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Storage Characteristics of New Potato Introductions

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ABSTRACT

Release of new potato cultivars for grower production should be concurrent with cultural and storage recommendations to optimize economic returns. Estimation of tuber dormancy also raises an awareness for the need to have a rapid method to predict the stage of dormancy. This study characterized storage potential for several advanced selections and new potato cultivars by quantifying the number of days to 10 and 50% bud break for each of five storage temperatures following field harvest. The temperatures tested were 1.1, 2.2, 3.3, 4.4, and 6.7C. Storage temperatures strongly influenced the length of storage life. The three higher temperatures reduced storage life about the same and were far less effective than storage at 1.1 and 2.2C which prolonged time to 50% tuber sprout by 30-60 days. The cultivars were ranked longest to shortest storage life, using 10% tuber sprout at 1.1C as follows: Russet Nugget (112 days), Russet Norkotah #3 (109 days), Russet Norkotah #8 (95 days), Cherry Red (89 days), Durango Red (87 days), Chipeta (70 days), and Keystone Russet (<30 days). Sugar levels were highest about 60 days after storage was initiated. Soluble sugar levels were highest at the lowest temperature, 1.1C. A rapid enzyme assay (based upon production of PNP(p-nitrophenyl)) was tested to predict dormancy. This assay uses p-nitrophenyl, alpha-D-galactopyranoside (PNPG) as a substrate for tuber tissue producing PNP, the result of cleavage of terminal galactose units from raffinose oligosaccharides(RFO) as an indication of alpha galactosidase enzyme activity. The PNP produces a yellow pigment which can be measured spectrophotometrically. The correlation for PNP production with dormancy at a storage temperature of 1.1C was r=0.79.

INTRODUCTION

With the release of new potato cultivars, it is important to investigate the storage characteristics, as well as cultural production needs. Marketing organic potatoes requires abstaining from chemical sprout inhibitors. This knowledge of storage behavior with new cultivars is essential to develop a strategy targeted at marketing organic potatoes. The organic grower may be able to fill a niche with a cultivar which has longer dormancy release. Also, some of the materials currently available for sprout inhibitors may not be on the market in the future. This paper will report the results of storage experiments for 7 recently released cultivars: Cherry Red, Chipeta, Durango Red, Keystone Russet, Russet Norkotah #3 (RNK3), Russet Norkotah#8(RNK8) and Russet Nugget (www.coloradopotato.org). Potato dormancy release seems to be a complex interaction of biochemical changes (Sowokinos, 1978; Huhges, 1986; Claassens and Vreugdenhil, 2000) that is not well understood. Hughes (1986) examined the relationship between storage temperatures, fertility and accumulation of sugars, while Sowokinos (1978) evaluated the effect of preharvest sucrose content on storage life of potatoes. Claassens and Vreugdenhil (2000) investigated hormonal, carbohydrate and enzymatic activities as they tried to answer the question is dormancy release the reverse of tuber initiation? They proposed that perhaps dormancy release is not synonymous with the occurrence of visible sprouts. This paper will also introduce a new rapid colormetric method for possible determination of end of the dormancy.

MATERIALS AND METHODS

Storage temperatures tested were 1.1°C (34°F), 2.2°C (36° F), 3.3°C (38°F), 4.4°C(40°F), and 6.7°C (44°F) and storage humidity was approximately 80%. Potato tubers were grown at the San Luis Valley Research Center at Center, CO using standard growing practices for the area. The field tubers were harvested in mid to late September, after being treated with vine killers. The tubers which were not treated with sprout inhibitors were placed into storage at 14.4C(58F) with the temperature being dropped 1.1C(2F) per week, to allow for suberization and wound healing to occur, until the desired maximum storage temperature was reached(all storage experiments started about the 3rd week of November). The tubers were washed to remove field debris. Thirty 170 to 227 g(6 to 8 oz) tubers were selected for each of the 5 storage temperatures. Twelve tubers used for dormancy release studies were divided into 4 groups of 3 each. The tubers in each group were numbered and then used for monthly counts of visible sprouts (more than 1 cm in length). The remaining tubers (9 groups of 2 each) were designated for other studies. All tuber groups were put into perforated plastic bags(1 liter) which were put into replicated cardboard containers and placed in the appropriate storage temperature in the dark.

GC Analysis for Sugars: Prepared samples were immediately freeze-dried (Genesis 25 LL lyophilizer, Virtis, Gardiner, NY), ground with a Wiley mill, sieved through a 80-mesh screen, and kept in airtight vials at –20C. About 1 mg of ground sample was derivitized using pyridine, hexamethyldisilazane and trimethylchlorosilane to volatilize sugar methyl groups for gas chromatography. Carbohydrate derivitization was carried out according to Cox and Stushnoff (2001) and Sweeley et al. (1963).

