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Alpine Russet: A Potato Cultivar Having Long Tuber Dormancy Making it Suitable for Processing from Long-term Storage

Jonathan L. Whitworth · Richard G. Novy · Jeffrey C. Stark · Joseph J. Pavek · Dennis L. Corsini · Steven L. Love · Nora Olsen · Sanjay K. Gupta · Tina Brandt · M. Isabel Vales · Alvin R. Mosley · Solomon Yilma · Steve R. James · Dan C. Hane · Brian A. Charlton · Clinton C. Shock · N. Richard Knowles · Mark J. Pavek · Jeffrey S. Miller · Charles R. Brown

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Abstract Alpine Russet is a later maturing, oblong-long, lightly russeted potato cultivar, notable for having tuber dormancy comparable to Russet Burbank. Processing quality of Alpine Russet from long-term storage is superior to Russet Burbank, with low percent reducing sugars and uniform fry color due to a low percentage difference of sugars between the bud and stem ends. Alpine Russet yields were comparable to Russet Burbank in early harvest trials and were comparable or significantly larger in late harvest trials depending on the location. At two late season locations, Alpine Russet had the largest total and percent No. 1 yields and the largest percent mid-range No. 1 tubers compared to Ranger Russet and Russet Burbank. It has moderately high specific gravity and is resistant to most external and internal defects. Alpine Russet has been evaluated in public and industry trials throughout the Western U.S. for over 15 years.

Resumen Alpine Russet es una variedad de papa de madures tardía, larga-oblonga, ligeramente como Russet, notable por

J. L. Whitworth (✉) · R. G. Novy · J. J. Pavek · D. L. Corsini
Research & Extension (R & E) Center, U.S. Department of Agriculture (USDA)-Agricultural Research Service (ARS),
Aberdeen, ID 83210, USA
e-mail: Jonathan.Whitworth@ars.usda.gov

J. C. Stark · S. L. Love
Aberdeen R & E Center, University of Idaho,
Aberdeen, ID 83210, USA

N. Olsen · S. K. Gupta · T. Brandt
Kimberly R & E Center, University of Idaho,
Kimberly, ID 83341, USA

M. I. Vales · A. R. Mosley · S. Yilma
Oregon State University,
Corvallis, OR 97331, USA

S. R. James
Oregon State University,
Madras, OR 97741, USA

D. C. Hane
Oregon State University,
Hermiston R&E Center,
Hermiston, OR 97838, USA

B. A. Charlton
Oregon State University,
Klamath Basin R&E Center,
Klamath Falls, OR 97603, USA

C. C. Shock
Oregon State University,
Malhuer Experiment Station,
Ontario, OR 97914, USA

N. R. Knowles · M. J. Pavek
Washington State University,
Pullman, WA 99164, USA

J. S. Miller
Miller Research,
Rupert, ID 83350, USA

C. R. Brown
USDA-ARS,
Prosser, WA 99350, USA

Present Address:
M. I. Vales
ICRISAT,
Patancheru, India

tener una dormancia del tubérculo comparable a Russet Burbank. La calidad de procesamiento de Alpine Russet después de un almacenamiento prolongado es superior a Russet Burbank, con bajo porcentaje de azúcares reductores y color uniforme de freído debido a la baja diferencia en porcentaje de azúcares entre la yema apical y la base. Los rendimientos de Alpine Russet fueron comparables a Russet Burbank en ensayos de cosecha temprana y fueron comparables o significativamente mayores en ensayos de cosecha tardía, dependiendo del lugar. En dos lugares de ciclo tardío, Alpine Russet tuvo los mayores rendimientos totales y en porcentaje de No. 1, y el mayor porcentaje de tubérculos de amplitud media No. 1 comparada con Ranger Russet y Russet Burbank. Tiene moderadamente alta gravedad específica y es resistente a la mayoría de los defectos externos e internos. Alpine Russet ha sido evaluada en ensayos públicos y de la industria a lo largo del oeste de los E.U. por más de 15 años.

Keywords *Solanum tuberosum* · Variety · Tuber dormancy · Breeding · French fry

Introduction

Alpine Russet is a potato cultivar with light russeted oblong to long tubers. It is notable for its excellent processing characteristics and its extended tuber dormancy. The ability to store Alpine Russet for as long as Russet Burbank and produce a lighter colored fry gives this cultivar an advantage over Russet Burbank-the industry standard for long-term storage and processing. Alpine Russet originated in 1993 from the USDA-Agricultural Research Service Aberdeen, Idaho Potato Breeding Program. It was designated as A9305-10 upon selection from the progeny that resulted from a hybridization between breeding clones A8343-12 and A85103-3. Notable cultivars in its background include Green Mountain (released 1885, [Hils and Pieterse 2005]), Butte (Pavek et al. 1978), and Norgold Russet (Johansen 1965) on the maternal side and Maris Piper (released 1966, [Hils and Pieterse 2005]) and Lemhi Russet (Pavek et al. 1981) on the paternal side (Fig. 1). The selection of Alpine Russet in the field was made in 1995 and was entered into replicated yield trials in Aberdeen, Idaho in 1997. Subsequently it was trialed in Idaho, Oregon, and Washington in 2001 and in Western U.S. Regional Trials that included these states and also California, New Mexico, Colorado, and Texas in 2002 through 2004. Trials included evaluations for yield, fertility, disease resistance, and post-harvest testing that included storage, processing, taste panels, and biochemical/nutritional analyses.

On the basis of its high percentage of U.S. No. 1 yields both in early and late harvests, its long dormancy, allowing storage periods equal to Russet Burbank, and its exceptional fry qualities after long term storage, Alpine Russet was released by the Northwest (Tri-State) Potato Variety Development Program Committee. The Tri-State program participants are the USDA-ARS and the Agricultural Experiment Stations of Idaho, Oregon, and Washington. Release documents for Alpine Russet were completed in 2008.

