PROGRESS IN DEVELOPING BIOLOGICAL CONTROL SYSTEMS FOR POTATO

by [1/]
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The use of root-inhabiting bacteria to suppress soilborne pathogens and promote potato growth is an important component of the new biotechnology in agriculture that should soon be used to improve yields. Progress is being made in identifying beneficial bacteria and understanding the mechanisms that underlie their role in plant protection. Improved strategies for selecting biocontrol agents are being developed that are integral to the eventual release of a product that can be used for potato production in Washington. This report will illustrate the potential benefits of biological systems aimed at control of potato pathogens, and our initial progress in developing such systems for use in the Columbia Basin.

Beneficial Effects

The influence of rhizosphere bacteria on potato growth may take one or more different forms such as nutrient availability, soil structure, and microbial composition within the root zone (5). Pioneering research in California, beginning in the 1970's, first showed the important and often dramatic effects of rhizosphere bacteria on potato growth (1,2,3,4). Bacteria, usually fluorescent pseudomonads, were selected that as seed inoculants caused significant increases in potato growth and yield in greenhouse and field trials. For example, it was reported (4) that pseudomonads increased growth of potato plants up to 500% as compared to checks in greenhouse trials and up to 17% in California field trials. Significant increases in early stolon length were reported 2 wk after plant emergence, which were believed to somewhat mirror subsequent yield increases. These introduced fluorescent pseudomonads were named plant growth-promoting rhizobacteria (PGPR) due to their ability to promote growth resulting from suppression of "deleterious" root-colonizing microorganisms (6).

Research in my laboratory over the past three years has been centered on selection of bacteria that are antagonistic to Erwinia carotovora, a pathogen that causes several soft-rot diseases and is at least partly responsible for the early dying syndrome so common in the Columbia Basin. A large number of pseudomonad strains were systematically selected that significantly reduced potato seedpiece decay (up to 63%) and increased plant weights six-fold in greenhouse trials. Moreover, in field trials, treatment with one pseudomonad increased Russet Burbank yield 12 and 10% in 1982 and 1983, respectively, and reduced the soft rot potential of the tubers.

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The Selection Process

My initial approach to developing biocontrol of soilborne pathogens in Washington was four-fold: (A) Select beneficial bacteria that are highly competitive in the potato rhizosphere and are a predominant type found on roots and tubers; (B) Select bacteria that are specifically antagonistic to E. carotovora; (C) Develop a screening procedure for beneficial bacteria based on production of siderophores and antibiotics, and greenhouse suppression of pre-emergence seedpiece decay; (D) Develop procedures for applying these bacteria in the field and for monitoring changes in microbial populations in the rhizosphere to identify possible reasons for effects on plant growth. Consequently, a prototype system has been developed for improving the overall growth and development of potatoes.

The first step of the selection process was to isolate bacteria that were the predominant residents of root and tuber systems of commercially grown potato plants. Isolations were performed at mid-season, a time when the bacteria would need to be present in sufficient quantity to inhibit the pathogen and warrant further screening as potential biological control agents.

In the next step, the bacteria were screened in the laboratory for antagonism of E. carotovora resulting from production of siderophores and antibiotics. A large percentage (88%) of the strains were inhibitory to E. carotovora. Inhibitory antibiotics and siderophores were produced by 56% and 80% of the pseudomonads, respectively. Siderophores are substances produced by the pseudomonads that bind iron, making it unavailable to E. carotovora for essential growth processes (2).

Greenhouse screening for control of seedpiece decay caused by E. carotovora was the central step in identifying those antagonistic strains that would improve plant emergence and increase plant weights. In comparison to Erwinia-inoculated checks, all strains showed at least a small increment of disease suppression; increases in plant emergence ranged from 6.7 to 63.4% (Table 1). Some strains, such as W4F151, increased plant fresh weights six-fold as compared to the check. Thus, the screening procedure readily identified those strains that were highly suppressive to E. carotovora on root surfaces. Strains that produced siderophores and antibiotics inhibitory to E. carotovora, increased emergence by an average of 48% as compared to the check treatment. Strains that produced bactericidal antibiotics appeared to show the greatest effects in improving plant emergence and plant weights.

Field Tests

The ultimate test of a biological control agent is to demonstrate in the field: (A) its growth and survival on plant surfaces, and (B) the expression of a protective effect. The latter can be measured as lower pathogen numbers, suppression of pathogen growth, and/or enhancement of plant growth and/or yield. Most fluorescent pseudomonads aggressively colonized emerging roots following seedpiece treatment. Strain W4P63 spread to newly developing roots and increased in overall numbers to nearly 10^5 bacteria/g by mid-August.

