuber wounds were each reinoculated with 50 µl suspensions of *Fusarium*, and all tubers were incubated another 4 wk. The secondary inoculum was a 1:1 mix of *F. sambucinum* and *F. solani* strains previously isolated as invaders of blighted tuber tissue. Each isolate was replicated four times with four (tuber) subsamples. In the fourth experiment, tubers were inoculated and incubated as before (excepting *Fusarium* inoculation), replicated four times, and subsampled at three intervals. The varieties Ontario and FL1533 were used in the first study, and Atlantic was used in the subsequent studies.

At the end of trials 1, 2, and 3, the tubers were cut lengthwise through the inoculation point and the tuber outline and area of the cross-section showing visible rot were recorded on filter paper pieces. The percentages of area affected were determined by weighing the paper sections. In trial 4, the extent of visible penetration ("depth") and spread at the surface ("circumference") were measured directly. Data were analyses by mean separation (Tukey's hsd), analysis of variance (SYSTAT), and regression.

Results and Discussion

The initial three studies indicated that the newer clones (US-6, US-7, US-8) spread further during the incubation period than US-1, the original clone (Table 1). Subsequent infection with *Fusarium* dry rot pathogens differentially increased the spread of visible rot in Ontario and FL1533 tubers inoculated with US-8 (1st trial), but not in Atlantic tubers (2nd trial). In the third study, with a shorter incubation period and earlier assessment, secondary infection with *Fusarium* increased visible rot as much as two-fold in association with certain *P. infestans* isolates. The pattern of *Fusarium*-associated increases was not always consistent by isolate between trials. In general, enhanced rotting with added *Fusarium* was most evident when the rate of *Phytophthora* spread was at least moderate and before most of the tuber was colonized.

The fourth trial, in which rot development was measured in greater detail with a larger set of isolates, confirmed the preliminary studies (Table 2). Lateral spread of rot was faster for most "new" strains, particularly at an early stage. On average, development was most rapid with US-8 isolates, although US-6s

TABLE 1.—*Percentage of visible rot in tuber cross-sections inoculated with isolates of four* Phytophthora infestans *clones, with and without subsequent inoculations with Fusarium spp*[1].

Clone	Isolates[2]	Expt. 1				Expt. 2		Expt. 3	
		Ontario[3]		FL 1533		Atlantic		Atlantic	
		Fus-	Fus+	Fus-	Fus+	Fus-	Fus+	Fus-	Fus+
US-1	3, 3, 4	23	29	28	22	35	41	2	2
US-6	-, 1, 4					74	69	18	39
US-7	-, 2, 4					52	48	7	11
US-8	4, 6, 4	65	80	57	75	74	73	26	45

Factor	Probability[4]		
Clone	0.000	0.000	0.000
Fusarium	0.004	0.785	0.329
Variety	0.239	–	–
Clone X Fusarium	0.001	0.787	0.504
Isolate X Fusarium	0.013	0.543	0.037

[1]A 1:1 mixture of *F. sambucinum* and *F. solani* strains isolated from blighted tubers.
[2]Numbers of isolates used in the first, second, and third experiments.
[3]Potato varieties.
[4]Probability that factor treatments or interactions do not differ at P = 0.05 by ANOVA. Other interaction terms in the clone analysis are not significant.

were statistically indistinguishable. Both the US-6 and US-7 populations were bimodal, each having three isolates as aggressive as the US-8s. However, the remaining four US-7s were in the range of the much slower US-1 isolates, and the three remaining US-6s were intermediate between the US-1s and the US-8s. The rate of visible spread appeared to decrease as rot became more extensive. When individual isolates were plotted, there was a linear relationship between rot depth and rot circumference which did not differ substantially among clones.

The faster breakdown of blighted tubers recently experienced by growers in North American corresponds to trends in Europe and Israel. Secondary infection by *Fusarium* accelerates apparent rot in many cases, but this was not directly related to the *Phytophthora* clone causing the primary rot.

Faster clone-associated tuber rot might alter fungal strain survival and disease transmission. In Israel, seasonal fluctuations in the *Phytophthora* population have been explained by a reduction in overseasoning of metalaxyl-resistant isolates, offset by superior fitness during the growing season (Kadish and Cohen, 1992). In North America, no evidence yet exists to indicate reduced transmission of new strains in overwintered seed, culls, or volunteers, or of a slowdown in the changeover from US-1 to newer clones.

The usual recommendation for storage of slightly infected lots is careful inspection and immediate cooling and drying. One might expect that faster rot development would improve the detection of blighted tubers, but would hinder attempts to arrest disease in storage before secondary bacterial rots created conditions conducive to widespread soft rot.

Acknowledgments

The authors wish to thank Drs. Kenneth Deahl, Neil Gudmestad, and William Fry for many of the *Phytophthora* strains used in this study.

TABLE 2.—*Depth and extent of visible rot in tubers infected with isolates of four* Phytophthora infestans *clones over a 4 wk period.*

Clone Isolates[1]		Rot Depth - mm			Rot Circumference - mm		
		May 11	May 22	May 31	May 11	May 22	May 31
US-1	5	1.9A[2]	2.0A	3.3A	2.2A	9.7A	12.4A
US-6	6	6.9AB	10.0 B	10.4 B	19.6 B	32.0AB	46.0 B
US-7	7	5.1AB	8.0AB	6.9AB	17.4 B	17.1A	32.1AB
US-8	6	7.2 B	12.2 B	11.6 B	29.3 B	57.5 B	64.0 B

[1]Number of isolates per clone.

[2]Within each column, means followed by the same letter do not differ at P = 0.05%.

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