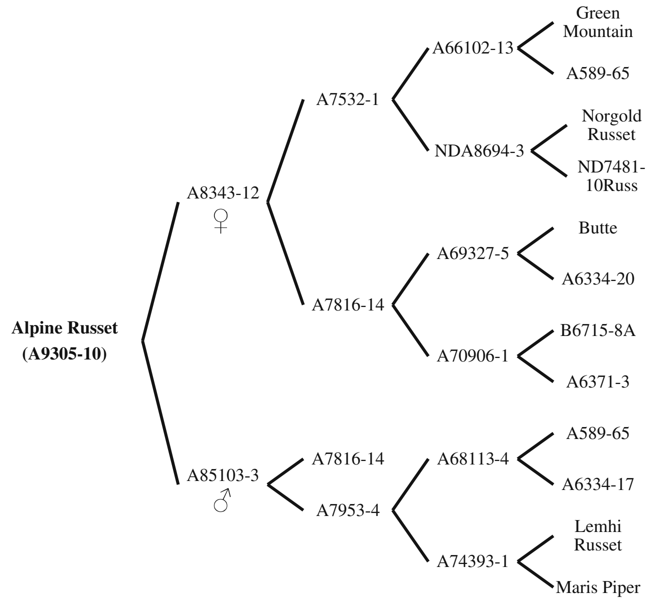

Fig. 1 Four generation pedigree of Alpine Russet

Cultivar Description

Plants

Alpine Russet has a semi-erect plant habit with open foliage and vine and stems clearly visible (Fig. 2a). Maturity was approximately 130 days after planting (DAP) in trials conducted in the states of Washington, Oregon, and Idaho. This puts Alpine Russet in a late maturity class of 121–130 DAP compared to Russet Burbank which has a mid-season maturity class of 111–120 DAP. Stems and petioles have weak anthocyanin coloration and weak prominence of wings on the stem. Leaves are medium green with a lower density of trichomes compared to Russet Burbank, but trichomes for both are similar in length. Leaf silhouette is open with an average of four primary leaflet pairs and 6.4 secondary and tertiary leaflet pairs. The primary leaflets are small with a medium ovate shape, a cuspidate leaflet tip shape and an obtuse leaflet base. The terminal leaflet is medium ovate in shape, with an acuminate leaflet tip and an obtuse leaflet base with weak leaflet margin waviness (Fig. 2b). Stipule leaf size is medium.

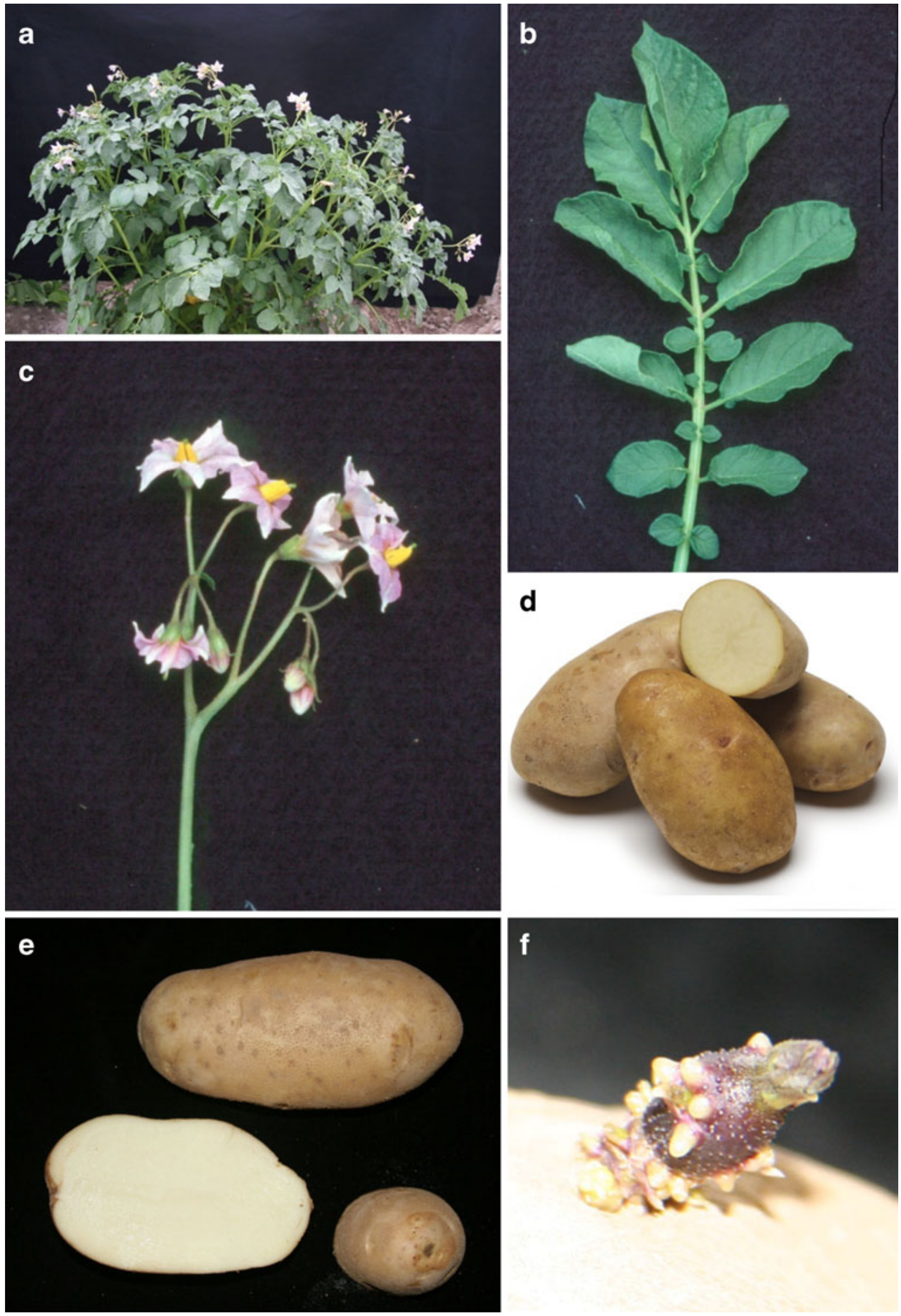

Fig. 2 Photographs of Alpine Russet showing **a** whole plant, **b** compound leaf, **c** inflorescence, **d** field tubers, **e** external and internal tuber appearance, and **f** diffuse light sprout (Fig. 2d photo courtesy of Potato Variety Management Institute)

Flowers

The shape of the Alpine Russet corolla is semi-stellate and the color is purple (76B on the royal Horticulture society Color Chart-RHSCC) with a violet-white halo (Fig. 2c). Average number of inflorescences per plant is 3.9 (range 1–8) and florets 11.9 per inflorescence (range 5–22) . Anthocyanin coloration on the calyx is medium. Anthers are yellow-orange (14A RHSCC) and form a narrow cone. Pollen production from the anthers is abundant, allowing use of Alpine Russet as a male in hybridizations. Stigma color is yellow–green (146A RHSCC) and the shape is capitate. Berry production in the field is moderate.

Tubers

Tubers from Alpine Russet are russetted with light tan skin (164B RHSCC). Secondary skin color is not present. Tuber flesh color is white (158C RHSCC) with no secondary flesh color present (Fig. 2d, e). Tubers are medium thick and the shape is oblong to long with an average length to width ratio of 1.7 compared to Russet Burbank with a ratio of 1.9. Eyes are shallow and eyebrows have a medium prominence with tubers having an average 14.8 eyes. Distribution of eyes is predominantly apical. Number of tubers is low with an average of 6.7 per plant. Alpine Russet has a long dormancy; 10 days longer than Russet Burbank in trials conducted at Kimberly, Idaho (storage at 5.5°C, dormancy break=80% tubers with visible sprouting).