One µl samples were injected into an HP 5890 series II gas chromatograph (Hewlett Packard, Boulder, CO) with a 30 m silica capillary column (J & W DB-1, 0.25 mm inner diameter, 0.25 µm film thickness) and a flame ionization detector. Helium was used as carrier gas at a flow rate of 2ml/min. Sugars in the samples were identified by comparing retention times with known standards that included raffinose, stachyose, sucrose, fructose and glucose. Carbohydrate quantifications were determined by comparing peak areas to glucopyranoside as the internal standard area using peak simple 1.72 (SRI, Inc., Torrance, CA).

Alpha galactosidase test This test measures the cleavage of terminal galactose units by ∝ galactosidase (White and White, 1997). The cleavage releases p-nitrophenol(PNP), a yellow color which indicates that enzyme activity is occurring. Even though there is no evidence that RFO (raffinose family oligosaccharides)are present in potato, preliminary tests indicated considerable activity with this assay, which is normally used to detect cleavage of galactose units from complex carbohydrates. This test was modified by our lab from a liquid media for use with bacteria to a system which uses a solidified agar base and has been used to evaluate bud dormancy in woody species. The substrate was prepared under sterile conditions using 0.8%(w/v) agar with 2.5μm PNPG (p-nitrophenyl, ∝-D-galactopyranoside) available from Sigma St. Louis MO 63178 USA catalog number N-0877. Three ml of the liquid substrate wa poured into 13x100mm test tubes and allowed to solidify. The tubes were placed in the dark at 4C until needed. Two tubers were removed from storage for each cultivar, for each temperature. Two cores were removed from each tuber, one core each from basal and stem end of the tuber. The cores which included an eye/bud were made using a cork borer, 5mm diameter. Each core was 5mm long. The cores were weighed, dipped in 70%ETOH, placed flesh side down on the agar and the tubes stoppered with a cork. The racks of test tubes with core samples were placed in the dark at 15C for incubation. The tubes were removed and absorbance recorded every 24 to 48h with a digital spectrophotometer (Spectronic 20+ by Spectronic Instruments, Rochester NY) at a wavelength of 400 nm. The tubes were read for 10 days or until the maximum absorbance was detected. The absorbance value was divided by the fresh weight to normalize the absorbance data. The balance of the tubers were freeze dried for additional analyses.

RESULTS AND DISCUSSION

Dormancy Release In general there was little or no difference in the time to 50% dormancy release for the 3 higher storage temperatures of 6.7, 4.4 and 3.3C. The two lower temperatures (2.2 and 1.1C) delayed dormancy release and increased the storage life by an average of 43 days (Figure 1). RNK#3, RNK#8 and Russet Nugget consistently stored best. Cherry Red, Durango Red and Chipeta ranked next while Keystone Russet stored only 30 to 60 days even at 1.1 and 2.2C (Table 1). Following 210 days at the respective storage temperatures, tubers were cut and evaluated for chilling injury. After they had been left at room temperature (22-25C) for 3 weeks, there was no visible vascular damage nor discoloration in any regions of the tubers that suggested chilling injury. Sprouts on the tubers appeared to be growing normally.

Sugars The GC analysis for sugars showed that only 3 sugars, sucrose, glucose and fructose were found in the tubers. All cultivars showed similar patterns in that sucrose was present in lesser amounts than the reducing sugars (fructose and glucose)(Table 2). The lower temperature (1.1C) induced elevated sugar levels for the entire storage period examined (240 days) when compared to the three higher temperatures. Sugars for the higher temperatures tended to be stable during the storage duration with a slight tendency toward an increase at the end (240days). Hughes (1986) reported an initial rise in total reducing sugars with the level going down at a slower rate in the lowest storage temperature evaluated (5C). Sowokinos (1978) found a linear relationship with preharvest sucrose levels and $\log_{10}$ storage life. However, his storage temperature, 11.7C, was much higher than our conditions.

Alpha galactosidase Test The relationship of alpha galactosidase activity to dormancy release is not clear. When we examined the relationship of ∝-gal activity to storage temperature, using all temperatures, the correlation was $r=0.25$ with $P=0.02$(data not shown). However, the relationship between ∝-gal activity with the onset of dormancy release, which we defined as 10% of the tubers having sprouts greater than 1 mm, was more strongly correlated with an $r = 0.79$.(Figure 2) at the coolest temperature(1.1C). Perhaps PNPG (p-nitrophenyl, ∝-D-galactopyranoside) substrate acted upon some other glycosyl cleaving enzymes that become active under certain metabolic conditions. In conclusion, we have presented storage profiles for 7 cultivars at 5 different storage temperatures. Tuber storage life can be lengthened if the increased sugar levels can be tolerated or if a process can be devised to reverse the increased sugar levels. Additional experiments designed to more definitely define the release of dormancy versus using visible sprouts perhaps using a rapid colormetric assay such as PNP are needed.

