



Targhee Russet: A High Yielding, Dual Purpose Potato Variety with High Protein and Vitamin C Content and Resistance to Tuber Soft Rot

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Abstract Targhee Russet is a darker-skinned russet potato variety that has shown higher total and marketable yields than Russet Burbank in most yield trials conducted in the western United States. A major strength of Targhee Russet is resistance to tuber soft rot, and it also has moderate resistance to common scab, Verticillium wilt, and net necrosis associated with *Potato leafroll virus*. Targhee Russet also has exhibited resistance to hollow heart and blackspot bruise. Analyses have shown Targhee Russet to have significantly higher tuber protein and Vitamin C content than Russet Burbank and Ranger Russet. It produces lighter colored fries out of storage than standard processing varieties, indicating its high potential for the production of premium quality frozen and fresh-cut fries. High merit scores for fresh use are also indicative of it having

excellent potential as a dual-purpose russet variety, suitable for both processing and fresh-pack operations.

Resumen Targhee Russet es una variedad de papa de piel más oscura y corrugada que ha mostrado más rendimiento total y comercial que Russet Burbank en la mayoría de los ensayos de rendimiento desarrollados en el occidente de los Estados Unidos. Una fortaleza mayor de Targhee Russet es su resistencia a la pudrición blanda del tubérculo, y también tiene resistencia moderada a la roña común, a la marchitez por Verticillium y a la necrosis asociada con el virus del enrollamiento de la hoja de la papa. Targhee Russet también ha mostrado resistencia al corazón hueco y a la mancha oscura por daño mecánico. Los análisis también han mostrado que Targhee Russet tiene significativamente más proteína en el tubérculo y contenido de vitamina C que Russet Burbank y que Ranger Russet. Produce hojuelas más ligeramente pigmentadas al salir del almacén que las variedades estándar para proceso, lo que indica su alto potencial para la producción de papa frita congelada de calidad Premium y para corte en fresco. Las altas calificaciones para uso en fresco también son indicativas de tener excelente potencial como una variedad russet de doble propósito, apropiada tanto para operaciones de proceso como para paquetes en fresco.

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Introduction

Targhee Russet is a product of the cooperative USDA/ Agricultural Research Service (ARS) potato breeding program and University of Idaho potato variety development

program in Aberdeen, Idaho. Targhee Russet (A01010-1) originated from a hybridization of A92303-7 and A96004-8 in 2001, conducted by ARS personnel at Aberdeen, ID (Fig. 1). It was selected in the field in 2003 and then evaluated for over nine years in trials in the western U.S. It entered the Tri-State Variety Trials in Idaho, Oregon, and Washington in 2009 and was entered into the Western Regional Variety Trials from 2010 through 2012 in California, Colorado, Idaho, Oregon, and Washington. The name Targhee is associated with landmarks in and around Idaho, such as the Caribou-Targhee National Forest and a mountain pass near Yellowstone National Park that Chief Joseph led the Nez Percé through in their flight from U.S. Army forces in 1877 (Aarstad et al. 2009). The name is thought to have originated from an Indian Chief noted in the Hayden Expedition of 1871 in the Yellowstone area. The release was made jointly by the USDA-ARS and the agriculture experiment stations of Idaho, Washington, and Oregon, which represent the collaborating institutions that comprise the Northwest (Tri-State) Potato Variety Development Program.

Varietal Description

Plants (Fig. 2a, b)

Growth habit: Medium to large size, erect vine expressing medium maturity (125 days from planting to harvest, which is equivalent to Russet Burbank). Vine architecture is open

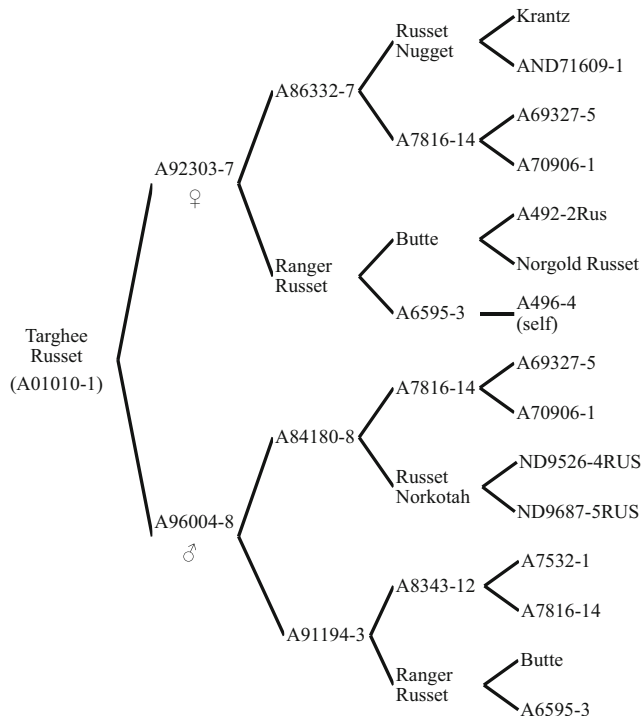


Fig. 1 Four generation pedigree of Targhee Russet

with stems partially visible. **Stems:** Moderately thick, medium green with medium red-purple anthocyanin pigmentation, and medium prominent wings (~2 mm wide). **Leaves:** Medium size, green color (Royal Horticulture Society Color Chart, RHSCC green 147 A), with an open silhouette, and weak red-purple anthocyanin pigmentation on the petioles and mid-ribs. **Terminal leaflets:** Medium ovate shape with acuminate tip and cordate base; moderately wavy margins; average length 73 mm, width 50 mm (average of 80 mid-canopy leaflets). **Primary leaflets:** Three to four pairs with an average of 3.7 pairs; medium ovate with an acuminate tip and lobed base. **Secondary leaflets:** Two to four pairs, average 3.5 pairs. **Tertiary leaflets:** Zero to nine pairs, average of 3.6 pairs. **Stipules:** Medium, non-clasping.

Flowers (Fig. 2c)

Flowers are relatively abundant in number, averaging 17 florets per inflorescence and 8.0 inflorescences per plant. **Buds:** Anthocyanin pigmentation is strong and purplish-red in color; moderate pubescent calyx and pedicel. **Calyx:** Sepals long, awl-shaped, fused to more than one-fourth the length of the bud. **Corolla:** Semi-stellate shape; white (RHS white 155 A on the inside surface, white 155 A on the outside), medium to large, averaging 38 mm diameter as measured from corolla tips. **Anthers:** Yellowish-orange (RHSCC yellow-orange 17 A); arranged as a pear shaped cone. **Stigma:** capitate, yellowish-green (RHSCC yellow-green146A). **Pollen:** Shed pollen has limited fertility, with no, or a low number of true potato seed observed when used as a male parent in hybridizations. **Berries:** spherical, medium green, very low production in the field and only when another pollinator variety is present.