Light Sprouts

Sprouts grown in the presence of light are ovoid in shape with the tip having an intermediate habit (Fig. 2f). Some root initials are present on the sprout and there is weak pubescence on the sprout base and medium pubescence on the sprout tip. Coloration of the sprout base is medium red–violet, while the sprout tip is a weak red–violet.

Agronomic Performance

Alpine Russet had the highest total yield at all Tri-State trial locations and harvest dates and was significantly higher than Russet Burbank in two of the three late harvest locations. Alpine Russet percent U.S. No. 1 yields were higher than Ranger Russet and Russet Burbank at all locations for both early and late harvests and the Alpine Russet yields were always significantly higher than Russet Burbank (Table 1). In early harvest Western Regional Trials at five locations conducted over a 2 to 3 year period, Alpine Russet total yields were similar and not significantly different than Ranger Russet and Russet Burbank. Percent U.S. No. 1 yields were always higher, but not significantly higher, except for at Malheur, Oregon with Alpine Russet having significantly higher percent U.S. No. 1 yield than Russet Burbank (Table 2). In late harvest trials at nine locations, Alpine Russet had statistically greater total yields than Russet Burbank at one location and Ranger Russet at two locations. The percentages of U.S. No. 1 were significantly higher than Russet Burbank in two of the nine locations (Table 3).

In late season trials at Aberdeen, Idaho and Hermiston, Oregon in 2001, total yields for Alpine Russet were significantly higher than Ranger Russet and Russet Burbank at Aberdeen and were comparable but not significantly different at Hermiston (Table 4). Alpine Russet had a significantly higher percentage of U.S. No. 1 yield than Ranger Russet and Russet Burbank at both locations. An examination of the tuber size distribution as a percentage of the total yield showed that Alpine Russet had the greatest mid-range size (114–340 g, significant at Hermiston). Alpine Russet oversize tuber (>340 g) yields were in-between Ranger Russet and Russet Burbank at both locations. At Hermiston, a longer growing season location, Ranger Russet oversize yield was significantly

Table 1 Total yields, percentages of U.S. No. 1 yield, and specific gravities of Alpine Russet, Ranger Russet and Russet Burbank in Tri-State Potato variety trials, 2001

Location[a]	Late harvest			Average late harvest	Early harvest
	ABE	HER	OTH		PAS
Total yield (mt/ha)	**[b]	ns	*		ns
Alpine Russet	62.1 a[c]	116.3	91.6 a	90.0	48.5
Ranger Russet	52.3 ab	111.3	89.6 a	84.4	38.2
Russet Burbank	42.6 b	112.2	75.9 b	76.9	45.5
% U.S. No. 1	**	*	*		**
Alpine Russet	88.0 a	83.7 a	80.4 a	84.0	93.8 a
Ranger Russet	72.8 a	73.3 b	75.3 ab	73.8	90.0 a
Russet Burbank	53.6 b	69.6 b	65.6 b	62.9	67.2 b
Specific Gravity	**	*			
Alpine Russet	1.077 ab	1.077 ab	–	1.077	–
Ranger Russet	1.083 a	1.083 a	–	1.083	–
Russet Burbank	1.072 b	1.076 b	–	1.074	–

[a] Trial locations were ABErdeen, ID; HERmiston, OR; OTHello, WA; PASco, WA

[b] Symbols pertain to Tukey's HSD means separation tests for comparison of the data in the column below. **significant at $P<0.01$;* significant at $P<0.05$; *ns* not significant

[c] Values for each category that are followed by a different letter within the column are significantly different

Table 2 Early harvest total yields, percentages of U.S. No. 1, specific gravities, and fry colors of Alpine Russet, Ranger Russet, and Russet Burbank in the 2002 to 2004 Western Regional Potato variety trials

Location[a]	CA	OR		TX	WA	Average
	KER	HER	MAL	SPR	PAS	
Total yield (mt/ha)	ns[b]	ns	ns	ns	ns	
Alpine Russet	45.3	69.7	57.7	28.0	43.1	48.8
Ranger Russet	48.5	61.6	49.6	36.4	45.5	48.3
Russet Burbank	41.6	64.5	57.3	32.5	44.8	48.1
U.S. No. 1 (%)	ns	ns	*	ns	ns	
Alpine Russet	95.2	83.7	75.3 a[c]	75.8	75.3	81.1
Ranger Russet	81.4	75.8	73.0 a	49.3	58.0	67.5
Russet Burbank	76.8	63.8	47.9 b	23.5	54.9	53.4
Specific Gravity	ns	ns	**	*	ns	
Alpine Russet	1.081	1.069	1.077 ab	1.066 ab	1.069	1.072
Ranger Russet	1.076	1.070	1.086 a	1.067 a	1.071	1.074
Russet Burbank	1.086	1.076	1.070 b	1.061 b	1.072	1.073

[a] Trial locations were KERn County, CA(2 years); HERmiston (3 years); MALhuer, OR (3 years); SPRinglake, TX (3 years); and PASco, WA (2 year)

[b] Symbols pertain to Tukey's HSD means separation tests for comparison of the data in the column below. **significant at $P<0.01$; *significant at $P<0.05$; *ns* not significant points immediately below each symbol

[c] Values for each category that are followed by a different letter within the column are significantly different

Table 3 Late harvest total yields, percentages of U.S. No. 1, and specific gravities of Alpine Russet, Ranger Russet, and Russet Burbank in the 2002 to 2004 Western Regional Potato variety trials

Location[a]	CA	CO	ID		NM	OR			WA	Average
	TUL	CEN	ABE	KIM	FAR	HER	MAL	KLA	OTH	
Total yield (mt/ha)	ns[b]	**	ns	ns	ns	ns	*	*	ns	
Alpine Russet	50.8	63.3 a[c]	67.0	63.6	50.3	123.2	64.3 a	65.7 a	85.7	70.4
Ranger Russet	42.2	52.8 b	53.8	56.3	67.2	96.7	59.2 ab	56.7 b	81.1	62.9
Russet Burbank	44.2	60.7 ab	51.6	55.9	60.8	103.3	53.4 b	65.4 ab	78.3	63.7
% U.S. No. 1	ns	**	ns	**	ns	*	**	ns	ns	
Alpine Russet	79.6	84.5 ab	82.5	86.5 a	79.9	69.4 ab	80.7 a	77.6	81.9	80.3
Ranger Russet	77.3	87.6 a	84.9	70.0 ab	88.7	80.6 a	74.5 a	71.1	85.7	80.0
Russet Burbank	65.2	81.2 b	63.4	64.7 b	68.4	54.5 b	46.0 b	66.4	70.9	64.5
Specific gravity	ns	ns	*	ns	ns	ns	**	ns	*	
Alpine Russet	1.087	1.092	1.086 a	1.085	1.085	1.076	1.082 b	1.085	1.080 ab	1.084
Ranger Russet	1.084	1.088	1.085 ab	1.086	1.089	1.075	1.093 a	1.087	1.086 a	1.086
Russet Burbank	1.089	1.089	1.077 b	1.081	1.081	1.072	1.069 c	1.086	1.076 b	1.080