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TABLES

Table 1. Days in storage to attain **10%** or **50%** dormancy release (DR) mean values for 1999/00, 2000/01, 2001/02 at 5 storage temperatures.

Cultivar	**DR %**	44F (6.6C)	40F (4.4C)	38F (3.3C)	36F (2.2C)	34F (1.1C)	Rank[1]
Cherry Red	**10**	<30[2]	<30	<30	45±5[3]	89±5	4
	50	<30	<30	48±2	95±30	125±14	5
Chipeta[4]	**10**	< 50	<50	<50	53±3	70±20	6
	50	<50	<50	<50	85±15	143±58	3
Durango Red	**10**	<30	<30	<30	47±3	87±21	5
	50	<30	<30	48±2	103±24	162±38	2
Keystone Russet	**10**	<30	<30	<30	<30	<30	7
	50	<30	<30	<30	<30	63±13	6
Russet Norkotah #3	**10**	45±6	45±5	50±1	65±1	109±45	2
	50	54±12	57±9	67±10	95±3	176±24	1
Russet Norkotah #8	**10**	<30	44±6	45±5	55±7	95±16	3
	50	47±9	62±7	66±12	105±10	176±24	1
Russet Nugget	**10**	<30	44±6	54±4	55±3	112±44	1
	50	48±2	53±3	63±13	72±4	133±33	4

[1] From longest to shortest dormancy release at 1.1C.

[2] Observations of dormancy release were done based on monthly intervals, therefore more exact

data not available.
[3] Value is standard error of the mean.
[4] Two years data only 1999/00 and 2000/01

Table 2. Sucrose and reducing sugars content (µmole g^{-1}dw) of 7 potato cultivars stored at four different temperatures (C).

Cultivar	Sucrose				Reducing Sugars			
	1.1	3.3	4.4	6.7	1.1	3.3	4.4	6.7
Cherry Red	9.3[1]	3.8	2.1	2.2	49.7	23.2	9.2	11.1
	1.0[2]	0.7	0.3	0.3	6.4	6.0	0.7	3.7
Chipeta	12.4	2.5	0.78	0.45	39.5	10.0	4.35	6.4
	1.5	0.3	0.18	0.1	6.8	1.0	0.8	1.3
Durango Red	23.1	5.0	1.7	2.8	68.0	19.8	11.0	7.0
	3.8	1.1	0.3	0.9	13.4	4.6	3.6	2.4
Keystone R.	13.3	4.5	2.0	3.2	99.3	41.6	18.5	24.0
	3.0	1.0	0.4	0.8	14.5	10.2	2.4	6.3
RNK3	6.9	2.7	0.78	1.2	70.0	23.0	8.8	12.1
	1.5	0.5	0.3	0.4	12.3	5.1	1.6	2.7
RNK8	11.4	2.6	1.5	1.2	82.1	16.7	9.1	5.7
	2.6	0.3	0.5	0.1	17.1	3.6	2.4	0.6
Russet Nugget	22.6	3.0	1.5	1.4	89.5	19.9	10.3	7.6
	6.3	0.6	0.6	0.2	10.8	5.2	3.1	1.5

[1] Mean of 7 monthly samples during the storage duration for the fall 2000 harvested tubers
[2] Standard error