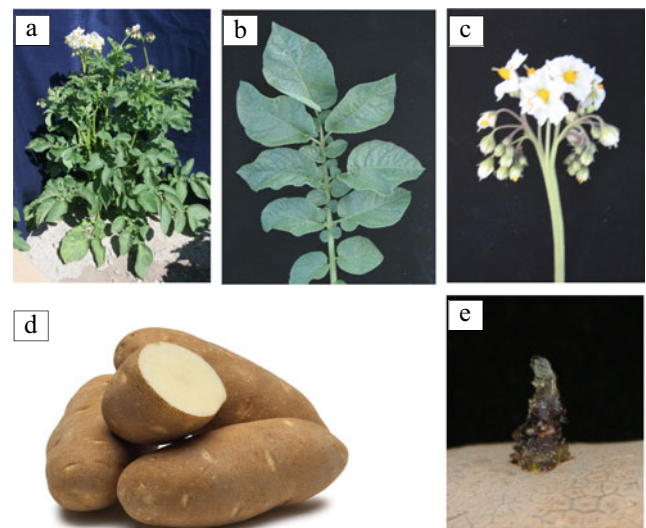


Fig. 2 Photographs of Targhee Russet showing a) whole plant, b) compound leaf, c) flower, d) tubers, e) light sprout (tuber photo courtesy of Potato Variety Management Institute)

Tubers (Fig. 2d)

Long; similar in shape to Russet Burbank; medium thick; mean length of 126 mm, range 90 to 157 mm; slightly flattened with a mean tuber width of 59 mm; range 47 to 76 mm; mean thickness 51 mm, range 40 to 64 mm; average tuber weighing 233 g, range 168 to 336 g. *Skin*: Brown (RHSCC of 165C), with a medium russet pattern. *Eyes*: Intermediate in depth, with a medium prominent eyebrow, evenly distributed, with the average number of eyes per tuber at 22.7 (range of 16 to 30). *Flesh*: Light cream colored (RHSCC 158 A); slightly prominent pith region. *Dormancy*: Medium, approximately 110 days when stored at 7 °C.

Light Sprouts (Fig. 2e)

Strong anthocyanin coloration of the base of the light sprout is red-violet, while the tip color is weakly green. The base is weakly pubescent, while the tip has medium pubescence. The tip is intermediate in habit, neither open nor closed, and the overall shape of the light sprout is conical. Root initials are abundant.

Agronomic Performance

In six full-season, replicated trials conducted at Aberdeen and Kimberly, Idaho over a three year period, Targhee Russet had significantly higher total and U.S. No.1 yields than Ranger Russet and Russet Burbank. Targhee Russet total yield was 10 % higher than Ranger Russet and 12 % higher than Russet Burbank and U.S. No.1 yield was 21 % higher than Ranger Russet and 54 % higher than Russet Burbank. As a result, it produced a significantly higher percent pack-out of U.S. No.1 yield tubers at 83 % (Table 1) with a significantly higher percentage of tubers in the 170–341 g category. The percentage undersize tubers (<114 g) were significantly different for all three varieties, with the Targhee Russet percentage (7.7 %)

in between Russet Burbank (11.3 %) and Ranger Russet (6.3 %). The percentage oversize tubers (>341 g) for Targhee Russet (21.0 %) was significantly lower than Ranger Russet (28.9 %) and higher than Russet Burbank (15.6 %), although not statistically significant (Table 1). Cull tuber percentages for Targhee Russet were significantly reduced relative to Russet Burbank with 67 % fewer in this tuber category.

In Tri-State late season trials in Idaho, Oregon, and Washington, Targhee Russet had consistently greater total yields, U.S. No. 1 yields, and percentage of U.S. No.1, in all states relative to Ranger Russet and Russet Burbank, averaging 8.7 mt/ha total yield higher than Ranger Russet and 10.7 mt/ha higher than Russet Burbank (Table 2). For U.S. No. 1 yield, Targhee was 11.2 mt/ha higher than Ranger Russet and 20.8 mt/ha higher than Russet Burbank.

In early season Tri-State trials, Targhee Russet produced higher total and U.S. No. 1 yields than Ranger Russet and Russet Norkotah in Oregon and Washington, but not in Idaho (Table 3). The three-state averages for total and U.S. No. 1 yield were higher for Targhee Russet than Ranger Russet and Russet Norkotah, with total and U.S. No. 1 yields for Targhee Russet being exceptionally high in the one year of trial data from Oregon relative to variety standards. The average percent of U.S No. 1 yield for Targhee Russet was lower than Ranger Russet but higher than Russet Norkotah.

Targhee Russet was evaluated in full season trials across five states and eight locations for three years (2010–2012) as part of the Western Regional Variety Trials (Table 4). In all but Colorado and at Parma, Idaho, Targhee Russet had higher total yields than Ranger Russet and Russet Burbank. This pattern was also observed for U.S. No. 1 yield with Targhee Russet out-yielding Ranger Russet and Russet Burbank at all sites, including now Parma, Idaho where its high percentage of U.S. No. 1 yield compensated for its lower yield at that site; U.S. No. 1 yield in Colorado for Targhee Russet was similar to that of Ranger Russet and higher than Russet Burbank. Targhee

Table 1 Total yield, U.S. No. 1 yield, percent U.S. No. 1 yield, specific gravity, tuber size distribution, and French fry color of Targhee Russet, Ranger Russet, and Russet Burbank from 6 irrigated, full-season yield trials (125–135 day growing seasons) conducted at Aberdeen, and Kimberly, Idaho¹

Cultivar	Yield (mt/ha)				Tuber Size Distribution as Percent of Total Yield					Fry color ³	
	Total	U.S. No. 1	% No. 1	Specific Gravity ²	>341 g	170–341 g	114–169 g	<114 g	Cull	4.4 C	7.2 C
Targhee Russet	62.6	51.9	83	1.085	21.0	48.0	13.9	7.7	3.4	3.3	0.6
Ranger Russet	57.0	43.0	76	1.089	28.9	36.7	10.3	6.3	6.8	3.2	0.8
Russet Burbank	55.9	33.6	60	1.080	15.6	31.4	12.7	11.3	15.0	3.8	1.0
LSD _{0.05}	5.3	5.2	6.1	0.003	6.7	8.1	2.9	1.8	4.4	0.4	0.2

LSD, Least Significant Difference, $P < 0.05$

¹ Trials were conducted from 2010 to 2012

² Specific gravities were determined using the weight-in-air, weight-in-water method

³ French fry scores rated using USDA standards, with 0 = light and 4 = dark. A rating of ≤ 2.0 is an acceptable score. Tubers were evaluated following 3–4 months storage at 4.4 or 7.2 C

Russet had the highest % U.S. No.1 yield across all sites compared to the other two standard varieties.