[a] Trial locations were TULe Lake, CA(3 years); CENter, CO (3 years); ABErdeen, ID (3 year); KIMberly, ID (3 years); FARmington, NM (2 years); HERmiston (3 years), MALhuer (3 years), KLAmath, OR (3 years); and OTHello, WA(3 years)

[b] Symbols pertain to Tukey's HSD means separation tests for comparison of the data in the column below. **significant at $P<0.01$; *significant at $P<0.05$; *ns* not significant $P<0.01$;* significant at $P<0.05$; *ns* not significant

[c] Values for each category that are followed by a different letter within the column are significantly different

Table 4 Total yield and tuber size distribution of Alpine Russet, Ranger Russet, and Russet Burbank at two full season locations in 2001 (Aberdeen, ID and Hermiston, OR)

	Total yield (mt/ha)	Tuber size distribution as a percentage of the total yield					
		U.S. No. 1				U.S. No. 2	Culls
		Total	<114 g	114–340 g	>340 g		
Aberdeen, ID	**[a]	**	ns	ns	*	*	**
Alpine Russet	62.1a[b]	87.9 a	12.7	42.3	33.0 ab	5.1 b	6.9 b
Ranger Russet	52.3 b	72.8 b	2.7	33.6	36.5 a	20.6 a	6.6 b
Russet Burbank	42.6 c	53.6 c	9.4	32.2	12.0 b	16.0 ab	30.4 a
Hermiston, OR	ns	**	ns	**	*	*	**
Alpine Russet	116.2	57.7 a	7.8	49.9 a	33.8 b	6.9 b	1.5 b
Ranger Russet	111.3	23.8 b	4.5	19.3 b	50.4 a	17.1 a	8.7 a
Russet Burbank	112.1	35.7 b	5.9	29.9 b	43.5 ab	12.6 ab	8.1 a

[a] Symbols pertain to Tukey's HSD means separation tests for comparison of the data points immediately below each symbol. **significant at $P<0.01$;* significant at $P<0.05$; *ns* not significant

[b] Values for each category that are followed by a different letter within the column are significantly different

greater than Alpine Russet and Russet Burbank. U.S. No. 2 yields were significantly lower for Alpine at both locations compared to Ranger Russet. Alpine Russet culls, consisting of misshapen tubers and/or rotted tubers, were significantly lower than both standard cultivars at Hermiston and significantly lower than Russet Burbank at Aberdeen. Therefore, Alpine Russet generally had the largest percentage of mid-sized U.S. No. 1 tubers and the smallest percentage of U.S. No. 2 and cull tubers compared to the standard cultivars.

Tuber Quality Characteristics and Usage

Post-harvest Processing Evaluations

Rating scores from evaluations that include fry color, reducing sugar concentrations, specific gravity, and sensory evaluations of fried product by taste panel evaluators showed that Alpine Russet had the highest average score compared to Ranger Russet and Russet Burbank (Table 5). These ratings were developed from samples grown in Washington, Idaho, and Oregon and then evaluated under the identical conditions at Pullman, Washington. Alpine Russet had the highest post-harvest merit scores regardless of where the tubers were produced.

Fry Color

Fry color of Alpine Russet, Ranger Russet and Russet Burbank was compared between the tuber's stem and bud end for tubers produced in Washington, Oregon, and Idaho using a Photovolt reflectance meter. Uniform fry color (defined as a change ≤9 units between stem and bud end) was obtained with Alpine Russet grown in Washington and Idaho, but not in Oregon. In Washington and Idaho, Alpine Russet had lower differential stem/bud readings compared to the standard cultivars (Table 6). An examination of the difference in the percent reducing sugars between the bud and stem end shows that Alpine Russet also had the smallest differences relative to the cultivar standards in all three states.

A summary of Western Regional trial data averaged over 3 years for fry color shows that Alpine Russet had the lightest fry color when compared to Ranger Russet and Russet Burbank at two different storage temperatures

Table 5 Mean post-harvest ratings of Alpine Russet, Ranger Russet, and Russet Burbank in full-season studies included in the 2002–2004 Western Regional Potato variety trials

	Washington	Idaho	Oregon	Mean
Alpine Russet	27.0	32.0	22.8	27.3
Ranger Russet	23.7	26.4	16.1	22.0
Russet Burbank	22.1	20.3	13.9	18.7

Post-harvest evaluations and ratings were conducted at Pullman, WA using tubers from trials at Aberdeen, ID, Hermiston, OR, and Othello, WA. Values were assigned based on the sum of individual ratings for fry color from the field, after storage at 8.9° and 6.7°C (63 days; 0–5 scale), reducing sugar concentrations following 63 days storage at 8.9° and 6.7°C (1–5 scale), specific gravity (0–5 scale), and average sensory evaluations by taste panels (1–5 scale). Total scores are added based the following categories; 3-fry, 2-reducing sugar, 1-specific gravity, 1-sensory for a total of 7, and if all categories receive the highest score the sum is 35. Additionally ±3 points for uniform fry color are given for a highest possible value of 38 indicating the best result

Table 6 Post-harvest ratings of Alpine Russet, Ranger Russet, and Russet Burbank following 7 months of storage (3 months at 8.9°C and 4 months at 6.7°C). Sprouting was measured following 65 days of storage at 8.9°C

Clone	Reflectance meter reading[a]			Difference[b]	USDA color rating[c]	% Reducing sugars[d]			Sprouting	
	Stem	Bud	Avg.	Stem vs. Bud		Stem	Bud	Average	% of Tubers	Sprout length (mm)
Washington										
Alpine Russet	34.8	41.0	37.9a	7.2a	1.0	0.92	0.66	0.26	22b	3.2
Ranger Russet	25.3	31.1	28.2b	7.4a	1.7	1.58	1.03	0.55	98a	14.8
Russet Burbank	34.0	40.2	37.1a	7.8a	0.3	0.88	0.48	0.40	19b	2.5
Idaho										
Alpine Russet	38.1	45.7	41.9a	8.3b	0.0	0.77	0.61	0.16	0b	0
Ranger Russet	29.7	39.0	34.4b	9.6ab	0.7	1.78	0.71	1.07	76a	10.6
Russet Burbank	31.6	43.0	37.3b	12.4a	0.3	1.62	0.57	1.05	0b	0
Oregon										
Alpine Russet	26.4	40.4	33.4a	14.3a	1.3	1.89	0.81	1.08	0c	0
Ranger Russet	20.9	32.4	26.6b	12.8a	2.3	3.18	1.07	2.11	96a	23.3
Russet Burbank	25.7	39.9	32.8a	15.0a	1.3	1.84	0.72	1.12	35b	2.5

All post-harvest evaluations and ratings were conducted at Pullman, WA in 2001–2003 using tubers from trials at Aberdeen, ID, Hermiston, OR, and Othello, WA