Figures

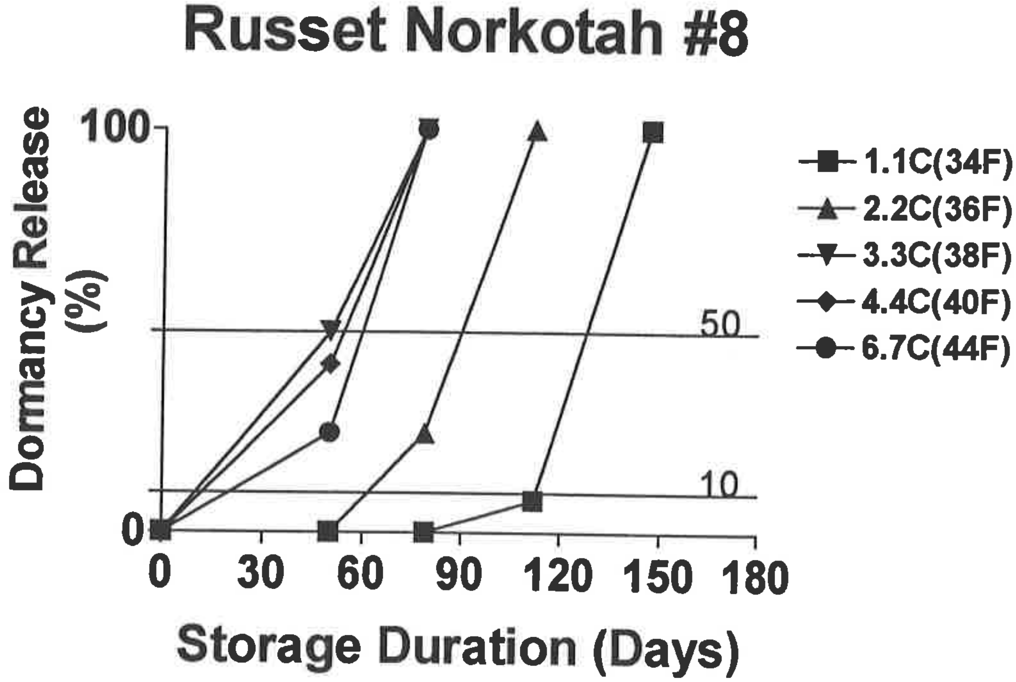

Figure 1. Example of the storage duration for 5 different storage temperatures. The 10 and 50% dormancy release are noted. Similar patterns were seen in most cultivars.

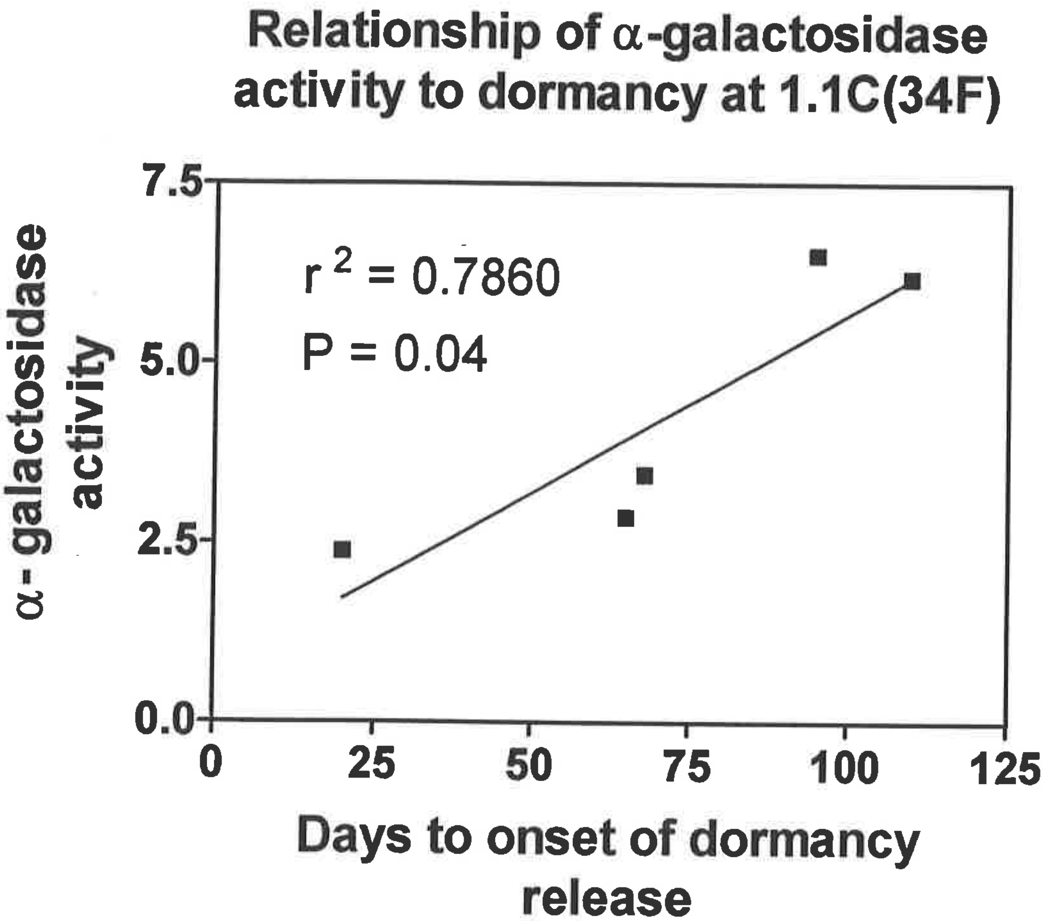

Figure 2. Normalized ∝- galactosidase activity of 5 cultivars as function of days to onset of dormancy release (10% tubers with visible sprouts).