Tuber Quality Characteristics and Usage

Processing Characteristics

In full-season trials (Tables 1, 2 and 4), fry scores for Targhee Russet, Ranger Russet, and Russet Burbank tubers stored at 6.7° to 7.2 °C ranged from 0.6 to 1.4 on the USDA scale (0 = light, 4 = dark: acceptable fry colors are ≤2.0). Targhee Russet fry color scores were comparable or better than standard varieties across trial sites (Tables 1, 2, and 4). When potatoes produced in Idaho were stored at a lower temperature (4.4 °C), all three varieties had unacceptably dark fry colors (Table 1), indicative that all three lacked resistance to cold-sweetening. Averaged across five states, Targhee Russet fry colors from 7.2 °C storage were intermediate between Ranger

Russet (darkest) and Russet Burbank (lightest), but all varieties produced acceptably light colored fries (Table 4). Based on this data, Targhee Russet produces acceptable fries comparable to the standards when stored at 7.2 °C. In longer term storage studies, Targhee Russet tubers stored for seven months (3 months at 8.9 °C followed by 4 months at 6.7 °C) had lower reducing sugars, resulting in significantly lighter fries than Ranger Russet and Russet Burbank, regardless of production site (WA, ID, OR) (Table 5). Reducing sugar concentrations were highest in the stem ends of tubers, resulting in lower photovolt reflectance values and darker color than the bud ends of fry planks. Non-uniform fry color is indicated by a difference in photovolt reflectance values between bud and stem ends of fries of nine reflectance units or higher. Fry color was non-uniform for the check varieties, regardless of production site. While Targhee Russet tubers from WA and OR produced light but non-uniform fry color, samples from ID were uniform.

Percentage of tubers sprouting and length of sprouts for Targhee Russet were comparable to Ranger Russet tubers following seven months of storage for samples from all production sites, and significantly higher than Russet Burbank (Table 5). These data indicate that natural tuber dormancy of Targhee Russet is less than Russet Burbank but comparable to Ranger Russet. The average dormancy length for Targhee Russet tubers was estimated at the postharvest facility in Kimberly, Idaho to be approximately 60 days shorter than Russet Burbank.

Table 2 Total yield, U.S. No. 1 yield, percent No. 1 yield, and tuber specific gravity of Targhee Russet, Ranger Russet, and Russet Burbank in full-season irrigated trials grown in Idaho, Oregon, and Washington, 2009 to 2012¹

	ID	OR	WA	Mean
<i>Total Yield (mt/ha)</i>				
Targhee Russet	63.2	94.5	100.8	86.2
Ranger Russet	58.9	84.0	89.5	77.5
Russet Burbank	58.9	86.9	80.8	75.5
<i>U.S. No. 1 Yield (mt/ha)</i>				
Targhee Russet	54.1	79.4	89.6	74.4
Ranger Russet	48.2	63.1	78.1	63.2
Russet Burbank	39.0	54.7	67.2	53.6
<i>% U.S. No. 1</i>				
Targhee Russet	85.4	84.0	88.9	86.1
Ranger Russet	81.5	75.2	87.3	81.3
Russet Burbank	65.6	63.0	83.1	70.5
<i>Specific Gravity</i>				
Targhee Russet	1.085	1.076	1.082	1.081
Ranger Russet	1.089	1.081	1.087	1.086
Russet Burbank	1.080	1.078	1.078	1.079
<i>Fry Color from 7.2 C²</i>				
Targhee Russet	0.6	1.0	0.5	0.7
Ranger Russet	0.8	1.5	1.0	1.0
Russet Burbank	1.0	1.9	1.0	1.2

¹ Trial locations were Aberdeen, Kimberly, and Parma (ID), Hermiston and Klamath Falls, (OR), and Othello (WA). Means represent combined data from 2011 Tri-State Potato Variety Trials, and 2012 to 2014 Western Regional Potato Variety Trials

² French fry scores rated using USDA standards, with 0 = light and 4 = dark. A rating of ≤2.0 is an acceptable score. Tubers were evaluated following 6–11 weeks storage at 7.2 C (6.7 °C for WA)

Table 3 Total yield, U.S. No. 1 yield, percent No. 1 yield, and tuber specific gravity of Targhee Russet, Ranger Russet, and Russet Norkotah in early-season irrigated trials grown in Idaho, Oregon, and Washington, 2010 to 2012¹

	ID	OR	WA	Mean
<i>Total Yield (mt/ha)</i>				
Targhee Russet	49.2	82.9	60.5	64.2
Ranger Russet	49.3	55.3	43.6	52.7
Russet Norkotah	55.9	46.9	43.1	48.6
<i>U.S. No. 1 Yield (mt/ha)</i>				
Targhee Russet	39.4	73.4	48.3	53.7
Ranger Russet	42.7	47.3	46.5	45.5
Russet Norkotah	48.1	37.7	32.7	39.5
<i>% U.S. No. 1</i>				
Targhee Russet	80.0	88.6	79.8	82.8
Ranger Russet	86.6	85.6	86.8	86.3
Russet Norkotah	86.0	80.4	76.0	80.8
<i>Specific Gravity</i>				
Targhee Russet	1.085	1.070	1.077	1.077
Ranger Russet	1.091	1.080	1.079	1.083
Russet Norkotah	1.082	1.067	1.076	1.075

¹ Trial locations were Parma, (ID), Hermiston, (OR), and Othello (WA). ID and WA. means represent 2010 to 2012 Early Western Regional Potato Variety Trial data. OR data represent 1 trial only, conducted in 2012

Table 4 Total yield, U.S. No. 1 yield, percent U.S. No. 1 yield, specific gravity, and fry color of Targhee Russet, Ranger Russet and Russet Burbank in full-season irrigated field studies conducted as part of the 2010–2012 Western Regional Potato Variety Trials¹

	CA	CO	ID			OR		WA	Mean
			1	2	3	1	2		
<i>Total Yield (mt/ha)</i>									
Targhee Russet	57.3	49.1	57.8	66.7	75.2	128.6	65.0	101.8	75.2
Ranger Russet	51.5	52.7	50.4	62.8	72.8	101.3	57.2	88.5	66.7
Russet Burbank	46.7	51.1	53.9	57.2	78.5	109.1	46.2	76.0	64.9
<i>U.S No.1 Yield (mt/ha)</i>									
Targhee Russet	45.4	43.1	47.3	55.9	66.9	111.2	50.0	90.4	63.8
Ranger Russet	39.7	43.2	38.4	47.1	64.4	79.6	35.0	75.9	52.9
Russet Burbank	35.2	38.8	31.9	34.7	58.6	74.5	27.0	59.0	44.9
<i>% U.S. No. 1</i>									
Targhee Russet	79.4	87.8	82.0	83.9	88.8	86.5	77.6	88.9	84.9
Ranger Russet	76.5	82.4	76.4	75.7	88.1	78.4	61.7	85.7	79.3
Russet Burbank	75.2	75.7	59.4	60.5	76.0	68.3	58.1	77.8	69.5
<i>Specific Gravity</i>									
Targhee Russet	1.093	1.096	1.090	1.089	1.084	1.077	1.088	1.087	1.088
Ranger Russet	1.090	1.090	1.081	1.080	1.081	1.073	1.085	1.081	1.083
Russet Burbank	1.091	1.088	1.084	1.086	1.082	1.071	1.086	1.082	1.084
<i>Fry Color²</i>									
Targhee Russet	n.a.	2.0	0.7	0.8	n.a.	1.5	n.a.	1.0	1.2
Ranger Russet	n.a.	1.7	1.0	0.9	n.a.	1.9	n.a.	1.7	1.4
Russet Burbank	n.a.	1.3	0.6	0.6	n.a.	1.0	n.a.	1.0	0.9

¹ Trial locations were Tulelake (CA), San Luis Valley (CO), Aberdeen (ID-1), Kimberly (ID-2), Parma (ID-3), Hermiston (OR-1), Klamath Falls (OR-2), and Othello (WA)

² French fry scores rated using USDA standards, with 0 = light and 4 = dark. A rating of ≤ 2.0 is an acceptable score. Tubers were evaluated following harvest cool down from field temperature to 7.2 °C and then 8 weeks of storage at 7.2 °C

n.a. not applicable, factor not scored

Overall post-harvest ratings over a four year period using tubers from trials conducted in Idaho, Oregon and Washington show comparable scores for Targhee and Ranger Russet, which both scored higher than Russet Burbank (Table 6). These scores are the sum of individual ratings for fry color at harvest, tuber reducing sugar concentration and fry color after 60 days storage at 8.9 and 6.7 °C, specific gravity, and sensory characteristics of fries evaluated by taste panels. Targhee Russet's average score of 25.8 was 7.8 points higher than Russet Burbank and consistently higher than Russet Burbank across all three states.