[a] Fries (9.5 mm×28.6 mm) were fried at 191°C for 3.5 min and color was measured with a Photovolt reflectance meter within 3 min of removal from oil (higher number = lighter color fry). A photovolt reading of ≤19 is considered unacceptably dark (see note 3 below). Within a state, means followed by different letters differed significantly (LSD, $P<0.05$)

[b] A difference of ≥9 photovolt units between bud and stem end constitutes non-uniform fry color. Values represent an average of actual photovolt differences in each of 3 years and therefore do not relate directly to averaged stem and bud values listed in the table

[c] USDA color (0 = light and 4 = dark) ratings were assigned based upon photovolt reflectance readings of the darkest ends of fries (typically stem ends); Photovolt readings ≥31 = USDA 0, 25–30 = USDA 1, 20–24 = USDA 2, 15–19 = USDA 3, ≤14 = USDA 4. Data are averaged over years

[d] Reducing sugars (dry matter basis) were assayed by the dinitrophenol method of Ross (1959)

(Table 7). In fry tests at Kimberly, Idaho, glucose concentrations were lower than Russet Burbank in 2004/2005 across temperatures and dates in storage (Fig. 3). At the lowest temperature (5.5°C), peak glucose concentration in Alpine Russet occurred at approximately 190 days after harvest in 2006–07 at 0.12%. Typically, Alpine Russet glucose concentrations remained near or below 0.10% at 5.6°C in all 3 years and near or below 0.05% at 7.2° and 8.9°C. The low levels of glucose were due to a low level of the sucrose hydrolyzing enzyme acid invertase. Alpine Russet had low basal acid invertase (enzyme activity in presence of acid invertase inhibitor protein) activity as compared to Russet Burbank (Table 8). Invertase activity as measured according to McKenzie et al. (2005) methods. Low glucose concentration observed in Alpine Russet following long-term storage primarily reflects low acid invertase activity relative to Russet Burbank with inhibitors also contributing to a further reduction in enzymatic activity. The result is that even though Alpine Russet has the highest sucrose levels of the cultivars, the resulting glucose levels and therefore fry colors are the lowest and lightest, respectively (Table 11). The higher reflectance readings on the fry slices in Fig. 4 at 5.6°C correlate well with the lower percent glucose in Fig. 3 compared to Russet

Table 7 Fry colors for Alpine Russet, Ranger Russet, and Russet Burbank[a]

Storage temperature	Alpine Russet	Ranger Russet	Russet Burbank
4.4°C	2.25[b] (0.6)[c]	3.33 (0.4)	3.53 (0.3)
7.2°C	0.73 (0.6)	1.36 (0.7)	1.67 (0.6)

[a] Tubers were evaluated following 3–4 months storage and data was collected from eight trials in Idaho, Oregon, Washington for 4.4°C and 19 trials in Colorado, Idaho, Oregon, and Washington for 7.2°C from 2002–2004. Standard holding times at these temperatures are usually for 3 months

[b] Color readings based on USDA Color Standards (0 = light–4 = dark)

[c] (standard deviation)

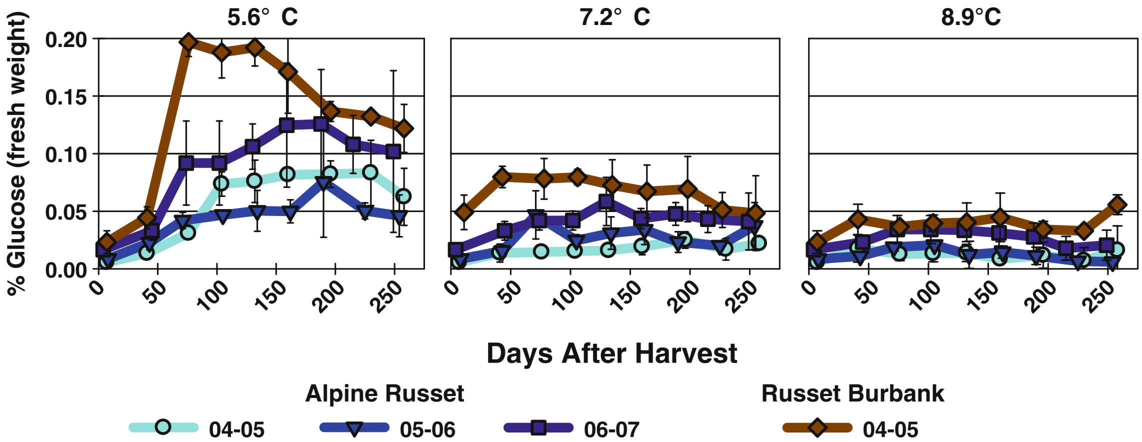

Fig. 3 Tuber glucose concentrations of Alpine Russet relative to Russet Burbank, following 0 to 250 days of storage at 5.6°C, 7.2°C, and 8.9°C. Russet Burbank glucose concentrations represent data from 1 year and are representative of a typical pattern while the Alpine Russet data are from three storage seasons

Burbank. Fry color was less than or equal to the lightest USDA fry color score of 1 when stored at both 7.2° and 8.9°C. At 5.6°C, fry color was USDA 2 or less, except in 2006/2007, between 70 and 180 days after harvest when fry color reached a USDA 3. Mottling, a dark, uneven coloration which can occur in fried products, scored at a mild level at 5.5°C, and mild to none at 7.2° and 8.9°C.

Specific Gravity

Alpine Russet had specific gravity similar to Russet Burbank with a mean in early harvest trials of 1.072 compared to Russet Burbank and Ranger Russet at 1.073 and 1.074, respectively (Table 2). In two separate late harvest trials the average specific gravity of Alpine Russet was 1.081 and Russet Burbank and Ranger Russet were 1.077 and 1.085, respectively (Tables 1, 3).

Tuber Defects

In 3 years of trials, Alpine Russet had consistently low incidences of growth cracks and second growth, with ratings which were approximately one point lower than Russet Burbank. Alpine Russet had blackspot bruising susceptibility similar to Russet Burbank and both were slightly more resistant to blackspot bruise than Ranger Russet. No incidence of hollow heart or brown center was noted for Alpine and Ranger Russet in the 3 years of trial (Table 9).

Table 8 Acid invertase activity in Alpine Russet and Russet Burbank tubers following 180 days of storage at 5.5°C

Cultivar	Acid invertase activity[a]	
	Basal[b]	Total[c]
Alpine Russet	3.51	6.10
Russet Burbank	5.18	42.09

[a] μmols glucose formed per mg protein per hour

[b] Enzyme activity in presence of inhibitor protein

[c] Enzyme activity after destroying invertase inhibitor

Disease Response

Disease trials were conducted at Aberdeen, Kimberly, and Bonner's Ferry, Idaho and at Hermiston and Corvallis, Oregon (Table 10). Data was from replicated trials over years and in some cases different locations. Comparison of the data and observations of the cultivars' reactions were used to assign susceptibility or resistance ratings.

