ASSESSMENT OF FREEZING INJURY TO RUSSET BURBANK TUBERS IN FIELD AND LABORATORY TRIALS

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INTRODUCTION

Potato tubers left in the field after harvest can become a serious problem in the production of subsequent rotation crops. Field leavings of up to 186,000 and 150,000 tubers per acre have been reported in the Netherlands and the UK, respectively (Lumkes, 1974; Lutman, 1977). Researchers in south central Washington have reported field leavings of up to 184,000 tubers per acre (Newberry and Thornton, 1999). Post-harvest tuber leavings represent 9 to 11 times the normal planting rate (Askew, 1993).

Tubers are susceptible to freezing injury, and cold winter soil temperatures can provide good volunteer potato control. Dutch researchers found that potato tubers are killed by exposure to 28.5□ F for 24 hours, and that at lower temperatures less time is required to kill tubers (Lumkes and Sijtsma, 1972).

In laboratory trials, Russet Burbank tubers were exposed for various times to a range of sub-zero soil temperatures to evaluate the effects on subsequent tuber and sprout viability. Field trials conducted in south-central Washington evaluated winterkill of potato tubers and contributed to an understanding of the critical temperatures required for tuber injury and death.

METHODS and MATERIALS

Laboratory Trials:

In 1996 and 1997, Russet Burbank tubers were placed in watertight acrylic columns that were partially filled with air-dried Quincy Sand. Thermocouples were placed in the soil and tuber to monitor temperature. Soil was added to cover the tubers, and the columns containing soil and tubers were placed in a refrigerated chamber prior to testing. In 1997, water was added to the soil, and the columns containing soil and tubers were placed in a refrigerated chamber for about 50 hours to equilibrate soil moisture prior to testing. In 1996, columns were placed in a glycol bath in which the coolant was maintained at a constant temperature during testing. In 1997 the temperature of the coolant was regulated to modify the thermal gradient between the soil and the coolant and also the rate of soil temperature change during testing. Tubers were weighed before and after testing, and tuber condition was evaluated for up to 2 weeks after testing.

Trials in 1999 evaluated the effects of exposure time at specified temperatures on tuber sprout injury. Tubers were placed in columns that contained oven-dried graded sand, and thermocouples were placed around the circumference of the tuber. Sand was added to cover the tuber, and deionized water was added to raise the soil water content to 7% (mass). A Neslab RTE 140 chilling unit was programmed to reduce the bath temperature at 1.8□ F per hour to the test temperature, and to maintain that temperature

for the specified duration. Tubers were stored at room temperature after treatment, and tuber condition and sprout length were evaluated 2, 3, and 5 weeks after treatment.

Field Trials:

Russet Burbank tubers were buried in the field in November at specified depths between 2 and 8 inches, and thermocouples were buried in the plots at tuber depth to record soil temperature. In 1994 through 1997, tubers were recovered in the spring and the number of viable eyes per tuber and symptoms of freezing injury were recorded. In 1998 and 1999, tubers were buried 18 inches apart at specified depths, and thermocouples were placed in the plots at tuber depth. Soil temperature was recorded during the winter, and potato plants were counted in the spring to estimate tuber viability.

Results:

Laboratory Trials:

Trials to evaluate the freezing point of Russet Burbank tubers in air-dried soils revealed that tubers can undercool to about 24.0□ F without injury. When tubers froze, an exotherm occurred and the release of the latent heat of freezing caused tuber temperature to rise rapidly. Tuber temperature then briefly stabilized at about 29.5□ F, which we believe is the freezing point of the tuber. Tubers that were exposed to such exotherms leaked cellular fluid at the time of removal from the soil columns and were not viable. Subsequent trials indicated that tubers in hydrated soils undercool to only about 28.0□ F before an exotherm occurred. The release of the latent heat of freezing caused tuber temperature to rise before briefly stabilizing at about 28.6□ F. Tubers that were exposed to such freezing events were not viable. The freezing temperature of the tuber falls between the values recorded for dry soil at 29.5□ F and moist soil at 28.6□ F.