Merit Scores

Average process merit scores assigned by researchers for overall tuber appearance and uniformity, and yield were similar for Targhee Russet and Ranger Russet, with both scoring higher than Russet Burbank (Table 7). Average fresh merit scores were highest for Targhee Russet with six of the seven sites being the same or higher than Ranger Russet and were

consistently higher than Russet Burbank. Factors that may affect process and fresh scores differently include skin color and degree of russetting, which likely have more influence on the fresh score, where uniform and heavier russetting of tubers is preferable for fresh pack operations. A blockier tuber shape is more critical for processing with less waste coming from a blocky shaped tuber. Lighter russetting is also more acceptable in processing types if the product is peeled.

Sensory Evaluations

Taste panel evaluations were conducted over a three year period, with two sessions conducted per year. Targhee Russet, Russet Burbank, and Russet Norkotah were evaluated for four attributes (aroma, flavor, texture, and aftertaste) on a 1–15 scale with 1 signifying 'extremely disliked' and 15 signifying 'extremely liked' (Table 8). From these scores an overall acceptance score was recorded. Targhee Russet was not significantly different than Russet Burbank, while Russet Norkotah

was the same as Russet Burbank, but significantly lower than Targhee Russet.

Specific Gravity

Average specific gravity readings for Targhee Russet in trials conducted in the Pacific Northwest were generally lower than Ranger Russet, but higher than Russet Burbank with an overall average of 1.083 (Tables 1 and 2). However, in Western Regional trials, that included California and Colorado, average specific gravities for Targhee Russet were higher than Ranger Russet and Russet Burbank, with an overall average of 1.088 (Table 4). An overall average for Targhee Russet from all of these full-season trials was 1.085.

Tuber Defects

Targhee Russet's resistance to growth cracks, second growth (knobs), and blackspot bruise was greater than both Ranger Russet and Russet Burbank (Table 9). Percent hollow heart was near zero, similar to Ranger Russet. In these trials, Russet Burbank had an average of 10 % hollow heart, but in two of the three trial years, it had scores of 27 % and 29 %. Targhee Russet's weight loss in storage is similar to Russet Burbank, with only 7 % shrinkage when stored for nine months across a range of storage temperatures at Kimberly, Idaho (5.6, 7.2, 8.9 °C).

Disease and Pest Responses

Methodology Evaluations of disease responses for Targhee Russet were based on data collected from replicated field trials conducted for a minimum of two years. Verticillium wilt (*Verticillium dahlia*) evaluations were conducted at Aberdeen, Idaho using naturally occurring inocula and protocols described by Corsini et al. (1988). Common scab (*Streptomyces scabies*) was evaluated on tubers collected from three replicates from field trials arranged in a randomized complete block (RCB) using naturally occurring inocula at Aberdeen, Idaho. Early blight (*Alternaria solani*) foliar evaluations were conducted at Aberdeen, Idaho and were based on visual estimates of the amount of leaf area infected in three replicate plots of a RCB design. Tuber evaluations for early blight were conducted using tubers harvested from plants used in assessing foliar resistance; following 3.5 months of storage at 10 °C, tubers were evaluated for early blight tuber lesions. To enhance the conditions for tuber lesions, green vines were removed by flailing and tubers were harvested two weeks after vine removal. Before tubers were placed in storage, each sample was tumbled for 30 s in a cement mixer lined with rough carpet to abrade and provide small wounds as entry points for *Alternaria* spores. Evaluations for soft rot were done on tubers washed at harvest and stored for approximately 3 months at

10 °C. These tubers from storage were then tumbled for 30 s in a carpet lined cement mixer. Tubers were then dipped for 5 min in a 5×10^4 cells/ml solution of *Pectobacterium atrosepticum* and then placed in a mist chamber with 100 % RH at 18 °C. When tubers were sufficiently rotted (~1 week) they were removed and scored on a 1–5, scale with 5 being more than 50 % rot.

Bacterial ring rot evaluations were done by Dr. Rob Davidson, Colorado State University, in Center, Colorado in 2012 and by the senior author in Kimberly, Idaho in 2015 using a pathogenic rifampicin-resistant strain (CIC31) of *Clavibacter michiganensis* subsp. *Sepedonicus*. Freshly cut seed pieces were dipped in a bacterial solution and placed in paper sacks. Seed pieces were planted the next day in a RCB design with seven inoculated seed pieces planted next to seven non-inoculated seed pieces for control plots. Starting mid-season, foliar symptoms were recorded weekly.

Late blight (*Phytophthora infestans*) field evaluations were conducted at Corvallis, Oregon as described by Mosley et al. (2003) and in the National Late Blight Germplasm Evaluation Trials as described by Haynes et al. (2002).

Evaluations of *Potato leafroll virus* (PLRV), *Potato virus Y* (PVY), and *Potato virus X* (PVX) resistances were conducted at Kimberly, Idaho using virus-infected spreader rows as described by Corsini et al. (1994). Mechanical inoculations with three strains of PVY were done in the greenhouse with foliar symptoms taken on a weekly basis and tuber symptoms noted at harvest and after four weeks at room temperature. Corky ringspot (*Tobacco rattle virus*) evaluations were conducted in the Columbia Basin of Washington using protocols described by Brown et al. (2000). Storage disease evaluations were performed as described by Corsini and Pavek (1986), with evaluations for *Fusarium* dry rot resistance also being conducted at the University of Idaho, Kimberly Research and Extension Center as described in Novy et al. (2012).

Disease and Pest Responses Targhee Russet possesses a significantly higher resistance to soft rot (*Pectobacterium atrosepticum*) with a score almost three times lower than Ranger Russet and Russet Burbank (Fig. 3). Targhee Russet had typical foliar symptoms of bacterial ring rot with plants under Colorado conditions with first symptoms at 62 days after planting compared to Russet Burbank with symptoms at 52 days. Foliar symptoms included interveinal chlorosis and necrosis, leaf margin necrosis, and whole stem green wilt and were similar in Colorado and Idaho. Targhee Russet resistance to common scab is higher than Ranger Russet, but lower than Russet Burbank which is considered resistant (Table 10).