Bacterial

Common scab trials were conducted at Aberdeen, Idaho for 5 years utilizing naturally occurring inocula with tubers visually rated for incidence, lesion type, and surface area covered. The incidence of serious defects was calculated from the number of tubers with a lesion type rating of 3 or higher representing lesions that were ≥0.6 cm and were raised or pitted (0–5 scale where 0 = no lesions). Alpine Russet was moderately resistant (defined as having lesions that are discrete and <0.6 cm) and was similar to Russet Burbank in the type of lesions and the amount of serious defects. Incidence of serious scab in Alpine Russet (average 1.4%) and Russet Burbank (average 2.7%) was much lower than Ranger Russet (average 48.3%).

Soft rot evaluations were done at Aberdeen, Idaho for 3 years with washed tubers collected from replicated field trials. Soft rot inoculations were done with *Pectobacterium*

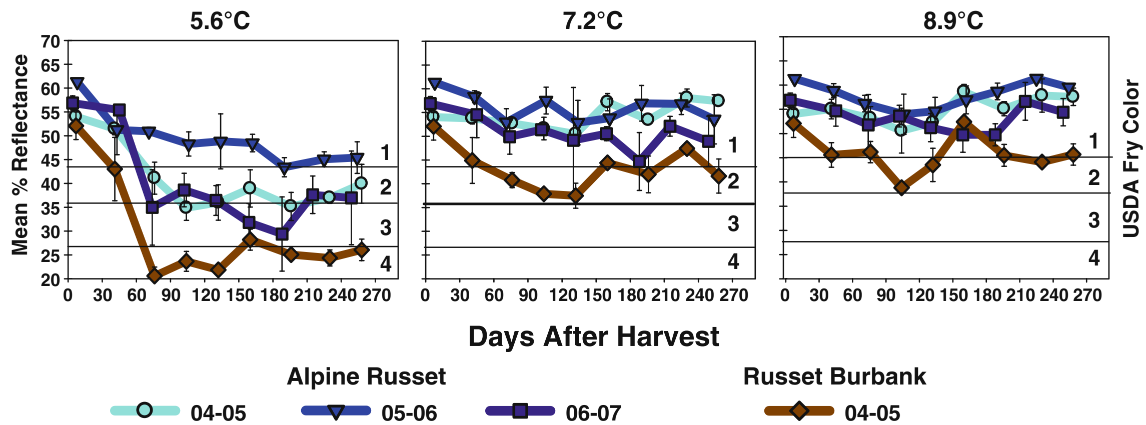

Fig. 4 Mean percent light reflectance (stem end) and USDA fry color of Alpine Russet relative to Russet Burbank, following 0 to 250 days of storage at 5.6°C, 7.2°C, and 8.9°C. Russet Burbank readings represent data from 1 year and are representative of a typical pattern while the readings for Alpine Russet are for three storage seasons

atrosepticum from culture of a field collected isolate. Tubers were placed in a rotating drum lined with a medium abrasive paper and then tumbled for 30 s to provide uniform wounding. Samples were then dipped briefly in a diluted *P. atrosepticum* solution (6×10^4 cells/ml) and allowed to drain and were then put back into storage. One week post-inoculation, tubers were rehydrated and placed in a warm mist chamber at 18°C for approximately 1 week (time was determined by the amount of rot in the control samples). Alpine Russet was susceptible to soft rot, similar to Russet Burbank and slightly more susceptible than Ranger Russet.

Fungal

Verticillium and Early blight trials were conducted for 5 years. Verticillium wilt trials were done at Hermiston, Oregon and Aberdeen, Idaho utilizing naturally occurring inocula and visual foliage ratings. Early blight trials were conducted at Aberdeen utilizing naturally occurring inocula and visual estimations of leaf area with typical lesions. Tubers were collected at harvest and after a three and a half month storage period were visually evaluated for early blight tuber lesions. Alpine Russet is susceptible to early blight of the foliage, moderately susceptible to early blight infection of the tuber, and is moderately resistant to Verticillium wilt.

Dry rot evaluations were done at Aberdeen, Idaho for 3 years with washed tubers collected from replicated field trials. Dry rot inocula from cultures of field collected isolates of *Fusarium sambucinum* and *F. solani* var. *coeruleum* were used to infect tubers by dipping a “wounding” tool with a set number of pins into solution with a concentration of 1.7×10^5 conidia/ml. This tool is then used to produce entry wounds in one end of the tuber with *F. sambucinum* and the other end is wounded with a tool carrying *F.s.*var. *coeruleum*. Before and after inoculation, the tubers are kept in 10°C storage. Approximately 4 weeks post-inoculation, tubers were cut and scored visually for dry rot. Three year averages indicate that Alpine Russet and Russet Burbank have similar susceptibility to dry rot caused by *Fusarium sambucinum,* both of

Table 9 Internal and external defects of Alpine Russet, Ranger Russet, and Russet Burbank tubers from trials grown in Idaho, Oregon and Washington from 2002–2004

Defect	Alpine Russet	Ranger Russet	Russet Burbank
Growth cracks[a]	4.6	4.4	3.5
Second growth[a]	4.6	4.5	3.5
Blackspot bruise[a]	4.1	3.5	4.0
Hollow heart/Brown Center[b]	0	0	7

[a] Scale 1–5 where 1 = severe occurrence of the defect and 5 = no occurrence of the defect. Growth cracks and second growth are rated from all tubers in each plot, Blackspot bruise is based on a ten tuber sample from each plot (four replications)

[b] Hollow heart/Brown Center measured as percent of >340 g tubers with the defect. Based on up to 10 of the largest tubers from each plot (four replications)

Table 10 Disease reactions of Alpine Russet compared with Ranger Russet and Russet Burbank

Disease[a]		Alpine R.	Ranger R.	R. Burbank
Common scab (*Streptomyces*)		MR[b]	S	MR
Verticillium wilt (*Verticillium*)		MR	MR	S
Early blight (*Alternaria*)	Foliar	S	S	S
	Tuber	MS	MS	MS
Dry rot	(*Fusarium sambucinum*)	S	MS	S
	(*F. solani* var. *coeruleum*)	MS	S	S
Soft rot (*Pectobacterium atrosepticum*)		S	MS	S
PVY		S	MR	S
PVX		VS	R	VS
PLRV foliar infection		S	S	VS
PLRV net necrosis		MS	MS	S
Corky ringspot		S	S	S
Root knot nematode (*Meloidogyne chitwoodi*)		S	S	S
Late blight (*Phytophthora infestans*)	Foliar	S	S	S
	Tuber	S	VS	S

[a] Data collected from trials grown in Aberdeen, Kimberly, and Bonner's Ferry, ID, and Corvallis and Hermiston, OR (not all trials conducted at each location). Virus trials for PVY, PVX, and PLRV were conducted for 1 year; PLRV net necrosis for 4 years at Aberdeen, ID and 1 year at Hermiston, OR; all other disease trials were conducted for a period of 2 to 5 years from 2000–2006

[b] *VS* very susceptible, *S* susceptible, *MS* moderately susceptible, *MR* moderately resistant, *R* resistant

which are slightly more susceptible than Ranger Russet. In the case of *F. solani* var. *coeruleum* caused dry rot, Alpine Russet is slightly less susceptible than Ranger Russet and Russet Burbank. Both species of Fusarium were predominant in Columbia Basin of Washington and Oregon storage surveys in 2000 and 2001 (Ocamb et al. 2007).

