Evaluation of Frost-hardy Potato Germplasm in the Absence of Frost Protection Measures

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Introduction

The Klamath Basin of southern Oregon and northern California is located in a semi-arid climatic zone. Distinctive climatic characteristics are low precipitation totals, large temperature ranges between summer and winter, large diurnal temperature fluctuations during the growing season, and plentiful sunshine. The valley floor, at 4,100 feet above sea level, is susceptible to frost any day of the year and typically experiences a frost-free season of about 100 days.

Freezing events are usually classified as radiational or advective. Radiational frosts occur mostly during clear, calm nights after cold air has moved into the area. Once the sun sets, surface heat is lost into space. The rate of radiational heat loss is partially determined by the amount of moisture present in the atmosphere. Dry conditions result in more heat loss, as latent heating is minimal. During radiational frost events, layers of cold air form with the coldest air settling to the surface.

Advective frosts occur when a large mass of Arctic air moves into the region. Existing warm air is moved upward as dense cold air settles near the surface. Advective frosts can occur during clear or cloudy conditions and are often accompanied by strong winds, but are rare during the growing season.

Protecting crops from damage during an advective frost can be difficult as temperatures can drop below 20°F. Most frost events in the Klamath Basin are the result of radiational cooling. Sprinkler irrigation is used to protect local potato crops from damage during frost events. Water supplied by irrigation provides heat to the surface and plant canopy environment. Heat is released as water is cooled to 32°F and subsequently frozen.

Excessive soil moisture and canopy conditions conducive to disease development can result from sprinkler protection during frequent frost events. However, the potential increase in disease severity is preferable to complete crop failure. Inherent varietal frost-resistance or frost-hardiness to 24°F would provide greater flexibility to frost protection in the Klamath Basin.

The NRSP-6 – United States Potato Genebank located in Sturgeon Bay, Wisconsin has been working in recent years to introduce frost-hardiness into advanced breeding material. Most advanced selections are a combination of two very frost hardy wild Solanum species and early-maturing *Solanum tuberosum* varieties. *S. acaule* (4x = tetraploid) was crossed with a synthetic 4x *S. commersonii* (2x = diploid).

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Subsequent *S. acaule* x *S. commersonii* progeny were then crossed to Katahdin (*S. tuberosum*) and retained progeny have been further crossed with other *S. tuberosum* varieties. Fifty four-hill clones from the U.S. Potato Genebank were planted at Copic Bay, about 15 miles south of Tulelake, California in 2002. Temperature in Copic Bay during frost events, is often 5-7^{o}F lower than most other areas in the Klamath Basin.

Procedures

Fifty clones were planted in four-hill observational plots on April 18, several weeks earlier than the first commercial fields. Early planting was chosen to maximize exposure to early spring frosts. Hobo® (Onset Computer Corporation) data loggers were installed in the upper plant canopy and air temperature was recorded at 15-minute intervals throughout the growing season. All clones were evaluated during the late afternoon following frost events to determine foliar damage. Tubers were harvested on September 12 with a single-row, level-bed digger. Tuber characteristics and general observations were noted at harvest.

Results and Discussion

Plant emergence was slow for several clones (Table 1). Long dormancy coupled with moderately cool soil temperatures undoubtedly slowed emergence. Clones 5, 6, 13, and 16 did not achieve full emergence by late June. Most clones fully emerged by June 10 and 22 clones were at least 50 percent emerged by May 22. Russet Burbank, which is usually among the first varieties to emerge in local variety trials, had not emerged by June 10. However, Russet Burbank was not planted until May 2.

Frost events occurred on 11 days in May, 5 days in June, 7 days in August, and on 7 consecutive days in early September (Table 2). Minimum temperatures below 28^{0}F were recorded on several dates in May, including May 23, June 8 and 19, and September 6, and 8-10. Frost events in mid-May and early September provided an opportunity to evaluate the tolerance of many of the clones to frost damage. Most clones that were fully emerged by May 22 suffered leaf injury. It is likely that stem injury was experienced in seedlings that had not yet emerged during frosts in mid-May. Notable tolerance for the May frosts was observed in 1255.10, 1263.12, and 1280.18. The June 19 frost resulted in minor damage to Russet Burbank and 6 clones. No injury was observed in Russet Burbank or any clones following several mild frost events in August.