Targhee Russet has moderate susceptibility to PVY (when exposed to high virus pressure) with an average infection percentage of 43 % compared to Russet Burbank with 83.5 %. Visual symptoms of PVY are typical for three virus strains (O,

Table 5 Post-harvest characteristics of Targhee Russet, Ranger Russet, and Russet Burbank following 7 months of storage at 95 % humidity (3 months at 8.9 °C and 4 months at 6.7 °C). All post-harvest evaluations and ratings were conducted at Pullman, WA in 2009–2012 using tubers from trials at Aberdeen, ID, Hermiston, OR, and Othello, WA

Clone	Photovolt Reading ¹			Difference ² Stem vs Bud	USDA Color Rating ³	% Reducing Sugars ⁴			Sprouting	
	Stem	Bud	Avg			Stem	Bud	Avg	% tubers	Sprout Length (mm)
<i>Washington</i>										
Targhee Russet	39.5	51.4	45.4b	12.1a ⁵	0.0	0.79	0.54	0.67	80b	14
Ranger Russet	33.0	42.6	37.8a	9.7a	0.3	1.18	0.65	0.92	88b	10
Russet Burbank	31.6	41.2	36.4a	9.8a	0.7	1.33	0.69	1.01	0a	0
<i>Idaho</i>										
Targhee Russet	39.5	43.9	41.7b	7.1a	0.0	0.76	0.62	0.69	62b	5
Ranger Russet	29.4	36.4	32.9a	9.5a	0.7	1.47	1.04	1.25	77b	6
Russet Burbank	28.6	39.0	33.8a	10.6a	0.7	1.56	0.78	1.17	0a	0
<i>Oregon</i>										
Targhee Russet	33.0	47.3	40.1b	14.9a	0.3	1.22	0.57	0.90	77b	14
Ranger Russet	26.7	39.0	32.9a	12.2a	1.0	1.81	0.80	1.30	79b	14
Russet Burbank	20.2	40.0	30.1a	19.8b	2.0	2.71	0.73	1.72	0a	0

¹ Fries (3/8" × 1 1/8") 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. A photovolt reading of ≤19 is considered unacceptably dark (see note 3 below)

² An absolute difference of ≥9 photovolt units between bud and stem end constitutes non-uniform fry color. Values represent the averages of actual photovolt differences of the replicate tubers in each of three years and are not computed directly from the averaged stem and bud values listed in the table

³ 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

⁴ Dry matter basis

⁵ Letter indicate LSD (*P* < 0.05)

NTN, N:O) in field and greenhouse trials (Table 11). No necrotic tuber symptoms were noted. Yukon Gold grown in the same trial produced from 5 to 37 % necrotic tuber symptoms. Resistance to net necrosis associated with PLRV is slightly higher than Ranger Russet, which is higher than Russet Burbank. All three varieties were susceptible to corky ringspot caused by *Tobacco rattle virus*.

Table 6 Mean post-harvest ratings¹ of Targhee Russet, Ranger Russet, and Russet Burbank in full-season studies included in the 2009–2012 Western Regional Potato Variety Trials. Post-harvest evaluations and ratings were conducted at Pullman, WA using tubers from trials at Aberdeen, ID, Hermiston, OR, and Othello, WA

	Washington	Idaho	Oregon	3 State Mean
Targhee Russet	27.1	30.5	20.0	25.8
Ranger Russet	28.5	28.7	22.9	26.7
Russet Burbank	22.7	16.7	14.7	18.0

¹ 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 (60 days) (0–5 scale), reducing sugar concentrations following 60 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). Maximum value possible was 38; higher values are indicative of superior post-harvest attributes

Targhee Russet is slightly more susceptible to early blight than Ranger Russet and Russet Burbank and susceptible to late blight, similar to Ranger Russet and Russet Burbank.

Table 7 Merit Ratings¹ for Targhee Russet, Ranger Russet, and Russet Burbank in full-season irrigated field studies conducted as part of the 2010 to 2012 Western Regional Potato Variety Trials²

	CA	CO	ID			OR		WA	Mean
			1	2	3	1	2		
<i>Process Merit Rating (1–5, 5 = best)</i>									
Targhee Russet	na	4.0	3.6	3.6	3.6	3.6	1.5	3.5	3.6
Ranger Russet	na	3.3	3.3	3.3	4.4	3.9	1.5	3.7	3.7
Russet Burbank	na	3.3	2.8	2.8	4.3	2.1	2.0	2.3	2.9
<i>Fresh Merit Rating (1–5, 5 = best)</i>									
Targhee Russet	3.7	4.0	3.5	3.6	2.7	2.5	na	2.8	3.0
Ranger Russet	3.3	4.0	3.1	2.7	2.9	2.0	na	2.2	2.7
Russet Burbank	3.2	3.3	2.1	1.8	2.5	2.0	na	1.6	2.3

¹ Fresh Merit Rating scale (1–5, with 5 = Best) a preference rating based on overall appearance, yield, and uniformity

² Trial locations were Tulelake (CA), San Luis Valley (CO), Aberdeen (ID-1), Kimberly (ID-2), Parma (ID-3), Hermiston (OR-1), Klamath Falls (OR-2), and Othello (WA)

Table 8 Sensory evaluations¹ of baked tubers of Targhee Russet, Russet Burbank, and Russet Norkotah, 2011–12

Cultivar	Aroma ²	Flavor	Texture	Aftertaste	Overall ² Acceptance	Average
Targhee Russet	9.8	10.1	10.7	9.9	10.3 a	10.1
Russet Burbank	9.9	10.1	10.9	9.5	10.1 ab	10.1
Russet Norkotah	9.7	9.7	10.8	9.4	9.9 b	9.9

¹ Blind sensory evaluations were conducted in Pullman, Washington during the 3 year period 2011–13 (2 sessions/year) using 100 untrained panelists under the supervision of the WSU Food Sensory Laboratory. Panelists were asked to evaluate each sensory attribute for each cultivar on a 1–15 scale with 1 being ‘extremely disliked’ and 15 being ‘extremely liked’; the midpoint between liked and disliked was 8. Tubers were baked at 204 °C for 1 h, and cooled to room temperature prior to evaluation. Means are a combination of early storage evaluations (conducted approximately 2 months after harvest; tubers held at a temperature of 9 °C from harvest until evaluation) and late storage evaluations (conducted following approximately 6 months of storage at 6.6 °C) across 2011–12

² Means in a column followed by different letters differ significantly (LSD Test ($p \leq 0.05$))

Dry rot response is similar to Ranger Russet and Russet Burbank. Targhee Russet and Ranger Russet are more resistant to *Verticillium* wilt than Russet Burbank, which is susceptible.

Biochemical and Nutritional Characteristics

Targhee Russet, Ranger Russet, and Russet Burbank were grown at Aberdeen, Idaho and analyzed four weeks after harvest over a four year period from 2009 to 2012. Tuber dry matter content of Targhee Russet was similar to Ranger Russet and higher than Russet Burbank (Table 12). Targhee Russet and Ranger Russet also had the same sucrose levels and were significantly higher than Russet Burbank. Glucose levels were significantly lower for Targhee Russet than Russet Burbank. Two nutritional values of note were the significantly higher protein and vitamin C contents for Targhee Russet relative to standards. It also had significantly lower total glycoalkaloid content than the two standard varieties, less than half the amount than the already acceptably low levels of Ranger Russet and Russet Burbank.