In studies done at Kimberly, Idaho during the storage season, three replications of 11.3 kg of unwashed tuber samples from field run bulk harvested potatoes were dropped through a potato wounding box (Schisler et al. 2000) to simulate wounding that can occur at harvest and increase tuber susceptibility to dry rot infection. Tubers were inoculated by spraying each side with 0.8 ml of 1×10^5 conidia/ml (50/50 mixture of a benzimidazole resistant isolate and a sensitive isolate) of *Fusarium sambucinum*. Tubers were stored for 14 days at 12.7°C with 95% RH, and the temperature decreased 0.5°F/day until the final holding temperature of 7.2°C was reached. Tubers were sliced longitudinally into quarters and evaluated for percent incidence and severity of dry rot infection after approximately 100 days in storage. The average dry rot severity was significantly higher in Alpine Russet, at 19% versus 10% for Russet Burbank ($P\leq0.05$). Incidence (rot >0%) was significantly higher in Alpine Russet, at 67% versus 55% for Russet Burbank ($P\leq0.05$). Interpretation of results from these trials indicates that Alpine Russet has a dry rot potential equal to or slightly greater than Russet Burbank for *F. sambucinum*.

Oomycete

Late blight evaluations are as described by Mosley et al. (2003) using inoculations of US-8 isolates on spreader rows within the plots. Trials at Corvallis, Oregon were conducted for 5 years and rated visually for leaf area with typical lesions and percentage of tubers with late blight symptoms. Foliar readings taken at Oregon in 2003 showed susceptibility very similar to Russet Burbank. However, tuber late blight incidence was higher for Alpine Russet at 19% than for Russet Burbank at 10%, when Ranger Russet was 25%. Two years of replicated trials at Bonner's Ferry, Idaho also using inoculations of US-8 isolates on spreader rows within the plots showed no statistical difference between Alpine Russet and Russet Burbank in incidence of either foliar symptoms (68.8% vs. 74.4% respectively) or tuber blight (9.6% vs 15.4% respectively) with t-tests at $P\leq0.05$. Results from these trials indicate that Alpine Russet is susceptible to foliar late blight at levels similar to or at slightly higher for tuber late blight than Russet Burbank.

Virus

Virus evaluations were done once in the field at Kimberly, Idaho and once in the greenhouse at Aberdeen, Idaho. At Kimberly, samples were grown in replicated field trials using mechanical inoculations for PVX and PVY and placement of green peach aphid (*Myzus persicae*) in PVY and PLRV infected spreader rows to provide aphid transmission of isolates as described by Corsini et al. (1994). Virus isolates were field collections from Idaho. In the field, average visual mosaic symptoms of 2.7 were accompanied by veinal necrosis and necrotic lesions on the leaves (94 days after planting; 42 days after inoculation) based on a scale where 0 = no symptoms, 1 = mild mosaic, 2 = typical mosaic, 3 = severe mosaic. For PVY strain evaluations, primary foliar and tuber symptoms were evaluated in a greenhouse at Aberdeen by manually inoculating plants grown from virus-tested certified minitubers. Plants were inoculated with one isolate each of PVY^{O}, $PVY^{N:O}$, and PVY^{NTN} strains. The plants were then ELISA tested 3 weeks post-inoculation and evaluated weekly until maturity. Tuber symptoms were evaluated at harvest and after 30 days at room temperature. Alpine Russet was susceptible to PVY (Table 10). Average foliage symptoms calculated from weekly observations in controlled greenhouse studies with PVY^{O} , PVY^{NTN} , $PVY^{N:O}$ were 2.1, 0.6, 0.8, respectively. The highest mosaic readings from the greenhouse trial for Alpine Russet were 3, 2, and 2 for PVY^{O}, PVY^{NTN}, and $PVY^{N:O}$, respectively. As determined by these evaluations, Alpine Russet produced good visual symptoms when infected with three different PVY strains, but the NTN and N:O strains were visible at a much later period than the common O strain (average PVY^{O} reading of 2 was at 35 days; $PVY^{N:O}$ and PVY^{NTN} were at 65 days).

Corky ringspot evaluations were done in replicated trials for 2 years in a Tobacco rattle virus infested field in Prosser, Washington. Tubers were sliced into quarters and scored at harvest and 2 months after storage at 10°C for the presence of necrotic arcs or spots in the tubers, characteristic to the spraing symptoms caused by Tobacco rattle virus. Alpine Russet is susceptible to corky ringspot as evidenced by typical spraing symptoms at harvest.

Nematode

Susceptibility to root-knot nematode was evident in Alpine Russet in 2 years of evaluations in replicated trials in *Meloidogyne chitwoodi* infested field plots in Prosser, Washington. Tubers were scored at harvest for the presence of visible galls on the tuber surface. Galling was severe enough that no peeling was performed to ascertain infestation sites.

Biochemical and Nutritional Characteristics

Alpine Russet, Ranger Russet, and Russet Burbank tubers were assayed in biochemical and nutritional trials at Aberdeen, Idaho from 2002–2005 (Table 11). Samples were freeze-dried as whole tubers after 4 weeks in storage at 8.9°C. Observed results show that: Alpine Russet had higher levels of sucrose and lower levels of glucose than both Ranger Russet and Russet Burbank, protein levels were all within one percentage point for all three cultivars, vitamin C (ascorbic acid) content was highest for Ranger Russet, while Alpine Russet and Russet Burbank had lower, but similar levels, and total glycoalkaloid content was lowest for Alpine Russet at 2.5 mg/100 g. The critical threshold level for acceptable glycoalkaloid content is 20 mg/100 g tuber fresh weight.

Management

Fertilization

Nitrogen (N) response trials were conducted for Alpine Russet and Russet Burbank on a Declo sandy loam soil at the University of Idaho Aberdeen Research and Extension Center. Trials were grown following grain in

Table 11 Biochemical analyses of tuber tissue of Alpine Russet, Ranger Russet, Russet Burbank stored at 8.9°C until 4 weeks after harvest at Aberdeen, Idaho (data from 2002–2005)

	Sucrose[a] % FWB[e]	Glucose[a] % FWB[e]	Protein[b] %DWB[e]	Vitamin C[c] mg/100 g FWB[e]	Glycoalkaloids[d] mg/100 g FWB[e]
Alpine Russet	0.28	0.05	5.9	22.9	2.5
Ranger Russet	0.19	0.12	5.4	31.6	4.1
Russet Burbank	0.16	0.11	5.2	22.0	5.3

[a] Sugar concentrations were calculated according to: Glucose and sucrose measurements in potatoes, Application Note No. 102, Scientific Division, Yellow Springs Instrument Co., Yellow Springs, Ohio 45387

[b] Protein content was determined using a Coomassie blue protein assay developed from the protocol of Bradford (1976)

[c] Vitamin C (ascorbic acid) content in tubers was determined using a microfluorometric method detailed in the Official Methods of Analysis Handbook, 14th edition, sections 43.069–43.075

[d] Total glycoalkaloids was determined using the protocol of Bergers (1980)

[e] FWB fresh weight basis, DWB dry weight basis

the rotation. Row spacing was 91 cm and in-row spacing was 27 cm. Crops were irrigated to maintain available soil moisture above 65%. University of Idaho recommendations were followed for herbicide, pesticide, and fungicide applications.