Hard frosts in early September provided an opportunity to evaluate frost tolerance in later maturing clones that maintained a vigorous canopy. Injury to Russet Burbank and several clones was rated as 20 percent damage or more following the September 6 frost with a low temperature of 25^{0}F. Late maturing 1255.10 and 1263.12 appeared tolerant to both early and late season frosts. Several other clones with maturity similar to Russet Burbank experienced much less injury as indicated by bold font in the injury column for September 7 ratings.

The frequency and severity of frost events at the evaluation site was fairly representative of summer conditions in the Klamath Basin. The trial was planted about 2-3 weeks earlier than commercial crops would be planted in Copic Bay and other frost-prone areas in the Klamath Basin. The 2002 season offered good opportunities to evaluate potato response to serious frosts in early

and late development stages. Differences in frost tolerance were evident among the clones evaluated. Plans are underway to continue the evaluation of breeding lines from the Wisconsin program in the Klamath Basin.

Table 1. Frost injury and plant and tuber characteristics of advanced breeding selections grown at Copic Bay, CA, 2002.

		Frost injury[1]				Emergence %				Vine	
	Entry	5-22[2]	6-10	6-19	9-7[3]	5-22	6-10	6-19	6-26	maturity[4]	Harvest notes
*	BC-11	80	0	2	----	100	100	100	100	1.00	good yield, oval white, good
*	BC-13	80	0	2	----	100	100	100	100	2.50	good yield, oval white, poor type
	286	----	0	0	----	0	100	100	100	1.00	poor yield, small, fair
	292	----	0	0	15	0	100	100	100	2.50	poor yield, small, lumpy, ugly
	295	----	0	10	4	0	50	50	75	4.00	very poor yield
	299	10	0	5	----	25	25	25	25	1.00	very poor yield
	300	----	0	2	80	0	100	100	100	2.00	fair yield, blocky, lumpy
	303	----	0	0	15	0	100	100	100	3.00	very poor yield, rough
*	310	40	0	0	----	100	100	100	100	1.00	fair yield, fair type
	316	----	0	0	5	0	100	100	100	3.50	no sample
*	319	30	0	0	----	100	100	100	100	1.00	nice, small, round
	320	----	0	0	----	0	100	100	100	3.00	fair
*	322	----	0	0	----	0	25	25	25	1.00	fingerling-type
	328	20	0	5	----	100	100	100	100	1.00	purple, rough, good yield
	335	----	0	0	5	0	25	75	100	4.50	no sample
*	337	----	0	0	5	25	50	50	50	3.00	big yield, long and lumpy
	339	----	0	0	2	0	50	75	100	3.00	small
	1252.1	----	0	0	**10**	0	50	75	100	5.00	no sample
	1253.29	----	0	0	----	0	100	100	100	1.00	very small
*	1254.4	60	0	0	----	25	100	100	100	1.00	long, skinny, poor yield
	1254.32	----	0	0	----	0	100	100	100	1.50	good yield, flat shape
	1254.43	80	0	0	2	75	100	100	100	4.00	knobby
	1254.61	0	0	0	5	25	100	100	100	3.00	ugly
	1255.1	40	0	0	----	100	100	100	100	1.50	no yield
	1255.2	80	0	0	30	100	100	100	100	4.50	knobby
*	1255.10	0	0	0	5	50	100	100	100	4.50	good, long and lumpy
	1258.9	----	0	0	----	0	100	100	100	2.50	ugly
*	1258.28	----	0	0	----	0	50	100	100	1.50	nice purple, smooth
	1258.46	50	0	0	----	100	100	100	100	2.00	no yield
	1258.51	----	0	0	----	0	100	100	100	1.50	fair
	1260.3	60	0	0	----	100	100	100	100	1.00	small, ugly
	1260.4	90	0	0	**5**	50	100	100	100	3.50	no sample
*	1261.4	80	0	0	**5**	100	100	100	100	2.50	very nice
	1261.21	10	0	0	----	100	100	100	100	2.00	scab
	1262.1	----	0	0	----	0	100	100	100	3.50	no sample
	1263.12	0	0	0	----	50	100	100	100	3.50	no sample
	1268.2	----	0	0	----	0	100	100	100	1.50	knobby, lumpy
	1277.1	----	0	0	----	0	50	100	100	2.00	fair
*	1277.3	60	0	0	----	100	100	100	100	1.00	long, smooth, purple
*	1280.5	50	0	0	----	100	100	100	100	1.00	long, smooth, purple
	1280.7	20	0	0	----	100	100	100	100	2.50	long, lumpy
	1280.9	40	0	0	**40**	75	100	100	100	3.00	fair
*	1280.18	5	0	0	----	100	100	100	100	1.00	small, large set
	1280.22	----	0	0	**20**	0	100	100	100	3.50	no sample
	1280.29	----	0	0	**25**	0	75	100	100	4.50	big yield, rough
	1280.32	40	0	0	**5**	100	100	100	100	5.00	no sample
*	1281.36	----	0	0	----	0	75	100	100	1.50	fair, long
	1282.10	----	0	0	**5**	0	100	100	100	4.00	no sample
*	1283.20	70	0	0	2	75	100	100	100	3.50	long, fair
	1285.2	----	0	0	----	0	100	100	100	1.00	junk
	R. Burbank	----	----	20	**60**	0	0	100	100	5.00	