The results of trials conducted in 1999 are summarized in Table 1. Sprout development of tubers held at 30.2□ F for all times of exposure, and at 29.3□ F for the shortest exposure was not significantly different from the non-treated control. Increasing the time of exposure at 29.3□ F significantly reduced sprout development compared to the non-treated control. Some sprout development occurred in all tests conducted at 29.3□ F, but only after 12 hours exposure did some tubers exhibit catastrophic injury characterized by leakage of cellular fluids and very rapid breakdown. Most tubers exposed to 28.5□ F for 0 and 2 hours produced some weakened sprouts, but 30% of the tubers were dead. After 12 hours exposure to 28.5□ F, all tubers leaked cellular fluids when they were removed from the columns and they were not viable.

Field Trials:

Winter minimum temperatures and percentage survival for each site and depth are reported in Table 2. In addition to freezing injury that caused the complete collapse of the tuber, we noted considerable injury that was restricted to the upper surface of tubers, mainly at the 5 inch depth of burial. Soil temperatures were recorded at the depth of the

center of the tuber, and the temperature on the upper surface of tubers was undoubtedly lower as the result of the thermal gradient of the soil. Results of field and laboratory trials indicate that soil temperatures in the range of 27.5□ F to 29.3□ F cause substantial tuber injury. Some injury occurred on the upper surface of tubers buried under 8 inches of soil in 1995-96 where the soil minimum temperature was 30.4□ F, higher than the temperature at which injury was believed to occur. No tubers survived exposure to 25.4□ F, and tuber injury was minimal at temperatures above 31□ F.

DISCUSSION

Field trials make forecasting the severity of volunteer potato populations possible, and they contribute to an understanding of the dynamics of tuber injury and mortality under field conditions. More than 82% of volunteer tubers are found in the upper 6 inches of the soil profile, and further field trials to evaluate winterkill of tubers should monitor that zone more intensively. Intensive soil temperature monitoring in 1inch increments to 6 inches in depth would enable researchers to more accurately forecast the potential for volunteer potatoes in rotation crops. Estimates of volunteer potato populations can be made available to growers early in the growing season, and can help them to make informed management decisions about the need for control measures or their choice of rotation crops following potatoes.

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Table 1. Tuber sprout length (in.) 5 weeks after specified exposure times to 3 soil temperatures in laboratory trials

	Exposure Time (Hours)					
	0	2	4	8	12	24
Soil temperature						
28.5^0 F	1.9	1.1	-	-	0.0	-
29.3^0 F	3.7	-	1.9	1.9	1.7	0.5
30.2^0 F	5.1	-	3.3	4.2	5.6	4.9
Non-treated control	5.6	-	-	-	-	-

Table 2. Percent total tuber freezing injury[1] to potatoes buried at 5 soil depths near Prosser and Paterson, WA from 1994 to 1999

	Depth of soil cover				
	2 Inch	4 Inch	5 Inch	6 Inch	8 Inch
1994-95 - Roza	100% [*24.7_F*][2]	-	7.5% [*30.5_F*]	-	0% [*31.7_F*]
1994-95 - Paterson	100% [*23.5_F*]	-	43.0% [*28.5_F*]	-	0% [*30.8_F*]
1995-96 - Roza	100% [*18.2_F*]	-	69.4% [*27.5_F*]	-	21.5% [*30.4_F*]
1996-97 B HQ[3]	100% [*24.2_F*]	100% [*25.4_F*]	-	72.0% [*29.3_F*]	0% [*31.9_F*]
1998-99 - Roza	100% [*20.4_F*]	100% [*24.4 _F*]	-	-	2.0% [*31.3_F*]

1 The combined percentage of dead and partially frozen tubers

2 Numbers in parentheses indicate minimum soil temperature recorded at the tuber center depth

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