The N response study was conducted using five N applications rates (0, 101, 202, 303, 404 kg N/ha). Half of total Nitrogen was applied pre-plant with the remainder divided into three equal applications at 2 week intervals starting at tuber initiation. Pre-plant soil nitrate amount was 34 kg N/ha.

Nitrogen requirements for Alpine Russet determined from these trials were about 15–20% less than for Russet Burbank to obtain similar yields. About 33–50% of the seasonal N requirements should be applied by row closure, with the remaining in-season applications being scheduled according to petiole nitrate concentrations, which are similar to those for Russet Burbank. For southern Idaho, total soil plus fertilizer N recommendations should range from about 224 kg N/ha where 45 mt/ha yield potential exists, 264 kg N/ha for 56 mt/ha yield potential, and 303 kg N/ha for 67 mt/ha yield potential. Nitrogen uptake decreased significantly after mid-August, so no N applications are recommended after that time.

Irrigation and Harvest Management

Alpine Russet required about 10% less water than Russet Burbank and was more resistant to water-stress induced tuber defects. Optimum available soil moisture was in the 65–80% range for best yield and quality. Plant water uptake decreased in late August; therefore irrigation rates should be adjusted according to soil moisture measurements to prevent disease and enlarged lenticels. Soil moisture conditions lower than 60% should be avoided during tuber maturation and harvest to decrease chances for tuber dehydration and blackspot bruising. Soil moisture should be reduced gradually in the few weeks prior to harvest and tubers handled carefully during harvest to limit wound induced diseases, shatter, and blackspot bruising. Alpine Russet tolerates harvesting in cool weather conditions relatively well, but care should still be taken to avoid harvesting when soil temperatures are below 7°C.

Storage Management

Alpine Russet is a long dormancy cultivar. On average, Alpine Russet has a dormancy length 10 days longer than Russet Burbank when measured in trials at Kimberly, Idaho. The time to Alpine Russet dormancy break was 185 days after harvest at 5.5°C, 165 days at 7.2°C, and 140 days at 8.9°C (dormancy break defined as 80% of tuber sprouts with pointed tips and elongated <5 mm). Dormancy for Alpine Russet is longer than for Ranger Russet and Russet Burbank. Alpine Russet sprout length after 7 months (3 months at 8.9°C and 4 months at 6.7°C) of storage is similar to or smaller than Russet Burbank. Sprout length for Alpine Russet and Russet Burbank was low and similar at Washington, Idaho, and Oregon after storage (Table 6).

Total percent weight loss in Alpine Russet was not significantly different than Russet Burbank at 5.6°C or 7.2°C, however at 8.9°C, it was significantly higher ($p \leq 0.01$). On average total weight loss in Alpine Russet was 5.3%, 4.6%, and 8.0% compared to Russet Burbank weight loss of 4.4%, 3.6%, and 5.0% at 5.5, 7.2 and 8.9°C respectively.

Seed Availability

In 2010, seed of Alpine Russet was available from potato seed growers in Idaho, Montana, Minnesota, Nebraska, North Dakota, and Wisconsin. Small amounts of seed for research purposes can be obtained from the corresponding author. The University of Idaho, acting on behalf of the Northwest (Tri-State) Potato Variety Development Program, has filed an application for Plant Variety Protection for Alpine Russet, with licensing of this cultivar by the Potato Variety Management Institute (PVMI).

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References

Bergers, W.W. 1980. A rapid quantitative assay for solanidine glycoalkaloids in potatoes and industrial potato protein. *Potato Research* 23: 105–110.

Bradford, N.M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein using the principle of protein dye binding. *Analytical Biochemistry* 72: 248–254.

Corsini, D.L., J.J. Pavek, M.W. Martin, and C.R. Brown. 1994. Potato germplasm with combined resistance to leafroll virus and viruses X and Y. *American Potato Journal* 71: 377–386.

Hils, U., and L. Pieterse. 2005. *World catalogue of potato varieties*. Germany: Agrimedia GmbH.

Johansen, R. 1965. Norgold Russet, a new, early maturing potato variety with good type and scab resistance. *American Journal of Potato Research* 42: 201–204.

McKenzie, M.J., J.R. Sowokinos, I.M. Shea, S.K. Gupta, R.R. Lindlauf, and J.A.D. Anderson. 2005. Investigations on the role of acid invertase and UDP-glucose pyrophosphorylase in potato clones with varying resistance to cold induced sweetening. *American Journal of Potato Research* 82: 231–239.

Mosley, A., S. Yilma, D. Hane, S. James, K. Rykbost, C. Shock, B. Charlton, E. Eldredge, L. Leroux. 2003. Oregon. In *National Potato Germplasm Evaluation and Enhancement Report*, eds. K. G. Haynes & Haynes, 369–388.

Ocamb, C.M., P.B. Hamm, and D.A. Johnson. 2007. Benzimidazole resistance of Fusarium species recovered from potatoes with dry rot from storages located in the Columbia Basin of Oregon and Washington. *American Journal of Potato Research* 84: 169–177.

Pavek, J., D. Corsini, D. Douglas, R. Ohms, J. Garner, H. McKay, C. Stanger, G. Vogt, W. Sparks, R. Kunkel, J. Davis, A. Walz, C. Dallimore, and J. Augustin. 1978. Butte: A long Russet potato variety with excellent dehydrating quality. *American Journal of Potato Research* 55: 685–690.

Pavek, J., D. Corsini, J. Garner, S. Michener, W. Sparks, G. Carnahan, C. Stanger, A. Mosley, M. Johnson, G. Carter, R. Voss, M. Martin, and R. Johansen. 1981. Lemhi Russet: A new high yielding potato variety with wide adaptation, attractive tubers, and high internal quality. *American Journal of Potato Research* 58: 619–625.

Schisler, D.A., P.J. Slininger, G. Kleinkopf, R.J. Bothast, and R.C. Ostrowski. 2000. Biological control of fusarium dry rot of potato tubers under commercial storage conditions. *American Journal of Potato Research* 77: 29–40.

Ross, F.A. 1959. Dinitrophenol method for reducing sugars. In *Potato processing*, ed. W.F. Talburt and O. Smith, 469–470. Westport: AVI.