* = Entries retained.

[1] Percent of foliage surface area damaged.

[2] Emerged plants did not exceed 2 inches in height, frost damage variable due to proximity to clods, etc.

[3] Most entries senesced, those in bold allowed for good ratings based on foliage condition.

[4] Vine maturity: 1=early - 5=late.

Table 2. Low temperature, average weighted temperature, and duration of time below freezing for advanced breeding selections grown at Copic Bay, CA, 2002.

Date	Low	Avg. temp. (weighted)[1]	# hrs. <28	# hrs. <26	# hrs. <24	Notes
5/9	23.3	26.6	2.00	1.50	0.75	
5/10	30.1	30.7	----	----	----	
5/11	16.9	22.9	6.50	5.25	4.25	
5/12	24.2	28.1	2.75	1.75	----	
5/14	22.4	26.2	3.00	2.50	0.75	
5/16	23.3	27.8	2.75	1.25	0.25	
5/20	27.6	30.5	0.50	----	----	
5/21	26.8	29.7	2.00	----	----	
5/22	24.2	28.3	2.00	1.00	----	* Plants just emerged -- injury varied from 10 - 90%
5/23	23.3	27.5	3.75	1.75	0.25	
5/24	28.4	30.8	----	----	----	
6/8	26.8	28.3	1.25	----	----	
6/9	29.3	30.1	----	----	----	
6/10	28.4	29.8	----	----	----	* Zero to minimal injury observed
6/11	28.4	29.1	----	----	----	
6/19	26.8	29.5	1.00	----	----	* Entries exhibiting injury had ≤5% while R.B avg. 20%
8/5	29.3	30.4	----	----	----	
8/6	30.1	30.8	----	----	----	
8/7	28.4	29.5	----	----	----	
8/8	28.4	29.8	----	----	----	
8/21	29.3	30.2	----	----	----	
8/22	29.3	30.5	----	----	----	
8/31	31.7	31.7	----	----	----	
9/5	31.7	31.7	----	----	----	
9/6	25.1	28.6	2.50	1.25	----	* Plant senescence -- frost injury difficult to rate
9/7	31.7	31.7	----	----	----	
9/8	23.3	27.6	4.75	2.00	0.25	
9/9	25.9	29.5	1.00	0.50	----	
9/10	26.8	30.1	0.25	----	----	
9/11	30.1	31.1	----	----	----	

[1]Temperature below 32°F - number of data points.