Mean protein content in Targhee Russet at 5.8 % is 1.3 percentage points higher than Russet Burbank (Table 12) which represents a 29 % increase in tuber protein compared to the industry standard. The largest protein level increase over Russet Burbank from a recently released russet variety from this breeding program is 33 %, recorded for both Clearwater Russet (Novy et al. 2010) and Teton Russet (Novy et al. 2013). Cultivation of potato accounts for a higher amount of protein per unit area than cereals (Galdon et al. 2010) and as potato is an important part of the diet in many developing countries (Dale and Mackay 1994), any gain of protein over standard, widely grown varieties is a nutritional step forward.

Vitamin C content in Targhee Russet is 92 % greater than in Russet Burbank (Table 12). At 36.3 mg/100 g on a fresh weight basis (FWB), it is the highest vitamin C level of all of the russet type varieties from this breeding program since Ranger Russet was selected in 1977 (Pavek et al. 1992). Previously, a survey of 75 North American breeding lines and varieties using tubers grown in 1999 and 2000 showed that the range of vitamin C was from 11.5 to 29.8 mg per 100 g FWB (Love et al. 2004). This study also showed the range of

Table 9 Evaluation of internal and external tuber defects of Targhee Russet, Ranger Russet, and Russet Burbank in California, Colorado, Idaho, Oregon, and Washington in full season irrigated Western Regional Potato Variety Trials from 2010 to 2012

Cultivar	Growth cracks ^{1,3}	Second growth ^{1,3}	Shatter bruise ^{1,4}	% Hollow heart ^{2,3}	Blackspot bruise ^{1,4}	Tuber Shrinkage ⁵
Targhee Russet	4.7	4.8	4.3	0.3	4.9	7
Ranger Russet	4.4	4.4	4.6	0.0	4.3	na
Russet Burbank	3.9	3.7	4.7	10.0*	4.6	8

¹ Rated using a 1–5 scale with 1 = severe and 5 = none observed

² Rated as the percentage of tubers >341 g with hollow heart and brown center

³ Average of 21 trials

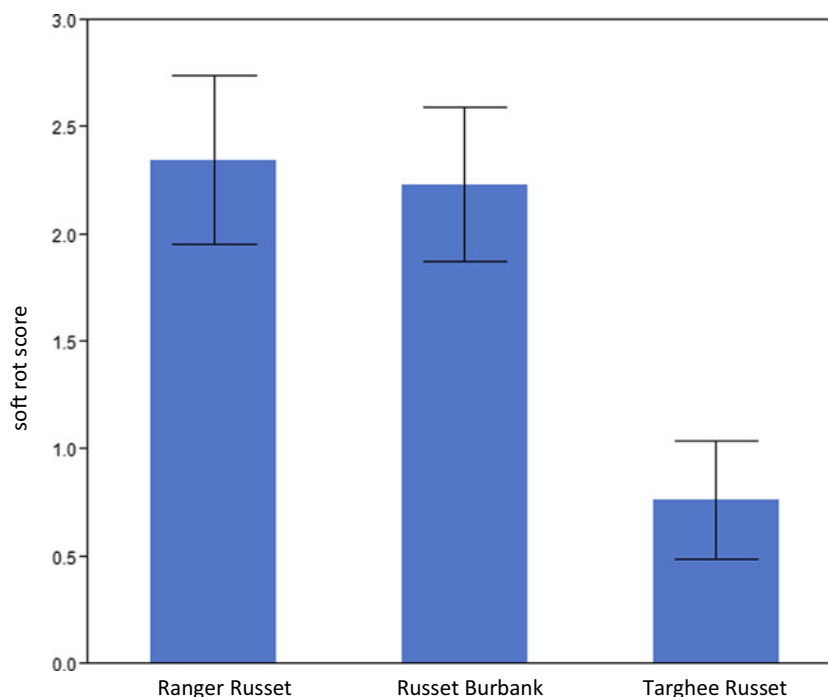
⁴ Average of 4 trials grown at Oregon and Idaho, mechanically bruised and incubated for bruise development then evaluated

⁵ Value is percent weight loss during 9 months of storage (2010–2011, 2011–2012, and 2012–2013) for tubers grown in Kimberly, ID. Values are averaged across 5.6, 7.2 and 8.9 °C at 95 % humidity

*In 2011 and 2012, hollow heart was 27 % and 29 % at Othello, respectively

na. not applicable, factor not scored

Fig. 3 Tuber soft rot (*Pectobacterium*) scores for Targhee Russet, Ranger Russet, Russet Burbank from inoculated tests from 2009 to 2012 (0–5 scale, with 0 indicating no rot and 5 indicating >50 % rot). $LSD_{(0.05)} = 1.03$



means for the Idaho program from 16.3 to 29.4 mg/100 g FWB. Targhee Russet represents a substantial improvement in the vitamin C amounts available in commercially available russet varieties.

Management

A number of studies on the management of Targhee Russet have been conducted in southern Idaho and the Columbia Basin. Results of these studies may provide growers in these and other production regions with a basis for developing appropriate management guidelines for their locale.

Southern Idaho

Optimal seed size for Targhee Russet is approximately 57 to 85 g. Recommended final planting depth is 20 cm from the top of the hill to the top of the planted seed piece. Seed should be treated and planted in soil with optimal temperature (7.2 to 12.8 °C) to facilitate early emergence and minimize the potential for soft rot decay. Dry rot potential of seed lots should also be determined and seed should be treated with an effective fungicide when needed.

Targhee Russet has exhibited good resistance to the herbicide metribuzin when applied at labeled rates. It has a semi-erect, medium-sized vine that matures late in the growing season, but competes reasonably well with weeds after row closure during early to mid-tuber bulking. Soils infested with Root-knot nematodes or with a history of severe early die problems should be fumigated. An appropriate fungicide

application program should also be made followed to prevent serious early blight infections.

Full Season Production

Targhee Russet typically requires full season production for maximum yield and quality in southern Idaho. For fresh market use, seed pieces should be spaced 23 to 25 cm apart and within rows spaced 91 cm apart. In-row spacing should be increased to 25 to 28 cm for processing.

The total seasonal nitrogen requirements for Targhee Russet are about 10–20 % less than Russet Burbank (Stark et al. 2004) per unit of yield produced, depending on the length of the growing season. For early harvest production in southern Idaho, total soil plus fertilizer N recommendations should range from about 200–220 kg N/ha in areas with a 45 t/ha yield potential, to 240–260 kg N/ha with a 56 t/ha yield potential, and 280–300 kg N/ha in areas with a 67 t/ha yield potential. About 120 to 160 kg N/ha (soil plus applied N) should be available at tuber initiation, with the remaining N applied via sprinkler irrigation prior to the last week of July. Nitrogen response studies conducted for two years at Aberdeen, Idaho indicate that petiole nitrate levels for Targhee Russet grown for early fresh market should be about 18,000–20,000 ppm at the end of tuber initiation, and decrease to 12,000–16,000 ppm during mid-bulking, and to about 8000–10,000 ppm during late bulking.