The population declined 10-fold in September just prior to harvest, corresponding with the senescence and death of the plants. On potatoes treated with strain W4P63, the general pattern of root colonization by E. carotovora was similar to that of the check; however root populations were reduced at least 10-fold throughout the growing season on potatoes treated with W4P63.

Treatment with strain W4P63 increased the yield of Russet Burbank by 11.7% and 10.2% in 1982 and 1983, respectively (Table 2). Moreover, treatments with W4P63 increased the yield of U.S. No. 1 Russet Burbank by 25.2% and 10.2% in 1982 and 1983, respectively. Overall results in 1984 were similar. Not all strain treatments, however, increased yield, showing the need to complete careful analyses of strains in the field.

In summary, field results show that introduced pseudomonad antagonists remain in the rhizosphere throughout the season and can comprise over 10% of the total bacteria on roots. Considering that strains which produce bactericidal antibiotics showed the greatest effects in improving growth, antagonism seems to result from antibiotic production. The growth-promoting effects, as measured by increased yield, would appear to result from antagonism of pathogens or deleterious microorganisms in the rhizosphere.

The Future of Biocontrol

There are numerous potential benefits from developing biocontrol agents. Foremost among these is halting the decline in yield that occurs with increased cropping of potatoes. This is the most serious problem that potato growers face today, and new approaches towards solving this problem are much needed; biocontrol may offer the best possible solution. The ecology of the interactions between antagonist and pathogen are complex; consequently, sustained research efforts are needed that will take new approaches to determine why it may work. Once this is accomplished, further improvements can then be made to increase the overall efficiency of the biocontrol system and make it available to growers. Thus, my research goal is to broaden the beneficial effects of the Erwinia biocontrol system and develop additional methods for screening suppressive agents. When the biological control system is fully developed, it will hopefully be an important step towards achieving the full growth potential of potatoes.

References

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Table 1. Effect of fluorescent pseudomonads on pre-emergence seedpiece decay of potato caused by Erwinia carotovora subsp. atroseptica.

Treatment[z]	Plant emergence	Fresh weight of whole plant
	(%)	(g/pot)
W4F35	86.7	20.6
W4P63	60.0	13.9
W4F586	30.0	1.5
W4F151	80.0	22.7
Pf-5	80.0	8.0
B10	73.3	19.2
Check[y]	23.3	3.6
Noninoculated[y]	100.0	32.6
LSD 0.05	46.3	7.1

[z] Fluorescent pseudomonads and E. carotovora were added at 10^8 and 10^6 bacteria/seedpiece, respectively. All treatements were planted into fumigated soil. Each strain was replicated ten times, three seedpieces/pot. Emergence and plant weights were recorded 2 wk after planting.

[y] Inoculated only with subsp. atroseptica strain W3C37. Noninoculated seedpieces were treated with methylcellulose-water slurry only.

Table 2. Effect of selected fluorescent pseudomonads on potato yield at Plymouth, Wa.

Year	Seedpiece treatment	Yield[z]	Increase	U.S. No. 1	Increase
		(kg/plot)	(%)	(kg/plot)	(%)
1982	W4P5	52.8	4.5	28.8	6.0
	W4F49	52.1	3.1	27.3	0
	W4F59	52.5	3.9	29.0	6.7
	W4P63	56.4	11.7	34.1	25.2
	W4F68	54.3	7.5	31.5	15.8
	B10	55.5	9.8	31.5	15.8
	Pf-5	47.4	-6.3	24.6	-9.7
	Check[y]	50.5	--	27.2	--
	LSD[x] 0.05	2.9		6.8	
1983	W4F35	63.2	0	48.1	-5.0
	W4P63	69.7	10.2	56.0	10.2
	W4P144	69.0	9.3	53.7	5.7
	W4F151	65.1	3.4	50.6	0
	W4F156	68.0	7.6	51.5	1.4
	B10	67.7	7.2	51.3	1.0
	Check[y]	63.2	--	50.8	--
	LSD[x] 0.05	9.9		4.9	

[z] Mean of five or six replications of Russet Burbank, two 6-m rows/replication.

[y] Seedpieces treated with talc-methylcellulose alone.

[x] Least significant difference.