Phosphorus, potassium and micronutrient requirements have not been established for Targhee Russet. Therefore, it is recommended that growers follow local nutrient

Table 10 Disease response of Targhee Russet relative to Ranger Russet, and Russet Burbank¹

Cultivar	Vert. Wilt	Common Scab	Early Blight		Late Blight		Viruses ²			Symptoms of Virus Infection		Storage Diseases	
			Foliar	Tuber	Foliar	Tuber	PLRV	PVY	PVX	Net Nec.	Corky Ringspot	Soft Rot	Dry Rot
Targhee R	MR	MR	S	S	S	S	S	MS	MS	MR	S	R	S/MS ³
Ranger R	MR	S	MS	MS	S	VS	S	S	MR	MS	S	MR	MS
R Burbank	S	R	MS	MS	S	S	S	S	VS	S	S	MS	S/MS ³

¹ Responses of Targhee Russet to diseases were based on a minimum of 2 years of controlled field evaluations. Responses were defined as very resistant (VR), resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S), and very susceptible (VS). Disease evaluations were conducted at the following locations: Verticillium wilt - Aberdeen, ID and Hermiston, OR; Root Knot Nematode, Corky ringspot – Prosser, WA; Common scab - Aberdeen, ID; Early blight, *Pectobacterium* (syn. *Erwinia*) soft rot, Fusarium dry rot - Aberdeen, ID; Viruses and PLRV net necrosis - Kimberly, ID; Late blight – Corvallis, OR

² Virus responses are based on seed borne infections as determined by ELISA, following field infection with PLRV from aphid vectored source of interplanted virus infected potato, mechanical inoculation and aphid vectored PVY, and mechanical inoculation with PVX

³ S for *Fusarium sambucinum*, MR or MS for *F. solani* var. *coeruleum*. Single ratings indicate approximately equal resistance responses for both Fusarium species

management recommendations for Russet Burbank (Stark et al. 2004) until new guidelines for Targhee Russet become available.

Irrigation Management

Seasonal available soil moisture (ASM) should be maintained within the range of 70 to 85 % for optimal yield and quality. Plant water uptake by Targhee Russet decreases significantly in late August as vines senesce, so irrigation application rates need to be adjusted to maintain ASM at about 60 % to 70 % to avoid developing excessively wet soil conditions that promote disease and enlarged lenticels. Late season irrigations can be reduced by about 10–15 % compared to Russet Burbank to reduce the potential for lenticel enlargement.

Targhee Russet has reasonably good resistance to blackspot bruise, so it can tolerate somewhat drier soil moisture conditions prior to vine kill and harvest. However, soil moisture levels appreciably below 60 % ASM should be avoided during tuber maturation and harvest to minimize tuber dehydration and blackspot bruise. Because of its susceptibility to shatter bruise, Targhee Russet should be harvested with a moderate tuber hydration level.

Harvest Management

Targhee Russet is susceptible to shatter bruise and therefore harvest operations should be optimized to minimize tuber impact. Irrigation rates should be gradually reduced during the last two weeks prior to vine kill to allow tuber hydration to decrease to an intermediate level during skin set. Vine kill two to three weeks before harvest to maximize skin set and harvest at pulp temperatures below 15 °C to reduce storage disease potential.

Early blight control for tubers in fields scheduled for storage can be facilitated by minimizing tuber skinning and bruising during harvest and subsequent handling and avoiding harvesting in wet weather conditions.

Columbia Basin of Washington

Targhee Russet typically produces a medium to large tuber size profile in the Columbia Basin of Washington and Oregon, similar to Russet Burbank and larger than Russet Norkotah (data not shown). Several years of in-field testing in Othello, WA revealed that Targhee Russet tends to produce one to four more tubers per plant than Russet Burbank (data not shown). Due to tuber size profile similarities with Russet

Table 11 Foliar and tuber symptoms in *Potato virus Y* infected plants of Targhee Russet and Yukon Gold. Foliar and tuber symptoms are from primary infections evaluated in a greenhouse over a four to six week period in 2012 and 2014

Cultivar	Average/Maximum mosaic foliar symptoms (other symptoms) ¹			%PVY tuber symptoms present		
	N-Wi/N:O	NTN	O	N-Wi	NTN	O
Targhee R	1.5/2 (LD, NS, RL)	1.5/2 (VN, RL)	1.6/2 (LD, VN, NL, RS)	0.0	0.0	0.0
Yukon Gold	0.7/2 (none)	1.7/3 (LD, VN, NL, RS)	1.6/3 (LD, VN, NL, RS)	5.0	37.4	0.0

¹ Foliar mosaic rating scale 0 = no symptoms; 1 = mild; 2 = typical; 3 = severe

Other typical foliar symptoms; LD-leaf drop, VN-veinal necrosis, NL-necrotic lesions, RS-ringspots

Table 12 Biochemical analyses of Targhee Russet, Ranger Russet, Russet Burbank, and Russet Norkotah, tubers from Western Regional Trials (2009–2012) conducted at Aberdeen, ID¹

Cultivar	Dry matter (%)	Sucrose ² (% FWB ⁶)	Glucose ² (% FWB ⁶)	Protein ³ (% DWB ⁶)	Vitamin C ⁴ (mg/100 g FWB ⁶)	Total Glycoalkaloids ⁵ (mg/100 g FWB ⁶)
Targhee Russet	22.3 a ⁷	0.17 a	0.05 a	5.8 a	36.3 a	1.2 a
Ranger Russet	23.0 a	0.17 a	0.08 ab	4.9 b	30.6 b	3.6 b
Russet Burbank	20.6 b	0.14 b	0.12 b	4.5 c	18.9 c	3.8 b
LSD 0.05	0.77	0.01	0.05	0.43	2.1	0.73

¹ Analyses were conducted on freeze-dried tuber tissue at Aberdeen, ID; tissue was taken from tubers stored at 8.9 °C for four weeks following harvest

² 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

³ Protein content was determined using a Coomassie blue protein assay developed from the protocol of Bradford (1976)

⁴ 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

⁵ Total glycoalkaloids was determined using the protocol of Bergers (1980)

⁶ FWB = Fresh Weight Basis; DWB = Dry Weight Basis; Sucrose and glucose values of 0.15 % and 0.10 % respectively are maximum values for acceptable fry color in this evaluation, with glucose being the greater contributor to fry color

⁷ Mean values within a column followed by different letters are significantly different ($P < 0.05$) from one another based on Student's *t*-test. NS equals not significant

Burbank, we recommend Targhee Russet seed pieces be planted in a spatial arrangement similar to that of Russet Burbank (recommendations shown below), regardless of market choice (fresh or process). Seed piece size should range from 43 to 85 g, planted into rows spaced 87 cm apart. Recommended final planting depth is 20 cm from the top of the hill to the top of the planted seed piece.

Early Harvest Production – Fresh and Process Markets

Although Targhee Russet is not an early-maturing variety, it could be grown in the Columbia Basin for an early-to mid-season harvest, especially if the vines were removed prior to natural maturity. For an early-to mid-season harvest between mid-July and mid-August, (100–120 days after planting (DAP)), seed pieces should be spaced approximately 31 cm apart in-row; beyond 120 DAP, space 25 cm apart. Total seasonal N applications should be 180 to 250 kg N/ha, including pre-plant and residual inorganic soil N (NO₃-N plus NH₄-N). A total of 140 to 170 kg N/ha (residual soil N plus fertilizer N) should be available in the root zone at emergence. The remaining N should be applied via overhead irrigation during tuber bulking. Adequate N should be applied to maintain petiole NO₃-N concentrations at the end of tuber initiation (about 60 DAP) above 18,000 ppm and total inorganic soil N above 55 kg N/ha. During early bulking (about 80–90 DAP), petiole NO₃-N concentrations should be about 15,000 ppm and soil inorganic N should be below 55 kg N/ha. Petiole NO₃-N should be allowed to decrease to <12,000 ppm at mid- to late-bulking (approximately 100–110 DAP).

Late Harvest (Full Season) Production – Fresh and Process Markets

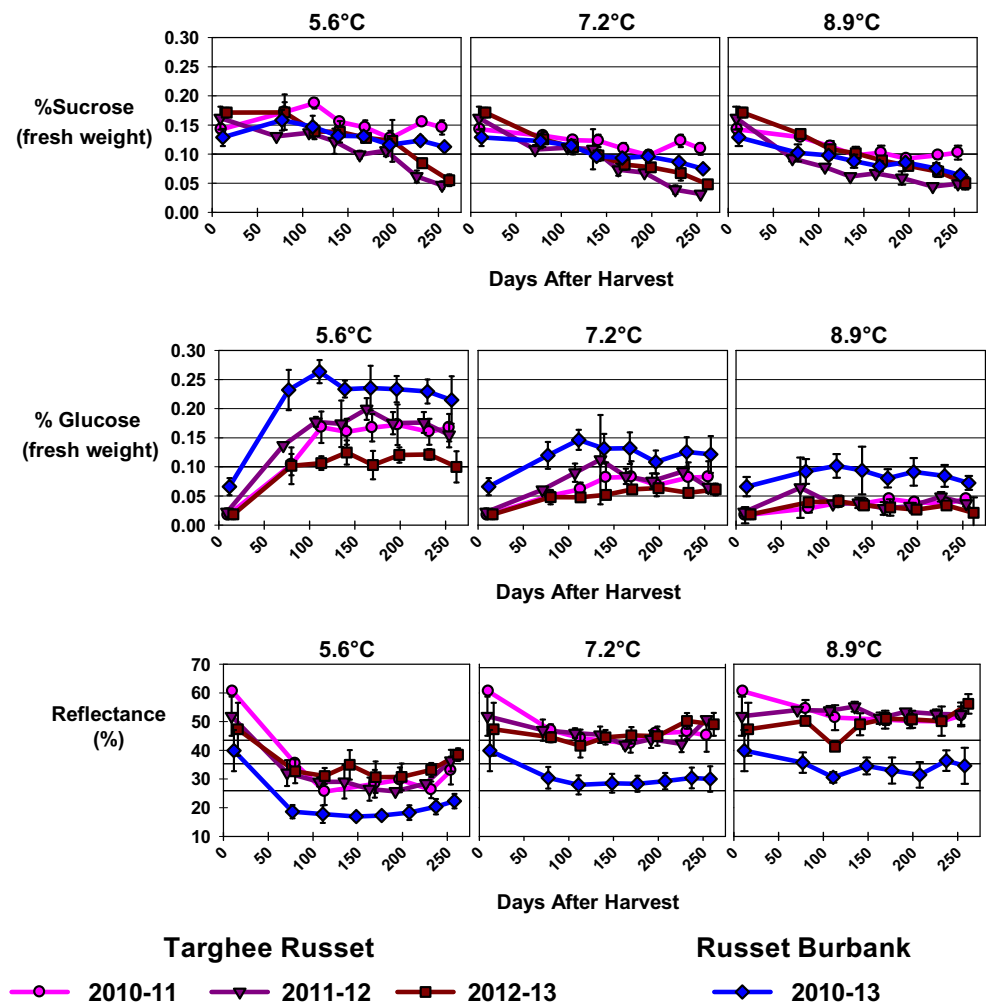
For full season growth with a harvest between mid-August and October (>130 DAP), seed should be spaced 25 cm apart in-row. Nitrogen fertilizer management should be similar to the recommendations for early harvest-fresh market, with the exception that for harvest later than mid-September, growers should strive to keep their petiole NO₃-N concentrations at the end of tuber initiation (about 60 DAP) above 22,000 ppm and total inorganic soil N above 100 kg N/ha, between 18,000 to 22,000 ppm at early bulking (80–90 DAP), and between 8000 to 13,000 ppm during late bulking (approximately 125 DAP).

Management guidelines for nutrients other than N have not been established for Targhee Russet. Therefore, it is recommended that growers follow local nutrient management recommendations for Russet Burbank (Lang et al. 1999) until new guidelines for Targhee Russet become available.

Irrigation Management

Specific irrigation management recommendations have not yet been developed for the Columbia Basin. However, agronomists should avoid excessive soil moisture from mid to late bulking to minimize tuber-lenticel swelling – a physiological issue commonly found on Targhee Russet tubers during in-field testing in Othello, WA. See Idaho recommendations above for additional irrigation and harvest management suggestions.

Fig. 4 Tuber sucrose and glucose concentrations of Targhee Russet tubers and fry color reflectance relative to Russet Burbank, following 0 to 250 days of storage at 5.6 °C, 7.2 °C, and 8.9 °C in three seasons



Storage Management

Targhee Russet was evaluated in storage at the University of Idaho Potato Storage Trial from 2010 through 2013. During the three years of storage evaluations, dormancy length was 130 days at 5.6 °C, 110 days at 7.2 °C, and 95 days at 8.9 °C. This compares to Russet Burbank which ranged from 195 days to 145 days across those storage temperatures. Glucose measurements each of the three years were lower for Targhee Russet than for Russet Burbank at harvest and at all three storage temperatures (5.6, 7.2, and 8.9 °C) throughout the storage time of nine months (Fig. 4). Fry colors for Targhee Russet were consistently one or more USDA fry color units lighter than Russet Burbank at each storage temperature. For example, stem end fry color for Targhee Russet was 2 to 3 at 5.6 °C, 1 to 2 at 7.2 °C, and ≤ 1 at 8.9 °C, while Russet Burbank was ≥ 3 at 5.6 and 7.2 °C, and ≥ 2 at 8.9 °C. Mottling, which is expressed as random discoloration in the cortex of fried tuber tissue, occurred more often in Targhee

Russet than in Russet Burbank when stored at 5.6 °C and 7.2 °C, but was substantially less when stored at 8.9 °C.

Seed Availability

In 2015, Targhee Russet seed was available from seed potato growers in Idaho, Colorado, and Minnesota. Small amounts of seed for research can be obtained from the corresponding author. The University of Idaho, acting on behalf of the Northwest Potato Variety Development Program and the Potato Variety Management Institute has applied for Plant Variety Protection for Targhee Russet.

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